SCHOOL OF SPORT, HEALTH AND EXERCISE SCIENCE

MSc Clinical Exercise Science

A single-centre prospective, cross-sectional study investigating the physiological function during ramp incremental cycling exercise, and physical activity in UK-based children, adolescents and adults, post-COVID with symptoms (long COVID) vs. post-COVID without symptoms.

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ACKNOWLEDGEMENTS

I would like to thank my friends, family and supervisor for their support and dedication. I would also like to express my gratitude to all the survivors of COVID-19 who participated in this study, for their time and energy, which enabled this study to be conducted.

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ABSTRACT

Background:

There is minimal research regarding the physiological changes between the post-COVID with symptoms and post-COVID without symptoms groups, and there is no research found with specialisation in measuring the physioflow of these groups during the Cardiopulmonary Exercise Test (CPET).

This research aimed to gain knowledge about physioflow data during ramp incremental cycling exercise, thereby initiating conditions for the betterment of lifestyles among children, adolescents and adults in the UK.

Methods:

The implied research methodology is based on a cross-sectional study of children, adolescents and adults with long COVID symptoms, and the data was collected via both qualitative and qualitative methods.

Results:

The attained results specifically noted that higher values for asymptomatic individuals from the post-COVID cohort without symptoms are marked to own better physical health as against the overall quality of life against those with long COVID.

Conclusions:

Comparative measurement of physioflow during CPET among the 'with' and 'without' SARS-CoV-2 infection is the most appropriate way to gain knowledge about the lifestyles of children, adolescents and adults in the UK.

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Keywords:

SARS-CoV-2, pandemic, COVID-19, COVID-19 pandemic, physiological function, ongoing COVID, post-COVID-19, ramp increment cycling exercise, cycling exercise, cardiopulmonary exercise, physical activity, children physiology, Adult physiology, cross-sectional study, long COVID, adolescent physiology, accelerometer/accelerometery, thoracic impedance cardiography, COVID recovery, SARS-CoV-2, pandemic, COVID-19, COVID-19 pandemic, Physioflow, Association of Respiratory Technology and Physiology, ARTP

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INTRODUCTION

The impacts of corona virus disease 2019 (COVID-19) in bringing changes in the physiological status of the entire human race has been marked as highly significant by many researchers (Narang et al., 2020; Epstein et al., 2021; Wuet al., 2021; Vogt et al., 2022). Following the post-hospitalisation COVID-19 study (PHOSP-COVID) for 1077 adult (aged ≥18 years) patients in the UK, Evans et al (2021) specified the impairments of physical, mental and cognitive health of the patients. Irrespective of its occurrence in 2019, the symptoms and state of distress are highly visible among people who encountered this pandemic (Cucinotta & Vanelli, 2020; Delbressine et al., 2021; Shah et al., 2021; Solera-Sanchez et al., 2021; Tabacof et al., 2021).

Woods et al (2020) referred to the impact of COVID on the immune system, the respiratory & musculoskeletal systems, cardiovascular stature, and the brain, and added the need to investigate pre-existing pathological conditions before any PA (physical activity). In this reference, Glaab and Taube (2022) established that the cardiopulmonary exercise test (CPET) offers effective provisions for recognising cardiopulmonary and metabolic changes among adults. According to Silva Andrade et al (2021), there are both short-term and long-term impacts of COVID that remains active or dormant in the post-COVID phase. With the novel, multiomics approach to literature analysis, Silva Andrade et al (2021) enlisted different physiological changes that mark the human body after being infected by COVID-19. Desai et al (2022) offered a well-comprehensive list of complications led by long COVID (see Figure 1).

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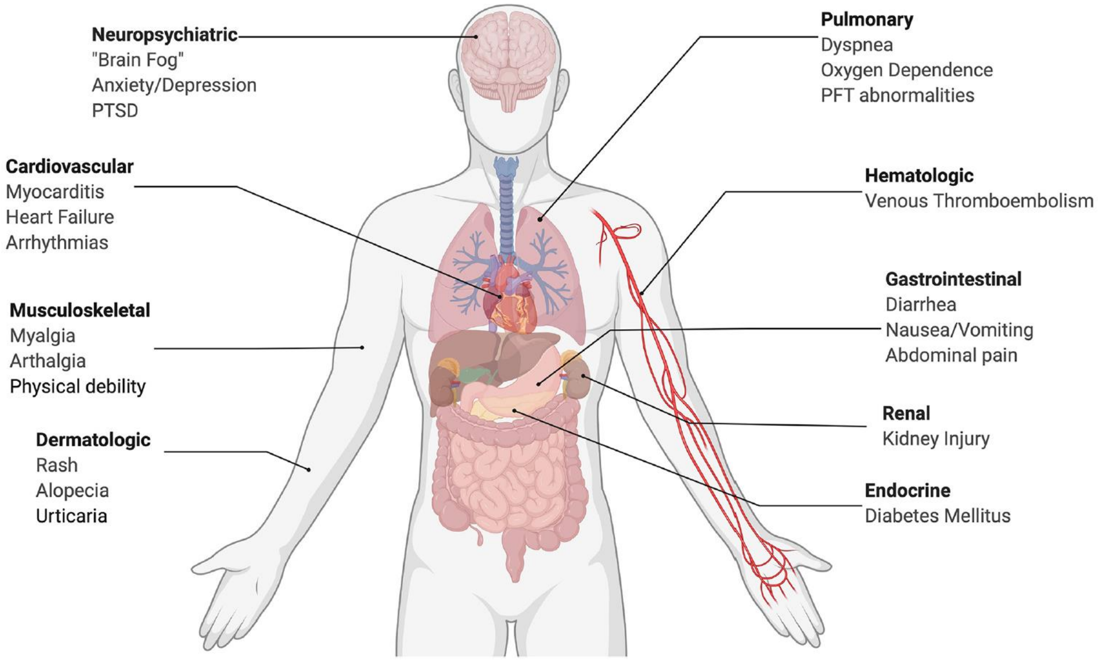

Figure 1 List of long COVID complications (Source: Desai et al., 2022, p. 2)

Garrigues et al (2022) specified that after 110 days post-admission, out of 120 patients, most of them were unable to return to exercise due to persistent fatigue and dyspnoea. However, out of 39 patients who did sports before being infected with COVID-19, 28 were able to return to physical activity and 18 at a lower intensity level. Research on long COVID by Serviente et al (2022) added that there are possibilities of adverse consequences on the body's physiological functioning. In this context, Mancini et al (2021) referred that CPET is effective in identifying the factors that lead to dyspnoea. Following CPET for symptom assessment of 41 patients with myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS), Mancini et al (2021) assessed patients with post-acute squeal of severe acute respiratory syndrome-coronavirus-2 infection (PASC) of 8.9 ± 3.3 months post- COVID. The results established a severe state of breathlessness among these participants even in the post-COVID phase.

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When it comes to the interrelation between physiological status and the long-term complications of COVID-19, there are some significant studies which have made some serious breakthroughs. As identified by Demir et al (2022) COVID-19 can damage and infect numerous internal parts of the body. On a specific note, research based on a systematic review of former research works and critically evaluated meta-analysis of 3523 articles from EMBASE, PubMed, and Web of Science, from Dec'21 to May'22 on the adults with SARS-CoV-2 infection, Durstenfeld et al (2022) noted that CPET measured peak VO2 showed physiological differences between people with and without SARS-CoV-2 infection. Durstenfeld et al (2022a) also initiated a systematic review of former research works and critically evaluated meta-analysis of 38 studies with 2160 participants and established that long COVID reduces exercise capacity among adults. Furthermore, Burstein et al (2022) developed a CPET-based single-centre retrospective longitudinal cohort study among children, adolescents and young adults from the Institutional Review Board of the Children's Hospital of Philadelphia, whereby it has been established that aerobically fit patients attain a greater decrease of aerobic capacity in the time of pandemic than the less fit. As for the systematic review led by over 5619 articles on 5&17 years children and adolescents respectively; Villaseca-Rojas et al (2022) established through CPET that the condition of congenital heart disease (CHD) is due to lower exercise capacities during childhood.

Physical activity (PA), added by the identified sedentary behaviour (SB) have noted key prognostic indicators, which can be detected as aerobic capacity followed by cardiopulmonary function (Curran et al., 2022). During the COVID-19, PA decreased and SB increased among children (Burstein et al., 2022).There are various methods to assess PA including questionnaires, interviews and wearable activity monitors(Hammond-Haley et al., 2021). In the case of this study, Geneactiv accelerometers were selected, as Duncan et al (2020) and Antczak et al (2021) noted that Geneactiv accelerometers are the best solution to collect and further classify the physiological differences produced from moderate-to-vigorous physical activity (MVPA) among the participants.

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Concerning closer inspection into multisystem inflammatory syndrome (MIS-C), added by the instance of long COVID sufferance, Lopez-Leon et al (2022) established that children and adolescents are less likely to get seriously impacted by COVID. The attained results referred to the top physiological complaints like fatigue among 9.66% of the participants, mood symptoms among 16.50% of the participants, headache among 7.84% of the participants, sleep disorders among 8.42% of the participants, and respiratory symptoms among 7.62% of the participants. In addition, Asadi-Pooya et al (2021) discovered that mild-COVID-led symptoms were much more visible among children and adolescents in the form of fatigue, body ache, cough, and breathlessness for a short-term of 2 weeks. For moderate to severe COVID, these symptoms persist from 4 to 6 weeks and sometimes beyond, reaching the status of long COVID. In October'21, the World

Health Organization, WHO through a Delphi consensus and proposed that clinically, the post-COVID-19 state generally occurs three months after being infected with COVID-19 (Soriano et al., 2021). However, the National Institute for Healthcare Excellence NICE made a clear declaration about the post-COVID phases in February'22, whereby long COVID was defined as "an inclusion of both ongoing COVID (4 to 12 weeks) and post-COVID-19 (≥12 weeks) symptoms".

Research Gaps & Hypothetical Views

For the effectiveness of this research, the current study considers the definition of NICE as a scale for understanding the post-COVID stages of the participants. It has been noted that there is minimal research to compare the physiological changes between the post-COVID with symptoms and post-COVID without symptoms groups.

Moreover, no studies have reported Physioflow measures during CPET. It is here that this research aims to meet these gaps with an emphasis on gaining knowledge about Physioflow data during ramp incremental cycling exercise, thereby initiating conditions for the betterment of lifestyles among children, adolescents and adults in the UK.

This will be achieved through the assessment of whether individuals with post-COVID-19 symptoms longer than 12 weeks following SARS-CoV-2 infection have reduced exercise capacity during PET and lower PA levels compared with recovered, asymptomatic individuals, as well as identify possible mechanisms to explain the reduced exercise capacity after SARS-CoV-2 infection. This research will assess both groups' physical fitness by measuring their pulmonary function before exercise, CPET variables, and breathlessness during exercise, physical activity, and health-related quality of life (HRQoL).It is hypothesized that:

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Hypothetical views:

Hypothetically, it can be stated that the capacity for functional exercise can worsen in people with long COVID against those recovered without symptoms, levels of physical activity levels can reduce after long COVID against post-COVID without symptoms, measures led by QOL measures for physioflow, heart rate (HR), stroke volume (SV), and cardiac output (CO) over time would be significantly reduced in long COVID cohort against those recovered without symptoms, and finally, there can be reduction in pulmonary function in people with long COVID against post-COVID without symptoms.

MATERIALS AND METHODS

Study design

This was a prospective cross-sectional study of children, adolescents and adults with long COVID symptoms, who participated in CPET and physical activity monitoring, and their results were compared to those of age- and sex-matched individuals with no symptoms post-COVID-19 infection.Data was collected for initiating qualitative research approach and qualitative research approach. Participants were recruited by word of mouth from the local area. Written informed consent was obtained.Each participant visited the laboratories once. On the test day, the research protocol was explained to the participants and their parents if they were children. They were also familiarized with the laboratory environment and measurement equipment and were allowed to practice. Demographic data were collected, and height, weight, gender and ethnic background were measured and documented. Participants were asked not to consume any kind of drug or consume alcohol, caffeine and were asked not to exercise before 24 hours o test day. In addition, all participants completed the Exercise and Health History questionnaire (see Appendix 1 Exercise and Health History Questionnaire. January 2020 version (Source: University of Portsmouth)).A general overview of the visit is outlined below followed by further specifics of each assessment technique. A schematic overview of visit 1 is presented in Figure 2.

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Data Collection & Sampling

The data for this research was collected from primary sources. This research concentrates on making a comparative analysis of the physiological functioning among people post-COVID with symptoms (long COVID) vs. post-COVID without symptoms. For this purpose, data were collected for ramp incremental cycling exercise and physical activity among UK-based children and adults. Following anthropometric and resting blood pressure measures, participants were asked to undertake a resting pulmonary function test before beginning the ramp incremental CPET phase. At the end of their visit, Geneactiv accelerometers were given to the participants. They wore these wristwatches for 7 days and returned the accelerometer either via post or in person, a week later. Necessary data on physical activity, pulmonary function, CPET variables, breathlessness during exercise, and QOL using the K-BILD questionnaire was collected.

Sample size: Participants

This was a study of patients who were diagnosed of COVID-19 with positive reverse transcriptase-polymerase chain reaction (RT-PCR) test. The number of participants for this research was30 people living in the UK from varied ethnicities. The selected samples of children, adolescents and adults have been categorised into three groups: Group A is a cohort of 15 participants with post-COVID symptoms, and Group B comprises a cohort of 15 participants without post-COVID symptoms. These groups included both male and female genders, with children from 10 to 12 years of age, adolescents from 13 to 18 years of age, and adults between 18 to 48 years of age.

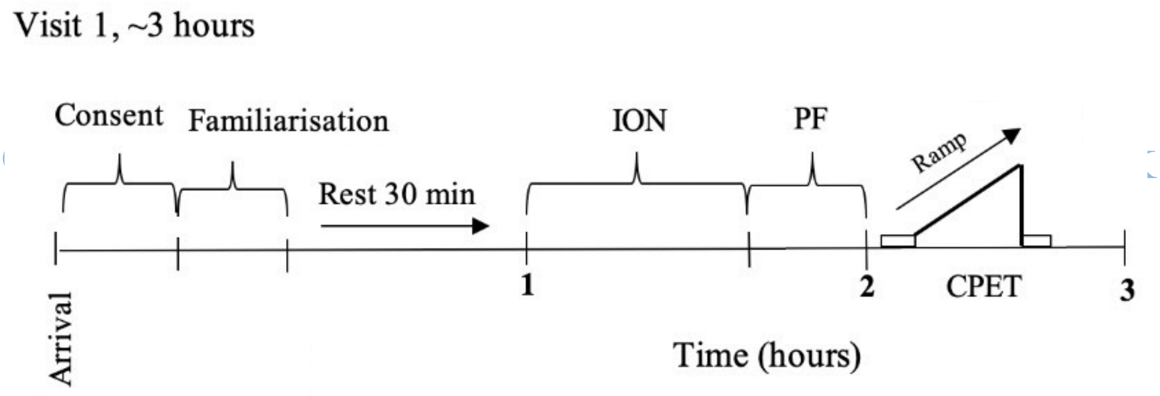

Figure 2 A schematic overview of experimental procedures in 1st visit, where BP (blood pressure measurements); PF (pulmonary function); & CPET (cardiopulmonary exercise test).

Participants characteristics

This was a study of patients who were diagnosed of COVID-19 with positive reverse transcriptase-polymerase chain reaction (RT-PCR) test.

Inclusion criteria

Inclusion of UK patients recovering from COVID-19 within ≥12 weeks after the start of COVID symptoms, with at least one negative COVID antigen test, not more than 5 days before the study; are only considered for this research. Moreover, males and females between 10 to 48 years of age were included after receiving signed informed consent, whereas parental consent is obtained for those under 16 years of age.

Exclusion criteria

People unable to perform exercise testing, presence of any pre-existing health conditions, and any injury in the past 6 months were deemed them to participate and were screened by the Exercise and Health History Questionnaire. Moreover, people diagnosed with any other significant respiratory disorder other than COVID-19, people with a physical disability (non-ambulatory patient e.g. wheelchair or bed-bound), learning difficulties or cognitive failure making them unable to give consent or understand questionnaires or instructions, and those with confirmed pregnancy were excluded from sampling.

Anthropometry and ethnicity

Anthropometric data: At the beginning of each visit, the measurement of the height and the counted body mass of the participants were recorded by using a stadiometer (Seca 213, UK) and the records of their weight are marked through weighing scales (Seca 770, UK).
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These measures calculated body surface area, by withstanding body surface area [m^2] = 0.20247 x height $(m)^{0.725}$ x weight $(kg)^{0.425}$ (Du Bois & Du Bois, 1989). For children aged 10-18, the pubertal staging was self-assessed according to pubic hair classification (Tanner, 1981).

Ethnicity: This study included a sample from the UK population, irrespective of their ethnicity. In other words, the study remained open to all the ethnic entities that belong to the UK population.

Research Procedure

Pulmonary function: Spirometry

Measurement of pulmonary function was conducted using a flow-volume spirometer (Microlab 3500 MK8, Carefusion, UK) as per guidelines stated by the American Thoracic Society (Graham et al., 2019). With a nose clip in place, participants were instructed to seal their lips around the mouthpiece and breathe normally. After a few tidal breaths, they were asked to perform a maximal inspiration followed by a hard and fast expiration and finished with a maximal inspiration before relaxing. This test was repeated until three acceptable blows not more than 5% apart from each other had been achieved (Radtke et al., 2019). No more than 8 trials were attempted, and the best acceptable FVC and FEV_1values were recorded.

Aerobic fitness: CPET

Through the cardiopulmonary exercise test (CPET), this study provides assessments regarding the exercise capacity of the participants and records the necessary physiological aspects which are responsible for limiting the performance of each individual. Selecting CEPT is justified as it can assess the integrative responses of cardiovascular, pulmonary, and skeletal muscle systems of the participants (Radtke et al., 2019) with and without COVID symptoms. The maximal exercise test was performed on a cycle ergometer (Lode Corival, Groningen, The Netherlands) (see Figure 3).

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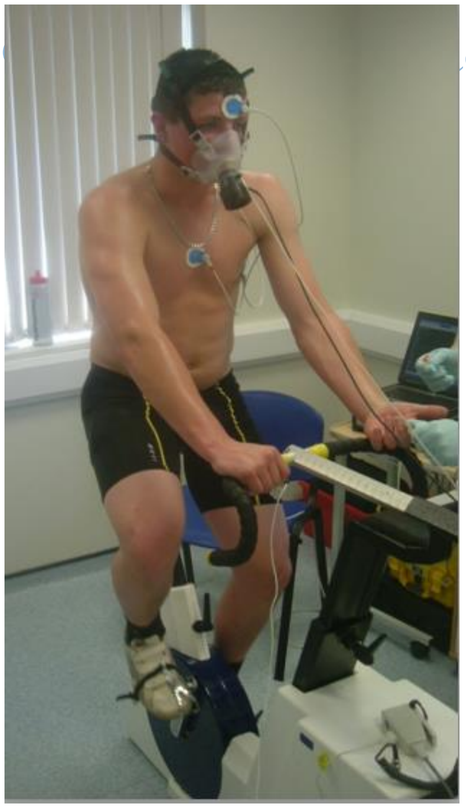

Figure 3Experimental set-up of cardiopulmonary exercise test using a bioelectrical impedance cardiography system in people with long COVID (Source: Author)

A ramp-incremental protocol was used, which has been shown previously to produce a safe, valid and repeatable assessment of $\dot{V}O_{2peak}$ in the post-COVID cohort (Durstenfeld et al., 2022). The test began with an initial 3-minute baseline period of pedalling at 20 W. Following this, participants completed the incremental ramp phase. Through which the power output was increased incrementally by 10-30 W·min-1, depending on the patient's age, body mass and/or health status (Hulzebos et al., 2012) to obtain a 10-minute test duration. The ideal time span counted for maximal cardiopulmonary exercise test gets fixed for a span of 6 to 10 minutes in case of children (Hebestreit, 2004), 8 to 12 minutes for adolescents and adults (Buchfuhrer, 1983; Radtke et al., 2019), these timelines are fixed as per the fitness regime of the participants, which is marked as common to both groups' ideal duration range. All participants self-selected a pedal cadence between 60-70 revolutions per minute (rpm), once chosen that cadence was fixed for the rest of the test. Verbal encouragement was given to push participants to their maximum potential and continue until volitional exhaustion. Volitional exhaustion was defined as the pedal cadence dropping by greater than 10 rpm for more than 5 seconds despite strong verbal
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encouragement. Participants were then given a recovery period of a total 15 minutes, which comprises 5 minutes fixed for of pedalling at a speed of 20 W and a fixed timeline of 10 minutes in order to gain passive recovery (which gets counted in the seated upright position) exhaustion, followed by post-exercise seated rest and monitoring.

Breath-by-breath changes in the exchange of the pulmonary gas added by the ventilation collected through face mask (Hans Rudolph 7450 series V2 mask, USA). This further gets added by the turbine flow meter system (COSMED Ltd, Rome, Italy), along with the display in terms of using an online gas analyser system (Quark CPET, COSMED Ltd, Italy). There is the means for subjective ratings made over the perceived exertion and the state of dyspnoea collected from the participants in every minute by the CPET protocol, as specified by the Borg 6-20scale (Borg, 1982).

SpO_2: A reusable finger clip pulse oximetry sensor (Nonin, Minnesota, USA) was attached to the index fingertip and measures of arterial blood oxygen saturation, SpO_2, were collected throughout the exercise. Participants were instructed to grip the handlebar loosely to avoid inducing a poor signal from poor perfusion, as well as to not wear any

nail polish before the test. If SpO_2 fell significantly, exercise was terminated and supplemental O_2 was given. End-exercise SpO_2measures were recorded.

Thoracic impedance cardiography: The changes in thoracic impedance during the cardiac cycle were measured using a bioelectrical impedance cardiography system (PhysioFlow, PF-05; Manatec Biomedical, France) using a high-frequency (75 kHz) and a low-magnitude (1.8 mA) current across the thorax (see Figure 4).

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Figure 4 Bioelectrical Impedance Cardiography System (Source: Author)

This device is portable in size and id very much non-invasive with the capability to adopt wireless monitoring in the real-time, via a Bluetooth USB adaptor for measuring morphology-based impedance cardiography signals. Through this provision, the researcher can measure heart rate (HR), stroke volume (SV), and cardiac output (CO) at 1-second intervals. The necessary data for HR gets collected from the ECG (Wang et al., 2010), SV was calculated from the cardiac ejection waveform, and the CO was obtained by multiplying SV with HR (Ferreira et al., 2012). Skin sites were shaved if necessary and disinfected with 75% alcohol. Electrodes as positioned in the forehead and at the base of the neck, the supraclavicular fossa are placed above it, and two were positioned on the xiphoid process.

Physical activity

Accelerometry: A GENEActiv (Original) accelerometer (Activinsights Ltd, Cambridge, UK) was handed to the participants at the end of the test. These accelerometers are small, lightweight, waterproof devices worn on the dominant wrist. We asked participants to wear this for7 days to measure the amount and intensity of physical activity they undertook, as well as the amount of sedentary time. Data were extracted on the return of the device using the application software. This provided information on time spent being active, the intensity of PA (light, moderate or vigorous), and sedentary time (Hees et al., 2015). Participants also completed a physical activity diary with the help of their parent/guardian depending on their age. They were asked to note down the sleep and wear times, and briefly, record activities undertaken and times that the monitor was removed. They were advised to not take the device off unless taking part in contact sports.

Health-related quality of life (HRQoL): K-BILD Questionnaire

The inclusion of King's Brief Interstitial Lung Disease (K-BILD) questionnaire in the context of this research is justified as K-BILD has been recognised as the most appropriate tool for the interstitial lung disease ILD-specific HRQL (health-related quality of life) analysis and is useful in the detection of the factors and state of health impairment (Birring et al., 2020). According to Birring et al (2020), K-BILD is effective for the analysis of breathlessness in participants involved in physical activity, and is accurate in the detection of chest symptoms, along with psychological health. The scores attained from the K-BILD questionnaire were rated from 1 to 100 on a seven-point Likert scale; the higher scores represent better health conditions.

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Quantitative Methodology: SPSS

For this purpose, the current research will follow quantitative research methodology with SPSS statistical analysis, as in comparison with qualitative research methodology, quantitative research methodology offers statistical and objective results (Wagner, 2019 & Jasrai, 2020). The core focus of quantitative research is to accumulate a higher count of information and knowledge regarding the selected research aim (Gogoi, 2020). The selection of quantitative research justifies this study as the researcher aimed to collect specific differences in the physiological changes among groups with long term display of post-COVID symptoms and those marked without post-COVID symptoms, and thereby identify possible reasons for these differences.

To attain appropriate data results, this research considers the usage of SPSS. SPSS is the statistical analysis software package for accomplishing quantitative data analysis with more effective precision than its contemporary software (Rahman and Muktadir, 2021, p. 301). For assessing the Physioflow, CPET variables, pulmonary function, RPE scores, and K-BILD results under two conditions, this research selected T-tests (Wadhwa. and Marappa-Ganeshan, 2022).

Descriptive Statistics: T-test

The descriptive statistical analysis through the K-BLID bar chart for this research will follow T-tests. Under this provision, this research will be facilitated to compare the two independent groups (Gerald, 2018) the post-COVID cohort with symptoms (long COVID) and the asymptomatic post-COVID group. These groups will be considered for the determination of statistical data related to the selected sample of children between 10 to 12 years, adolescents between 13 to 18 years, and adults between 18 to 48 years.

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Independent variables are –

Group A- Post-COVID with symptoms with physiological function after physical/aerobic exercises.

Group B- Post-COVID without symptoms with physiological function after physical/aerobic exercises.

The variables marked in this research can be noted in the structure as mentioned in Figure.

Here, the dependent variable is-

> Differences in the physiological functioning among people during ramp incremental cycling exercise and physical activity assessed through Geneactiv accelerometers.

Thus, the T-tests for this research are represented in Figure 5.

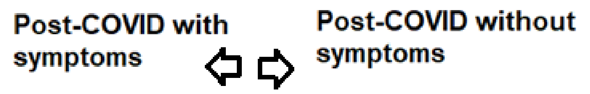
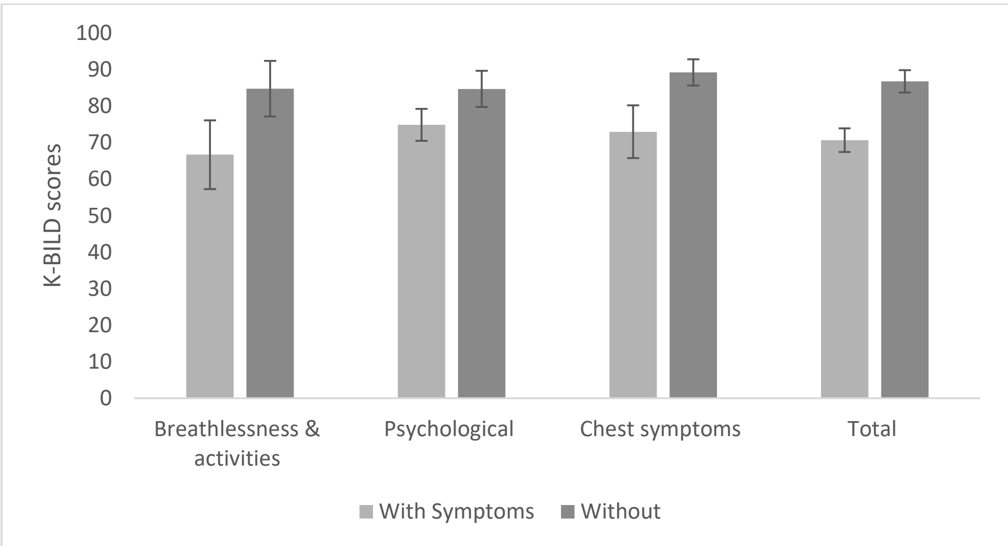


Figure 5 Distribution of Variables for T-tests (Source: Researcher adapted from Gerald, 2018).

RESULTS

Descriptive Statistics

In this section, the findings from the descriptive statistics have been presented. The first descriptive analysis depicts the K-BLID bar chart for the two different groups included in this study, namely the post-COVID cohort with symptoms (long COVID) and the asymptomatic post-COVID group.



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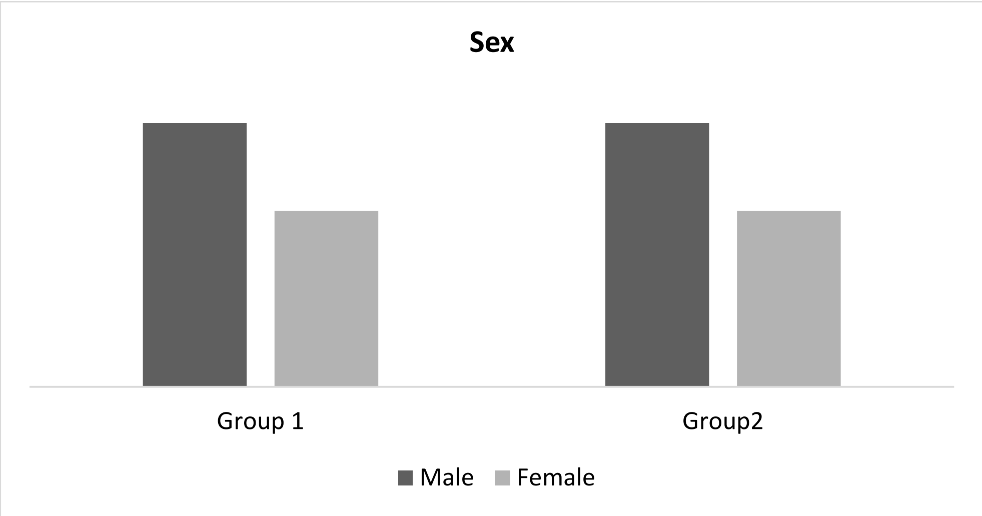
Graph 1 Attained K-BILD scores from Participants with & without symptoms

The findings show that there are three different variables to capture the K-BILD and the values are higher for asymptomatic individuals. This indicated that the post-COVID cohort without symptoms had better physical health and overall quality of life as compared to individuals with long COVID.

The next categorical variable is sex for which a descriptive graph was constructed as shown in the figure below. The findings suggested that the proportion of males was higher in both groups as compared to the number of females.



Graph 2 Attained K-BILD score differences among male 7 female genders

Outcomes

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Table 1 Attained Results on Variables

Variable	Post-COVID with symptoms (Mean ± SD) n=15	Post-COVID without symptoms (Mean ± SD) n=15	*p*-value	ES (*d*)
Gender	NA	NA	NA	NA
Age (years)	24 ±13.19	24.32±15.38	0.85	-
Stature (m)	166.83± 15.38	164.44±15.78	0.68	0.15
Body mass (kg)	69.33± 14.32	66.73±19.29	0.68	0.15
BMI (kg·m^2)	24.80± 3.64	24.26± 3.64	0.57	-
Pulmonary function				
FVC (L)	3.45± 0.99	3.64± 1.03	0.60	-0.19
FVC (% predicted)	84.2±24.6	95.5±25.6	0.23	-0.45

FEV_1 (L)	2.74±0.95	3.38±0.98	0.08	-0.66
FEV_1 (% predicted)	82.95±26.03	105.45±31.35	**0.04***	**-0.78**
CPET parameters				
$\dot{V}O_{2peak}$ ($L \cdot min^{-1}$)	2.3±0.84	2.95±1.02	0.38	-
$\dot{V}O_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	33.16±9.07	44.78±13.77	**0.01***	>-0.99
$\dot{V}O_2$ at the GET ($L \cdot min^{-1}$)	1.59±0.57	1.66±0.41	0.74	-0.12
$GET_{\%}$ (% of $\dot{V}O_{2peak}$)	71.99±23.98	1.66±0.41		-
Ramp PPO (W)	158.73±58.55	172.46±66.15	0.55	**-0.22**
SpO_2 (%)	98.33±0.89	98.53±0.99		-
BORG (6-20) scores				
Rest	6.1±0.4	6.1±0.4	>0.99	-
Peak	19.5±0.8	6.1±0.4	>0.99	-
K-BILD measures				
Breathlessness & activities	66.7±9.4	84.8±7.6	**<0.001***	-2.11
Psychological	74.9±4.4	84.7±4.9	**<0.001***	-
Chest symptoms	73.0±7.3	89.3±3.6	**<0.001***	-
Total	70.7±3.3	86.8±3.1	**<0.001***	-
Physical activity				
Sedentary time (in minutes)	779.6±53.2	703.7±41.4	**<0.001***	1.592
Light PA (in minutes)	147.6±28.0	171.0±32.6	**0.04***	-0.771
Moderate PA (in minutes)	63.0±9.0	85.4±7.2	**<0.001***	**-2.752**
Vigorous PA (in minutes)	15.5±8.3	33.5±11.4	**<0.001***	-1.806

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The researcher has also conducted descriptive statistics for the continuous variables included in the study. Concerning descriptive statistics, the measures of the central tendencies have been used along with variables for normality. The findings suggested that the average age of the participants included in the study is 24 years and the average height is 166 cm. Furthermore, the findings from the BMI show that the average BMI is 24.53 which indicated the participants have a healthy weight.

Table 2K-BILD measures on Variables

Variable	Post-COVID with symptoms (Mean ± SD) *n*=15	Post-COVID without symptoms *(Mean* ± SD) *n*=15	*p*-value	*ES (d)*
K-BILD measures				
Breathlessness & activities	66.7±9.4	84.8±7.6	**<0.001***	-2.11
Psychological	74.9±4.4	84.7±4.9	**<0.001***	-
Chest symptoms	73.0±7.3	89.3±3.6	**<0.001***	-
Total	70.7±3.3	86.8±3.1	**<0.001***	-
Physical activity				
Sedentary time (in minutes)	779.6±53.2	703.7±41.4	**<0.001***	1.592
Light PA (in minutes)	147.6±28.0	171.0±32.6	**0.04***	-0.771
Moderate PA (in minutes)	63.0±9.0	85.4±7.2	**<0.001***	**-2.752**
Vigorous PA (in minutes)	15.5±8.3	33.5±11.4	**<0.001***	-1.806

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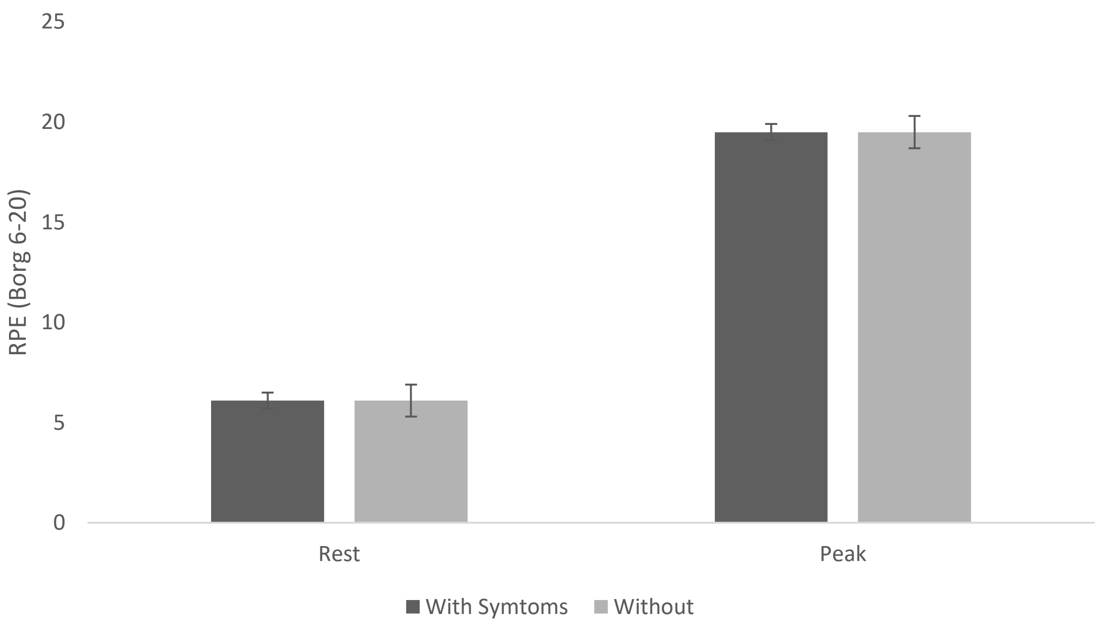
The findings from the K-BILD measures show that the average value for the breathless activities is 66.6 with a standard deviation of 9.4. Similarly, for psychological and chest symptoms, the average values are (*mean 74.9, SD±4.4) and (mean 73.0, SD*±7.3). The standard deviations for the variables are not a very large indication that most of the values are close to the mean value.



Graph 3Attained Borg scores from Participants with & without symptoms

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The researcher has also conducted descriptive statistics for RPE (Borg6-20) and the findings suggested that the values while at rest are similar for both groups. In addition, for the peak also, the values are similar for both post-COVID groups. This indicated that there is not much variations noted among the selected groups in terms of the RPE (Borg6-20). However, further inferential analysis is required to provide enough evidence.

Normality test

The second type of test included in the study is the normality test which examines whether the variables follow the normal distribution or not (Yap and Sim, 2011). To test the normality researcher has used the Kolmogorov- Smirnova and the Shapiro-Wilk test. The Shapiro-Wilk test tests the hypothetical views as the variable follows normal distribution; therefore, if the p-value is more than 0.05 we cannot reject the null hypothesis (Psaradakis and Vávra, 2020). In other words, the variable follows normal distribution if the p-value is more than 0.05. The normality test for the current study indicated that there were a few variables which do not follow the normal distribution. For example, the age of the first group (long COVID) does not follow a normal distribution. Some other variables failed to follow a normal distribution as well (the results for the normality are attached in the appendix). In terms of further analysis, it is generally believed that it is not advisable to conduct a t-test if the variable does not follow the normal distribution, in which case, other tests such as the chi-square test and Mann Whitney U (MWU) test can be conducted.

Independent T-tests

Based on the normality test, the researcher conducted an independent sample t-test to examine if there was a significant difference in the symptomatic post-COVID group from those who did not have symptoms. The findings from this analysis suggested that there was no statistically significant difference noted among the selected two groups regarding the following variables:

- Stature
- Body mass
- FVC (L)
- FVC %mpred.
- VO_2 at GET(Lmin-1)
- Ramp PPO (W)
- VO_{2peak} (mL.min.kg-1)

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On the other hand, the independent t-test shows that there was a statistically significant difference noted among the selected two groups for the following variables. The p-values for these variables were less than 0.05.

- Breathlessness & activities
- FEV1 (L)
- FEV1 %pred.
- CPET
- Sedentary time (in minutes)
- Light PA (in minutes)
- Moderate PA (in minutes)
- Vigorous PA (in minutes)

There was a difference among the long COVID and asymptomatic cohorts for the above-mentioned variables. There may be various reasons for the difference. However, the results also indicated that participants were selected in a similar group with a similar BMI index. This implies that the effect of the BMI index is controlled.

Mann Whitney U test

For the identified variables, there is the irregularity in following the normal distribution pattern. The Mann-Whitney U test was conducted and it examined the null hypothesis revealing that there is no possibility for any kind of statistical significance in delivering the difference between the two selected groups (Richardson, 2018; Rubarth et al 2022). In this case, the sample size is 30, so the researcher used the exact significance. The findings suggested there was no significant difference in the age of the two groups as the value of exact significance was more than 0.05. Similar results were shown for the SPO2%and VO_{2peak} (Lmin-1). In contrast, there was a significant difference in the BMI, psychological, chest symptoms, total K-BILD and GET (%VO_{2peak}) measures.

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Furthermore, the effect size of the variable from the Mann-Whitney U test has been calculated. The effect size shows the magnitude of the effect. An effect value of less than 0.3 is considered a small effect, whereas an effect size between 0.3-0.5 is considered a medium effect, and an effect size of more than 0.5 is a large effect (Fay et al., 2017; Fay et al., 2018). In this case, different variables have shown different effect sizes. For example, stature and BMI show a small effect whereas breathlessness and sedentary time show a large effect. Most of the variables in the Mann-Whitney U test showed either a small or medium effect.

The findings from the chi-square test for the gender indicated that the exact significance is more than 0.05 which indicated that there was no significant difference concerning gender among the two groups.

DISCUSSION

A discussion on the attained results noted above gets justified as the research gaps attained from the literature review get bridged through the empirical outcomes. It has been noted that there is minimal research to compare the physiological changes between the post-COVID with symptoms and post-COVID without symptoms groups, especially when it comes to the physioflow measures during CPET, there is no research found. To meet this gap the empirical research under qualitative and quantitative approaches emphasised gaining knowledge about Physioflow data during ramp incremental cycling exercise. Through this research, the conditions for the betterment of lifestyles among children, adolescents and adults in the UK in the post-COVID scenario have been attempted.

There is a general acceptance of the fact that the instances of distress remain high among people who suffered from COVID (Cucinotta & Vanelli, 2020; Delbressine et al., 2021; Shah et al., 2021; Solera-Sanchez et al., 2021; Tabacof et al., 2021). Variations were noted from the attained empirical findings of this research. From the results, it has been noted that the capacity for functional exercise worsens and levels of physical activity get reduced in people with long COVID compared to recovered individuals without symptoms. However, the attained results also signified that there were still some participants who attained effective recovery from COVID, as they continued exercising on a routine basis. Such declarations stand close to Woods et al (2020) whereby the impact of COVID on the immune system, followed by the musculoskeletal systems, respiratory system, cardiovascular stature, and even the brain were marked with pathological conditions before any kind of engagement with PA. However, Glaab and Taube (2022) offered the specialised notion of gaining insight into the cardiopulmonary exercise test (CPET) for the recognition of cardiopulmonary and metabolic changes among adults. Following such notions, CPET by this research also stated that there are differences in results among genders and body mass of the patients.

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The attained results of this research specifically noted that higher values for asymptomatic individuals from the post-COVID cohort without symptoms are marked to own better physical health as against the overall quality of life against those with long COVID.

Attained QOL measures through the K-BILD questionnaire lowered the long COVID cohort as against the recovered individuals without symptoms. Moreover, from the CPET led by physioflow data during ramp incremental cycling exercise, the pulmonary function was marked to get reduced in people with long COVID against those with post-COVID without symptoms. From the findings and aforementioned analyses, it has been derived that there is no possibility for any kind of statistical significance in delivering the difference between the two selected groups, particularly when the assessments were based on stature, Body mass, FVC (L), FVC %mpred, VO2 at GET(Lmin-1), Ramp PPO (W), and VO_{2peak} (mL.min.kg-1). However, when it comes to the independent t-test, the result shows that there is no possibility for any kind of statistical significance in delivering the difference between the two selected groups under the determined variables of Breathlessness & activities, FEV1 (L), FEV1 %pred., CPET, Sedentary time (in minutes), Light PA (in minutes), Moderate PA (in minutes), and Vigorous PA (in minutes). Since the attained p-values for these variables were less than 0.05, the conditions of the long COVID patients appeared more vulnerable than those without symptoms. Moreover, the attained empirical research further added that participants were selected under a similar group with a similar BMI index, whereby it gets implied that the effect of the BMI index is controlled and the variations are marked significantly. An in-depth analysis in this context gets noted as this research interpreted the research led by Silva Andrade et al (2021). These scholars analysed both short-term and long-term impacts of COVID and noted that there is fixed coronary atherosclerosis which is responsible for limiting myocardial perfusion, causes endothelial dysfunction, and state of severe systemic hypertension, led by high circulating levels of Ang II. Such declarations appear effective as the results of this research confirm the possibility of physioflow to get degenerated for long COVID cohorts against those without symptoms.

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On the other hand, it is significant to note Desai et al (2022) who established the list of complications that long COVID (see Figure), can cause to a patient and the CPET results of this research identified them while deriving the details related t the selected variables as mentioned in Table 2. Following a similar thread, Garrigues et al (2022) identified that patients who are much engaged in sports before infection are more active in gaining recovery and getting recognised in the cohort without symptoms, in this research. However, those who are not much engaged in sports are found to be a part of a cohort with long COVID. While referring to the possibilities of adverse consequences in the physiological functioning of the human body after getting infected by COVID, Serviente et al (2022) indicated the instances of cardiac impairments, added by the condition of persistent endothelial dysfunction in the peripheral vasculature for people who suffered COVID-19, and the results established that irrespective of any instance of severity over the illness phase, these people had lower $\dot{V}o_{2peak}$. However, such specifications are not marked in the empirical data analysis of this research as the concerns were to identify the differences between the selected groups through CPET. However, it is important to note that the assessments led by Serviente et al (2022) appear effective in terms of the pulmonary conditions of patients with long COVID, which instructed towards the involvement of exercises among children, adolescents and adults in the UK.

Confirmation of the effective usage of CPET can be marked as scholars like Mancini et al (2021), Demir et al (2022), Villaseca-Rojas et al (2022), and Durstenfeld et al (2022) implied it for identifying the factors that lead to dyspnoea, assessing damaged of numerous internal body parts by the infections of COVID, condition of congenital heart disease (CHD), and attaining data of people without SARS-CoV-2 infection; respectively. The assessment of this research in comparing people with long COVID symptoms and those without symptoms in the post-COVID phase offers the unattended dimension of adding an exercise routine for the betterment of lifestyles among the population of the UK. As Durstenfeld et al (2022a) acknowledges the positive effects of exercises in managing long COVID, especially in reducing anxiety among adults, this empirical research also confirms the higher rates of getting protected from COVID as exercises get included in the daily routine of the people. In this context, based on the CPET assessments, Burstein et al (2022) concluded that people involved in aerobics have experienced decreases in aerobic capacity in the time of the pandemic, and this research notes that such instances should be managed with greater efforts in adding other kinds of physical activities for better lifestyles of the UK population.

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CONCLUSION

Following the definition of NICE, "*an inclusion of both ongoing COVID (4 to 12 weeks) and post-COVID-19 (≥12 weeks) symptoms*", better knowledge about the post-COVID stages of the participants has been assessed by this research. The research findings offered information led by the Physioflow measures during CPET. While meeting the identified research gaps, the Physioflow data during ramp incremental cycling exercise initiating conditions for the betterment of lifestyles among children, adolescents and adults in the UK are much acknowledged. The attained results established that individuals with post-COVID-19 symptoms longer than 12 weeks following SARS-CoV-2 infection have reduced exercise capacity during PET and lower PA levels as against the recovered, asymptomatic individuals. It has been also noted that there is a reduction in exercise capacity after SARS-CoV-2 infection.

The secondary data sources already confirmed that there is a serious deterioration in the physical health of people of all ages and gender after COVID (Asadi-Pooya et al., 2021; Lopez-Leon et al., 2022). However, this research confirmed the relationship between physical activity and post-COVID conditions by generating empirical research through T-tests over the two selected groups- with and without COVID symptoms. The results-driven from the physical fitness by measuring their pulmonary function before exercise over CPET variables, and breathlessness during exercise, physical activity, and health-related quality of life (HRQoL) were accomplished to establish that inclusion of regular exercises and physical activities can protect the UK population from COVID, and in the case of infection can help the body to recover at the earliest.

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Conclusively, this research states that the hypothetical view of noting that the functional exercise capacity gets worse in people with long COVID compared to recovered individuals without symptoms appears as true. The results based on the Breathlessness & activities, FEV1 (L), FEV1 %pred., CPET, Sedentary time (in minutes), Light PA (in minutes), Moderate PA (in minutes), and Vigorous PA (in minutes), established that long COVID makes people vulnerable to weakness and as such, there is a deterioration in their functional exercise capacity. Moreover, this also lays a negative impact on the levels of physical activity and can cause a reduction in pulmonary function in people with long COVID as against those without symptoms. In terms of the measurements related to QOL, it is highly recommended by this research that the inclusion of regular exercise is very important for lowering the possibility of getting infected by COVID and developing more resistance to the virus even in long COVID.

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APPENDICES

Appendix 1 Exercise and Health History Questionnaire. January 2020 version (Source: University of Portsmouth)

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