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PRE-COVID-19 PHYSICAL ACTIVITY STATUS DOES NOT PROTECT AGAINST REDUCTIONS IN POST-COVID-19 SYMPTOMS: A CORRELATION RELATIVISTIC ANALYSIS DURING THE LOCKDOWN

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Abstract:
People who exhibit unhealthy lifestyle behaviours are at greater risk of severe disease outcomes, risk of hospitalisation and mortality when infected with COVID-19. Accordingly, it is suggested that those with higher levels of cardiorespiratory fitness and who engage in regular physical activity (PA) are associated with a reduced risk of adverse outcomes. Although improved physiological function may protect individuals against severe acute COVID-19 outcomes, it is unknown whether it offers protection against developing sustained symptom profile, known as post-acute COVID-19 syndrome or Long COVID. Affecting an estimated 2 million people in the UK and 144 million globally, Long COVID is challenging healthcare services with broader social and economic impacts. Accordingly, this project aimed to determine the impact of PA status on Long COVID. An online survey was developed Utilizing adapted versions of preexisting Patient Re-ports Outcome Measures (Qualtrics, Provo, Utah, United States). Participants self-reported PA status in line with the World Health Organisation guidelines and their pre- and post-COVID-19 health status and symptom profile. A Mann-Whitney U test was used to analyse between-group responses, and a Wilcoxon Signed Rank test was used to analyse within-group responses. The survey was completed by 381 participants, of which n=253 reported meeting or exceeding the recommended guidelines of PA. A significant difference was found between pre- and post-COVID-19 health, whilst a Mann-Whitney U test concluded that there was no significant difference between PA groups and post-COVID-19 health status. According to the results, increased PA and cardiorespiratory fitness might offer protection against severe disease outcomes in the acute phase of

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infection but this does not offer full protection against developing a long-term symptom profile and increased mechanistic understanding of the physiological determinants is needed to restore the pre-COVID-19 status and assist in the development of multi-disciplinary interventions.

Keywords: Long COVID; COVID-19; rehabilitation; physical activity; health and wellbeing; sports therapy

1. Introduction

Coronavirus disease 19 (COVID-19) is a highly transmissible viral infection that continues to impact communities and healthcare providers globally via sustained transmission and emerging mutations and variants of concern (Bedford et al., 2020). A plethora of patient factors (e.g., age, gender, ethnicity, immunological, biochemical, and radiographic status) have been identified as being associated with increased incidence of acute disease severity and reduced patient outcomes (Gallo Marin et al., 2021). Long COVID is a patient-made term that describes persistent symptoms and morbidity in the weeks, months and now years post-acute COVID-19 infection (Liu et al., 2020; Mo et al., 2021). During the early stages of the COVID-19 pandemic, it was suggested that recovery from COVID-19 occurs within 7-10 days following mild disease, extending to 3-6 weeks for those experiencing severe and critical illness (Gomes, 2020). Patients were expected to experience uncomplicated recoveries, with few long-term consequences anticipated (Sigfrid et al., 2021). However, research highlights the time to recovery from COVID-19 exceeded 35 weeks in 91% patients, reporting an average of 56 ± 26 symptoms, across different organ systems (Prescott & Girard, 2020). The episodic nature of symptoms and functioning with Long COVID is reported to affect 86% of participants (CI, 84.8% to 87.0%) with symptoms triggered by exercise training, or physical or mental activity (Davis et al., 2021). To this day, the symptomology of long-term sequalae associated with COVID-19 remains an international priority and the basis of scientific investigation (Desai et al., 2022).

The most reported symptoms of Long COVID include fatigue, dyspnea, headache, chest heaviness and muscle aches (Alwan, 2021; Mark A. Faghy et al., 2022; Hayes et al., 2021). Current estimates highlight that there are 2 million people living with Long COVID in the UK, with severe symptom profiles adversely impacting the daily activities of 1.4 million people (Thompson et al., 2022). To date, the determinants of developing Long COVID remain uncertain, but acute COVID-19 infection severity, cardio-respiratory fitness, physical activity (PA), age, and co-morbidities have been suggested, but not confirmed predictors of long-standing symptom profiles (Blomberg et al., 2021; Crook et al., 2021; Humphreys et al., 2020; Prescott & Girard, 2020). Physical activity is important in the prevention and treatment of chronic diseases and viral infections via improved physiological and immune function (da Silveira et al., 2021). Physical activity acts as a modulator of the immune system due to pro-and anti-inflammatory cytokines released during and after exercise, increasing lymphocyte circulation and cell recruitment (da Silveira et al., 2021). Thus, the incidence of acute infection symptom severity and mortality of common viral infections are decreased in individuals involved in regular PA (da Silveira et al., 2021). Research demonstrates that physical inactivity and adopting unhealthy lifestyle behaviors is a risk factor for acute COVID-19 infection, highlighting that patients who exhibit regular unhealthy lifestyle characteristics are at an increased risk of hospitalisation, admission to an intensive care unit, mechanical ventilation, and mortality and those who engage with regular PA are at a reduced risk of adverse outcomes (Arena & Lavie, 2021). Improved physiological function via regular PA may protect individuals against a severe acute COVID-19 infection (Lassalle et al., 2021), but at present, it is unknown whether regular PA protects against prolonged symptom persistence and the development of Long COVID. Accordingly sustained symptom profile following acute infection with COVID-19 has been reported amongst elite athletes, suggesting that fitness levels may not be a sole determinant of Long COVID (Hull et al., 2022; Rajpal et al., 2021). Accordingly, the following explorative study sought to determine the relationship between pre-COVID-19 PA status and post-COVID-19 health status (defined as health-behaviour that fosters not smoking, good nutritional practices and adequate physical activity (Zhang et al., 2021)) within the general population.

2. Material and Methods

An online web-based survey was developed incorporating adapted versions of pre-existing Patient Reported Outcome Measures (PROMs; Qualtrics, Provo, Utah, United States), following institutional ethics approval (ETH2021-1452) from the Human Sciences Research Ethics Committee. The survey was distributed via social media platforms and was available for completion between September 2020 and May 2021. Before progressing to the survey, participants provided informed consent in line with ethical standards, and all responses were anonymised using a unique participant ID code.

Inclusion criteria consisted of participants displaying symptoms of and believing they have had COVID-19, or a confirmed positive test (lateral flow test or polymerase chain reaction test). A positive test was not essential due to the availability of community testing in 2020 and due to the limitations of testing methods (Greenhalgh et al., 2020). Participants were over 18 years of age, with the ability to understand written English. If participants did not provide informed consent or confirmed that they did not understand the study requirements, their participation was terminated before data was collected.

The survey consisted of 7 sections, with a total of 70 questions incorporating validated measures aiming to assess the impact of COVID-19 on patients in community settings. Sections consisted of 1) participant characteristics (18 questions: age, sex, comorbidities, lifestyle factors [smoking status and weekly alcohol consumption], demographics [country of residence and ethnicity] and socioeconomic factors [employment status and role, living situation, number of household occupants, and approximate income]); 2) COVID-19 symptoms (10 questions: symptom profiling) 3)

Quality of Life (QoL) (8 questions: RAND Short Form 36 [SF-36] (Ware & Sherbourne, 1992) and Health Related Quality of Life survey [HRQoL] (Moriarty et al., 2003)); 4) sleep quality (8 questions: Pittsburgh Sleep Quality Index (Buysse et al., 1989); 5) breathlessness (4 questions: University of California, San Diego [UCSD] shortness-of-breath questionnaire (Eakin et al., 1998; Swigris et al., 2012), 6) PA (14 questions: International Physical Activity Questionnaire [IPAQ] (Craig et al., 2003) RAND SF-36 (Ware & Sherbourne, 1992), WHO (Organisation, 2020) PA guidelines); 7) mental health (6 questions: SF-36 (Ware & Sherbourne, 1992) and HRQoL (Moriarty et al., 2003)).

All questions were scored on frequency and Likert scales (Allen & Seaman, 2007). The survey was created as part of a collaboration between a wider research team assessing the impact of COVID-19 on patients discharged into community settings, with further data regarding QoL, sleep, and breathlessness previously published (Mark A. Faghy et al., 2022). Data collected within the demographics (age, BMI, sex, and comorbidities), PA and symptom profiling sections of the survey were most relevant to the aims of this study. Sections that were not used to measure to the impact of PA status on Long COVID symptom severity and duration were not used within data analysis (QoL, mental health, sleep, breathlessness).

A Mann-Whitney U test was used to analyse between group responses (physical activity levels and post-COVID-19 health status), and a Wilcoxon Signed Rank test was used to analyse within group responses (pre- and post-COVID-19 health status) following previous reported statistical analysis with ordinal variable (Blair & Higgins, 1985; Meek et al., 2007; Nanna & Sawilowsky, 1998). Spearman's correlation was used to test the relationship between variables (physical activity levels and post-COVID-19 health, and physical activity levels and symptom severity). Patients self-reported PA levels by selecting whether they complete less than, or met/exceed the recommended guidelines of PA (Organisation, 2020), and pre and post-COVID-19 health status was rated using a 4-point Likert scale and rated accordingly; "Excellent" (1), "Good" (2), "Fair" (3), "Poor" (4). Symptom severity was measured from "Not at all" (1), "Mild" (2), "Moderate" (3), "Severe" (4), "Critical" (5). Additional variance inflation factor and condition indices (multicollinearity tests), eigenvalue collinearity and proportional odds analysis (>0.05) were completed with the results the regression analysis factors were not met (Liang & Zeger, 1993).

3. Results

3.1 Participant Characteristics and Comorbidities

The survey received 381 responses (n=316 were female), with a mean age of 42.5 ± 12.3. The length of time from initial infection to completion of the survey was 6.7 ± 4.4 months. Within the sample, 71.1% of participants had been tested for COVID-19, and 28.9% had not. Of those who had been tested, 70% were positive, 26% were not and 4% were inconclusive. Most respondents lived in the United Kingdom (83.7%), followed by the United States (6.3%), and 94.2% of respondents were White. Additionally, 94.2% of respondents reported that they did not smoke. No comorbidities were reported by 63% of respondents, and the most reported comorbidity was obesity (11.8%) followed by hypertension (7.1%). Other comorbidities not included within the pre-determined options were reported by 20.7%. These comorbidities include, but are not limited to, Asthma, Thyroid issues, Myalgic Encephalomyelitis, and irritable bowel syndrome. Full participant characteristics including country of living at time of completion, ethnicity, smoking history, and alcohol consumption are presented in Table 1.

Table 1: Demographic profile of survey respondents

Country they are currently living in (n = 381)	
England	n = 252 (66.1%)
Wales	n = 40 (10.5%)
Scotland	n = 25 (6.6%)
United States	n = 24 (6.3%)
Germany, Northern Ireland	n = 2 (0.5%)
Ireland	n = 6 (1.6%)
Netherlands	n = 3 (0.8%)
Spain, Switzerland	n = 5 (1.3%)
Denmark, France, Hungary, Norway, Poland, Romania, Sweden, Ukraine	n = 1 (0.3%)
Other	n = 9 (2.4%)
Ethnicity (n = 381)	
White British	n = 286 (75.1%)
White Irish	n = 15 (3.9%)
White Other	n = 58 (15.2%)
Mixed Other	n = 5 (1.3%)
Indian	n = 3 (0.8%)
Arabian	n = 2 (0.5%)
Mixed White/Black African, Mixed White/Asian, Chinese, Asian Other	n = 1 (0.3%)
Other	n = 8 (2.1%)
Smoke (n = 381)	
Yes	n = 11 (2.9%)
No	n = 359 (94.2%)
Sometimes	n = 11 (2.9%)
Alcohol Consumption (n = 381)	
Never	n = 83 (21.8%)
Less than once per month	n = 109 (28.6%)
1-2 times per month	n = 57 (15%)
3-4 times per month	n = 29 (7.6%)
Once a week	n = 41 (10.8%)
More than once a week	n = 62 (16.3%)
Comorbidities (n = 381)	
None	n = 240 (63%)
Hypertension	n = 27 (7.1%)
Cardiovascular Disease	n = 4 (1%)
Type 1 diabetes	n = 1 (0.3%)
Type 2 diabetes	n = 11 (2.9%)
Chronic Lung Disease	n = 12 (3.1%)

Obesity	n = 45 (11.8%)
Hyperlipidemia	n = 3 (0.8%)
Renal Disease	n = 2 (0.5%)
Cancer	n = 2 (0.5%)
Other	n = 79 (20.7%)

Note: Countries respondent's ethnicity, smoking status, alcohol consumption and comorbidities of 381 participants that completed the survey.

3.2 Physical Activity Levels and Health Status

Within the sample, n=305 participants reported that they met or exceeded the recommended guidelines of PA, whilst n=65 participants did not and n=11 did not respond to this question. These 11 responses were excluded from statistical analysis. Mean post-COVID-19 health for those who complete the recommended guidelines of PA was 3.38 ± .871 (95% CI 3.29, 3.47) compared to 3.26 ± .871 (95% CI 3.05, 3.48) for those who do not. A Wilcoxon Signed Ranks Test concluded that there was a significant difference in pre- and post-COVID-19 health ($P<.001$). However, a Mann-Whitney U test concluded that there was no significant difference in post-COVID-19 health between those who complete the recommended guidelines of PA and those who do not ($p=.032$). A Spearman's correlation was run to determine the relationship between pre-COVID-19 physical activity levels and pre- and post-COVID-19 health status. Table 2 shows that there was no correlation between pre-COVID-19 physical activity levels, and pre- and post-COVID-19 health status.

Table 2: Pearson's correlation showing correlation coefficient and sig (2-tailed) between pre-COVID-19 physical activity status, and pre- and post-COVID-19 health

Pre-COVID-19 Health	-.153, .003
Post-COVID-19 Health	.058, .270

Table 3 summaries the level of PA by age and sex. The analysis was carried out by different age groups based on the assumption that the frailer people are more likely to show severe symptoms (Starke et al., 2021; Thompson et al., 2022). Due to the severely reduced and unequal group sizes after splitting the groups, no further statistical analysis was completed for age and sex.

Table 3: Self-reported physical activity levels and pre- and post-COVID-19 health between sex and age

Age	Sex	Level of Physical Activity	Pre-COVID Health	Post-COVID Health
18-24	Male (n = 9)	High 2.22 ± .97 (1.48, 2.97) Mod 2.22 ± .97 (1.48, 2.97)	1.67 ± .866 (1.00, 2.33)	2.00 ± 1.118 (1.14, 2.86)
	Female (n = 26)	High 2.00 ± .938	1.73 ± .667 (1.46, 2.00)	2.96 ± .999 (2.56, 3.37)

		(1.62, 2.38) Mod 2.23 ± .815 (1.90, 2.56)		
25-64	Male (n = 54)	High 2.13 ± .891 (1.89, 2.37) Mod 2.26 ± .678 (2.07, 2.44)	1.50 ± .720 (1.30, 1.70)	3.19 ± .848 (2.95, 3.42)
	Female (n = 268)	High 1.72 ± .856 (1.62, 1.83) Mod 2.10 ± .765 (2.01, 2.19)	1.71 ± .658 (1.63, 1.78)	3.47 ± .721 (3.38, 3.55)
65-74	Male (n = 0)	N/A	N/A	N/A
	Female (n = 12)	High 1.58 ± .793 (1.08, 2.09) Mod 2.42 ± .669 (1.99, 2.84)	1.92 ± .793 (1.41, 2.42)	3.67 ± .492 (3.35, 3.98)

3.3 Physical Activity Levels and Symptom Severity

A Spearman's correlation was run to determine the relationship between the severity of persisting symptoms, and pre-COVID-19 physical activity level. There was no correlation between physical activity levels and persisting symptom severity shown in Table 4.

Table 4: Pearson's correlation showing correlation coefficient and sig (2-tailed) between pre-COVID-19 physical activity status and persisting symptom severity

Symptom	Pre-COVID-19 Physical Activity Status
Breathlessness	.106, .043
Bodily Pain	.048, .364
Fatigue	.071, .175
Muscle Weakness	.020, .702
Chest Pain	.108, .040
Headaches	.091, .085
Sore Throat	.121, .023
Diarrhoea	-.041, .440
Memory Loss	.013, .799
Confusion	.063, .232
Eye Redness	.012, .818

5. Discussion

This explorative study sought to determine the existence of a relationship between pre-COVID-19 PA status and post-COVID-19 health status in the weeks and months following infection. The key findings show that there was no difference between those who complete and those who do not complete the recommended guidelines of PA, and their post-COVID-19 health status, in our cohort. There was also no correlation between pre-COVID-19 PA levels and post-COVID-19 health or symptom severity. This suggests that PA status may not influence or protect against a reduction in health following acute COVID-19 infection, or the potential to develop Long COVID.

Globally, physical inactivity is a growing burden, and along with maintaining other contributing healthy living behaviours such as a healthy diet, not smoking, and improved sleep quality, the risks of poor health outcomes associated with chronic disease are significantly reduced for those who are physically active (Arena et al., 2021). Additionally, in many health conditions, physical inactivity is a contributing factor to the increased susceptibility of fatigue and affects muscle metabolism (Bloomfield, 1997; Rimmer et al., 2012). Sustained PA results in enhanced muscle strength and function, and augments fatigue resistance in the muscle within healthy individuals (Bishop et al., 2011; Hurley et al., 2011). Therefore, in the context of Long COVID it would have been plausible to assume that those who meet or exceed the recommended guidelines of PA would experience better post-COVID-19 outcomes. However, the data presented here indicated no differences between those who complete and those who do not complete the recommended guidelines of PA, therefore suggesting that PA alone might not offer full protection from the development of a sustained and complex symptom profile. Accordingly, Hull et al. (2022) highlight that 14% of 147 Olympic level athletes (37% female, 25 paralympic) reported symptoms for >28 days, and whilst the issues reported in this study highlight lasting issues, there is no detail on the full time to recovery or return to training. Additionally, data suggests that mild, but persistent symptoms that may affect re-turn-to-play decisions and timing present in 8.3%-17% of athletes (Lemes et al., 2022). There are also a growing number of media reports that highlight the long-standing issues faced by athletes in attempt to return to training and competition activities (Mark A Faghy et al., 2022).

As previously highlighted, patients with COVID-19 who exhibit unhealthy lifestyle characteristics, or one or more comorbidities are at increased risk of mechanical ventilation, severe outcomes and mortality (Arena & Lavie, 2021). However, the development of chronic and episodic symptoms such as breathlessness has been reported amongst those living with Long COVID who were asymptomatic at the acute stage of infection, and those that not requiring hospital treatment and recovered in community settings (Raveendran et al., 2021). Therefore, the data presented in the current study offers a suggestion that PA habits and status may indeed not offer full protection from developing persisting symptoms.

Long COVID has been associated with increased comorbidities, severe clinical status at the acute phase of infection, advanced age, and being female (Cabrera Martimbianco et al., 2021). However, individuals at low risk of severe COVID-19 who are young with no underlying health conditions are also commonly reporting symptoms of Long COVID [46]. Similarly, one study reports that 40 out of 150 (32.7%) outpatients who experienced mild illness at the onset of acute infection, and 5 out of 16 (31.3%) previously hospitalized patients who experienced moderate or severe illness at the onset of acute infection, reported at least 1 persisting symptom following COVID-19 (Logue et al., 2021).

In response to growing prevalence, there is a demand and a need to devise bespoke interdisciplinary, holistic support pathways for patients living with Long COVID to improve quality of life and functional status (de Figueiredo & Larson, 2021; Faghy, Arena, et al., 2020; Faghy, Ashton, et al., 2020; Mark A. Faghy et al., 2022). Long COVID presents itself as a multifaceted condition affecting multiple organ systems, however, the medical implications are not yet completely understood [48]. The range of physical, cognitive, and psycho-logical symptoms reported by those living with Long COVID (Mark A. Faghy et al., 2022) encourages the need for an interdisciplinary approach to rehabilitation, to inform patient-centred care and improve Long COVID outcomes (Montani et al., 2021; Norton et al., 2021).

Hence physical interventions should be tailored with the specific needs of the patient. For example, recent studies have included dace-based approach as a potential rehabilitative strategy with Long COVID patients (Rąglewska & Demarin, 2021), or the use of inspiratory muscle training (Severin et al., 2022) and other intervention that can potentially mitigate patients' conditions (Chaabene et al., 2021). However, results have also showed that skilled adults had a decrement in balance following COVID-19 infection (Jaszczur-Nowicki et al., 2022) indicating that dance-based (or other form of dynamic) intervention might not be ideal as potently leading to a higher risk of falling.

The research attention should then focus on strategies that would allow practitioner to clearly define the level of holistic PA of Long COVID patients (i.e., considering the whole aspects psychological and physiological together rather than separate boxes of balance, mobility and strength).

6. Limitations

There are some factors that should be considered when interpreting the results of the current study. The sample size for both PA status groups varies, with 83% of participants reporting that they meet or exceed the recommended guidelines of PA compared to 17% who did not. However, this discrepancy may emphasise that physically active individuals are not protected against Long COVID. In addition, PA status was obtained using self-reported measures with intensity of exercise described using examples (e.g., cycling, swimming, team sports, resistance training and walking). The question also included 'how often did you participate in moderate or high intensity activities that cause in increase in breathing or heart rate for more than 10 minutes continuously' to ensure the participant understood what classed as PA. There is the possibility for participants to provide overestimations of PA levels. Whilst self-reported exercise assessment should be interpreted cautiously due to these over-estimations [56], the novelty and unforeseen circumstances of the pandemic and national lockdown meant that this was the most viable option to record PA levels.

Whilst primarily distributed widely through a variety of social media platforms, the survey was also shared between Long COVID support forums. Recruiting participants from such forums has likely resulted in potential selection bias towards those with diagnosed Long COVID, leading to the study population not necessarily being representative of the general population. Additionally, the authors acknowledge that this study includes a fairly homogenous sample, consisting of females, non-smokers with few comorbidities. Thus, the study does not indicate the prevalence of Long COVID within the community and should be interpreted with caution. Furthermore, due to availability and accessibility of testing at the early stages of the pandemic (the survey started in September 2020), inclusion criteria consisted of participants who had COVID-19 or believed to have had COVID-19. As the availability of tests is uncertain again, with government support for testing now ending, future studies should have consideration of those who have not had a positive COVID-19 test. Finally, as the questionnaire was made of 70 questions the study might have some boredom or fatigue related bias, and we recommend including a minor number of questions in the future. It is then essential to consider the above study with a relativist approach considering the specific cohort and time frame in which the data were collected.

7. Conclusion

The explorative study aims to determine the relationship between pre-COVID PA status and the likelihood of developing Long COVID in the weeks and months post-infection. Results suggest that PA does not influence or protect against the potential to develop Long COVID. With 1 in 10 individuals experiencing Long COVID, further research should investigate specific interdisciplinary, holistic rehabilitation interventions and objective assessments to support clinicians' and patients' fight against Long COVID.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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