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Incidence of long Covid-19 in people with previous SARS-Cov2 infection: a systematic review and meta-analysis of 120,970 patients

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Abstract

Background: The long-term consequences of the coronavirus disease 19 (COVID-19) are likely to be frequent but results hitherto are inconclusive. Therefore, we aimed to define the incidence of long-term COVID signs and symptoms as defined by the World Health Organization , using a systematic review and meta-analysis of observational studies.

Methods: A systematic search in several databases was carried out up to 12 January 2022 for observational studies reporting the cumulative incidence of long COVID signs and symptoms divided according to body systems affected. Data are reported as incidence and 95% confidence intervals (CIs). Several sensitivity and meta-regression analyses were performed.

Findings: Among 11,162 papers initially screened, 196 were included, consisting of 120,970 participants (mean age: 52.3 years; 48.8% females) who were followed-up for a median of six months. The incidence of any long COVID symptomatology was 56.9% (95%CI: 52.2-61.6). General long COVID signs and symptoms were the most frequent (incidence of 31%) and digestive issues the least frequent (7.7%). The presence of any, neurological, general and cardiovascular long COVID symptomatology was most frequent in females. Higher mean age was associated with higher incidence of psychiatric, respiratory, general, digestive and skin conditions. The incidence of long COVID symptomatology was different according to continent, age and follow-up length.

Interpretation: Long COVID is a common condition in patients who have been infected with SARS-CoV-2,regardless of the severity of the acute illness, indicating the need for more cohort studies on this topic.

Key words: COVID-19; long COVID; systematic review, cohort, SARS-CoV-2.

Introduction

Since the beginning of the COVID-19 pandemic on 8 March 2020, more than 500 million cases of SARS-CoV-2 infection have been reported worldwide with a daily global increase of approximately 500,000 cases per day.[1] While global health strategies, vaccines, antivirals and new monoclonal antibodies have significantly reduced COVID-19 mortality and severe illness, long consequences after the acute phase of the disease remain an unresolved issue.

During the first pandemic wave, several articles highlighted the possible medium-to long-term devasting consequences of SARS-CoV2 infection, for patients and healthcare systems [2, 3]. Article conclusions were based on follow-up studies of people who had coronavirus infections including SARS-CoV-1 in 2003 and MERS-CoV in 2012 [4, 5] and who, after months and years of follow-up, still had symptoms and signs linked to previous infection. There is an increasing body of global literature reporting the long-term sequelae of patients with previous SARS-CoV-2 infection.[2, 3] Reported symptoms vary and include, for example, dyspnea, hair loss, anxiety, depression, asthenia, fatigue and loss of appetite.[2, 3]

Furthermore, the terminology relating to long COVID in the literature is not standardized. Researchers have used different terms to describe the prolonged symptoms following COVID-19 disease, for example: Long COVID, Long-haulers, Post-acute COVID-19 syndrome, and Chronic COVID-19. Moreover, different time cut-offs have been used (from 2-3 weeks to months after COVID-19).[4] In October 2021, the World Health Organization (WHO) defined the long COVID as "a condition that occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually 3 months from the onset of COVID-19 with symptoms that last for at least 2 months and cannot be explained by an alternative diagnosis". [5] The real number of people living with long COVID is unknown, as well as the real incidence and which organs or systems are most frequently involved. Knowing the real incidence of long COVID is critical for addressing the problem and examining possible therapeutic approaches, preventative efforts, and global health policy. The

definition and inclusion criteria of previous studies on long/post COVID conditions may have masked the true burden. However, to explain the real incidence without the confounding influence of different follow-up lengths, we used the WHO definition. Importantly, our study is the first to include exclusively papers using the WHO proposed period to define long COVID.[6-9]

Given this background, we carried out a systematic review and meta-analysis regarding the incidence of signs and symptoms typical of long COVID, with a minimum follow-up time longer than at least 3 months and according to the WHO definition.

Materials and methods

Protocol registration

This study was conducted following the recommendations in the Cochrane handbook for systematic literature reviews to conduct the screening and selection of studies.[10] The original protocol was registered in https://osf.io/5b2tv.

This systematic review and meta-analysis was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, updated version to 2021.[11]

Research question

The research question for this systematic review is: "What is the incidence of long COVID signs and symptoms?" To guide the identification of adequate keywords to build search strategies to search bibliographic databases, the research question was framed into the PICO(S) (Participants, Intervention, Comparison, Outcome, Study design) format: (P) laboratory confirmed and/or clinically diagnosed COVID-19: long COVID was defined as the presence of signs and/or symptoms after three months and lasting at least two months and that cannot be explained by other medical conditions, in agreement with the indications of the WHO [5]; (I): none; (C) none; (O) incidence of signs and symptoms of long COVID; (S) observational studies.

Information sources and search strategies

We searched Medline (via Ovid) and Web of Science from database inception to 12 January 2022, through OVID. The search for individual studies in these bibliographic databases was supplemented by a manual search of references included in relevant systematic reviews already published regarding this topic.

Considering the main PICOS elements, we built the following search strategy for Medline: "("COVID-19" OR "Novel Coronavirus–Infected Pneumonia" OR "2019 novel coronavirus" OR

“2019-nCoV” OR “SARS-CoV-2”) AND (“lingering symptoms” OR “persistent symptoms” OR “long-term symptoms” OR "long-term Covid" OR “long-term” OR “long term” OR “long”)”. Then we adapted the search strategy for Web of Science.

The management of potentially eligible references was carried out using the Rayyan website (https://www.rayyan.ai/).

Eligibility Criteria

Inclusion criteria comprised the following: (1) observational studies (case-control, cohort, longitudinal studies); (2) studies that investigated the diagnosis of long COVID according to the criteria mentioned previously. ; (3) presence of long COVID for at least 12 weeks.[5] Only articles written in English were included.

Studies with a follow-up shorter than 12 weeks or with an unclear follow-up, case series and case reports were excluded.

Study selection

We followed the recommendations reported in the Cochrane handbook for Systematic reviews to select studies that were finally included in this review.[10] The selection of the articles was performed independently by six authors (OT, AB, LD, DFB, RB, VG), in couples. The agreement within the couples, evaluated with the K was 0.85 in couple 1, 0.81 in couple 2, and 0.86 in couple 3. Consensus meetings were held with all reviewers to discuss the studies for which divergent selection decisions were made. Two additional senior members (NV, FDG) of the review team were involved, when necessary. The studies selection process involved, first, a selection based on title and/or abstracts, then a selection of studies retrieved from this first step based on the full-text manuscripts.

Data collection and data items

We collected the following information: data regarding the identification of the manuscript (e.g., first author name and affiliation, year of publication, journal name, title of the manuscript), data on the characteristics of the population considered (e.g., sample size, mean age, location, gender, etc.), setting (e.g., hospital, intensive care unit, etc.), method of follow-up visit, follow-up in months, type of diagnosis of COVID-19, and signs and symptoms recorded during the follow-up period. These data were collected using a standard data extraction form. The data extraction was carried out independently by the six authors, in couples, with one author for each couple extracting the data and the other checking, with the senior authors checking the quality of the data extraction.

Risk of bias evaluation

The Newcastle-Ottawa Scale (NOS) was used to assess the study quality/risk of bias.[12] The NOS assigns a maximum of 9 points based on three quality parameters: selection, comparability, and outcome. The evaluation was made by one author and checked by another, independently. The risk of bias was then categorized as high (<5/9 points), moderate (6-7), or low (8-9).[13] The investigators solved any discrepancies by jointly re-assessing an article (NV, AB and FDG).

Data synthesis

Signs and symptoms were grouped into anatomical clusters, i.e., neurological, dermatological, and psychiatric conditions. The cumulative incidence of symptoms and 95% confidence intervals (CIs) were estimated using a meta-analysis, under a random-effect model.[14] Heterogeneity between estimates was assessed using the I^2 statistic. In case of an I^2 over 50% a series of meta-regression analyses (taking as moderators if the participants were hospitalized, the percentage of females, and the mean age of the sample size) was conducted. Several sensitivity analyses (continent, mean age, using the WHO classification in children, adults, older people [15], follow-up period, stayed in intensive care unit, hospitalized, type of follow-up, and risk of bias) were also conducted.[16]

Moderators and strata were chosen based on clinical judgment. Publication bias was assessed by visually inspecting funnel plots and using Egger bias test, with a p-value <0.05 indicative of possible publication bias.[17]

All analyses were performed using “metaprop”, a command available in STATA 14.0

Results

Search results

As shown in **Supplementary Figure 1**, among 11,167 records initially screened, 346 full-texts were retrieved, with a final selection of 196 articles (see the list in **Supplementary Table 1**).

Descriptive characteristics

As shown in **Supplementary Table 2**, the 196 studies included 120,970 participants (median per study: 190 participants, range: 17 to 31,013) with a mean age of 52.3 years. The participants were more frequently males (percentage of females=48.8%) ($p<0.0001$, Chi Square test). The majority of the studies took place in Europe (n=126, 64.3%), and used the polymerase chain reaction for the identification of SARS-CoV-2 (n=185, 94.4%). Furthermore, most studies considered only hospitalized patients (n=128, 65.3%) including people admitted to intensive care unit (n=101, 51.5%). Follow-up with a median of six months (range: 3-12 months) was predominantly conducted via outpatients' visits (n=86, 43.9%). Among the 196 articles included, only two reported data on the vaccination status against SARS-CoV-2.

Risk of bias

As reported in **Supplementary Table 2**, the risk of bias, evaluated with the NOS, was overall low in 129 (65.8) studies and moderate for the other works included. No study was at high risk of bias evaluated as a NOS score less than 5.

Incidence of long COVID signs and symptoms

Figure 1 and **Table 1** show the incidence of long COVID signs and symptoms. In the 196 studies included, comprising 120,970 people, the cumulative incidence of any long COVID symptomatology was 56.9% (95%CI: 52.2-61.6).

By grouping into anatomical clusters, we observed that in 156 cohorts (106,284 participants), the overall incidence of neurological signs/symptoms was 19.7% (95%CI: 17.4-22.1). In this cluster the most frequent sign/symptom was difficulty in concentrating (14.6%), and the least frequent was seizures (0.6%). The incidence of headache, taste and smell disorders, cognitive impairment, memory deficits, dizziness, and cramps were over 10%. Psychiatric conditions affected 20.3% of the participants (95%CI: 17.4-23.3), in 117 cohorts and for a total of 65,156 people. All the four signs and symptoms considered in this cluster (post-traumatic stress disorder [PTSD], depression, sleep disorder, anxiety) had an incidence over 10%.

Respiratory conditions affected approximately one quarter of the participants with long COVID (154 cohorts, 101,849 participants, 24.5%; 95%CI: 21.3-27.9). Among the respiratory signs or symptoms, the most frequent was dyspnea (142 cohorts, 97,065 participants, incidence of 24.1%). Mobility impairment disorders affected 13.7% (10.6-17.2) of the 19,747 participants included in 34 different cohorts, with a decreased exercise tolerance (incidence of 16.6%), being the most frequent. Heart conditions were also particularly frequent, affecting 11.0% of the participants. Palpitations were identified in 11.2% of the 32,784 participants considered. Among the clusters considered, digestive (incidence: 7.7%; 95%CI: 6.4-9.1) and skin disorders (incidence: 8.5%, 95%CI: 6.8-10.3) were the least represented.

Finally, general signs and symptoms, i.e., not includible in any of the clusters cited before, affected approximately one third of the 113,802 people included in 166 cohorts. Of particular interest, fatigue affected 31.4% (95%CI: 27.1-35.8) of the people included, being the most common symptom in the general cluster.

Meta-regression analyses

Considering the incidence of signs and symptoms clusters, all were affected by a high heterogeneity (I^2=99%). Therefore, we tried to explain the heterogeneity observed using a series of meta-regression and sensitivity analyses.

Supplementary Table 3 shows the meta-regression analyses. Higher percentage of females moderated the onset of any, neurological, general and cardiovascular long COVID symptomatology. Each increase in one percent of females in the sample size was associated with a small increase in any long COVID symptomatology (beta=0.02±0.01; p=0.047), neurological (beta=0.003±0.0009; p=0.001), general (beta=0.02±0.01; p=0.05), and cardiovascular (beta=0.003±0.0009; p=0.001) signs and symptoms. However, this moderator explained only a small proportion of the heterogeneity of the various outcomes (less than 10%, except for cardiovascular outcomes) (**Supplementary Table 3**).

Finally, higher mean age of the cohorts included was associated with higher incidence of psychiatric (beta =0.003±0.001; p=0.007), respiratory (beta=0.004±0.001; p=0.009), general (beta =0.004±0.002; p=0.03), digestive (beta =0.002±0.0009; p=0.04) and skin conditions (beta =0.002±0.0009; p=0.02) (**Supplementary Table 3**). Again, except for the last outcome, higher mean age explained only a small proportion of the heterogeneity found in the various outcomes.

Sensitivity analyses

Supplementary Table 4 shows the cumulative incidence stratified by some potential factors, i.e., continent, mean age and follow-up. Overall, the incidence of any long COVID was significantly higher in studies carried out in Oceania (63.4%) vs. Europe (48.5%) (p for the interaction <0.0001), whilst no significant differences were observed by mean age or by follow-up. When considering neurological conditions, the incidence was, again, significantly higher in Oceania and in Europe compared to North America (with an incidence almost doubled). Moreover, the incidence of neurological conditions was significantly higher in adults than in children (p for interaction=0.03)

and in studies having a follow-up of 3 months compared to those with a longer follow-up (**Supplementary Table 4**). Similarly, psychiatric conditions affected more frequently African participants than Asians (p for the interaction <0.0001) and participants older than 60 years, with an incidence approximately four times higher than children/youth. Similarly, respiratory conditions were more frequent in Europe than in the other continents and in the studies with a follow-up of 3 months. Another point of importance is that the incidence of mobility issues was significantly higher in adults than the other ages considered and in studies having a follow-up over six months. Finally, general and cardiovascular symptomatology was higher in studies carried out in Africa than in other continents and in adults (**Supplementary Table 4**).

Finally, **Supplementary Table 5** reports the data stratified by ICU admission, hospitalization status, type of follow-up, and presence of risk of bias. Overall, patients previously admitted in ICU reported a significantly lower incidence of neurological conditions and mobility issues than their counterparts. Similarly, patients not hospitalized reported a significantly higher presence of neurological and psychiatric conditions. When considering the type of follow-up method used for evaluating long COVID symptomatology patients interviewed in person usually reported lower incidence of several long COVID signs and symptoms. Finally, considering the presence of risk of bias, we observed a significantly higher incidence of neurological, psychiatric, respiratory, cardiovascular, digestive, skin conditions and mobility issues in studies having a moderate risk of bias compared to low.

Discussion

According to the WHO definition for long COVID, we carried out a systematic review of all the studies reporting data on long COVID symptomatology including 196 studies for a total of 120,970 patients with a previous SARS-CoV-2 infection. A key finding of this study was that more than half of the patients previously having COVID-19 had some form of long COVID symptomology, further strengthening the importance of this emergent condition.

Comparing our results with those reported in three previously published systematic reviews with meta-analyses [3, 18, 19], we observed that the incidence of any sign or symptom of long COVID remained high when only including studies having a follow-up of at least three months according to the new WHO definition. [5] Respiratory symptomatology, such as dyspnea, and general signs and symptoms, such as fatigue, may affect between one quarter to one third of all long CVOID patients. Moreover, different inclusion/exclusion criteria indicated that long COVID is a long term condition that will likely be experienced over coming years and with current limited therapeutical options.[20] These findings support the idea that COVID-19 could lead to persistence of symptoms even after the end of acute infection, as has already been demonstrated for SARS-CoV-1 and MERS-CoV. In 2003, after the end of the outbreak of SARS-CoV-1, Herridge *et al.* evaluated the respiratory function of 109 survivors at 3, 6 and 12 months after discharge, reporting a relevant reduction in respiratory function and quality of life.[21] Most patients had also extrapulmonary conditions, with muscle wasting and fatigue being the most frequent, similar to long COVID.[21] In addition, Ahmed *et al*. conducted a systematic review and meta-analysis investigating persistent symptoms of both SARS-CoV-1 and MERS-COV, demonstrating that up to 6 months after discharge impaired respiratory function was present in 27% of patients, PTSD in 39%, depression in 33%, and anxiety in 30%. Moreover, a reduction in exercise capacity was noted with a mean 6-min walking distance of 461 m in the cohort of patients analyzed.[22] It is important to remark that some studies demonstrated the persistence of symptoms for several years from SARS-CoV-1 infection. In particular, Ngai *et al*. performed a respiratory function-test 2 years after discharge on 55 SARS-CoV-1 infected patients,

showing a significant impairment of diffusing capacity of the lungs for carbon monoxide (DLCO), exercise capacity and health status, with a more marked adverse impact among health care workers.[23] Moldofsky *et al.*, evaluated the neuropsychiatric disorders that occurred in SARS-CoV-1-infected patients, demonstrating that chronic fatigue, pain, weakness, depression, and sleep disturbance, were still present over a 20-months follow-up. [24] This evidence suggests that for COVID-19 we should expect similar long-term consequences.

Another result of importance of our systematic review and meta-analysis was that long COVID signs and symptoms, and particularly general, neurological, and cardiovascular symptoms, were more frequent in females than in males supporting other literature which found that females appear to be at higher risk of long COVID than males, even though females are less represented in the present systematic review. [25] Moreover, higher mean age also represents an important risk factor to develop long COVID symptoms, particularly general, psychiatric, respiratory, digestive, and skin issues indicating that long COVID could be of epidemiological importance in older people. Sudre *et al.* in a cohort of 558 patients described a greater risk for people aged over 70 years of developing ongoing symptoms. Indeed, 22% of people aged over 70 reported symptoms lasting 4 weeks or more, compared to 10% of patients aged 18 to 49 years.[26] Notably, in our systematic review, there was not an increased risk of long COVID for patients who had been hospitalized or had stayed in intensive care units, contrary to what is reported by Jovanoski *et al*., who described an increased risk of respiratory, cardiovascular, and mental health outcomes up to 6 months after discharge in patients hospitalized with severe/critical COVID-19.[27] Overall, these findings indicate that people living in the community and not hospitalized can have a similar incidence of long COVID symptomatology, demonstrating the importance of follow-up among these patients.

Furthermore, the incidence of any and general signs and symptoms was significantly higher in Oceania, whilst respiratory symptoms were more commonly reported in Europe and Africa. North America reported the lowest incidence among all categories of symptoms. Even if a definitive conclusion cannot be drawn, we can hypothesize that genetic and environmental factors can justify

these different incidences. We can also report that this difference is partially ascribable to the process of symptoms' definition and perception, and data collection across countries that could greatly vary. However, future studies are needed to better understand these significant differences. Among all the results reported in the sensitivity analyses, we would like to underline the importance of mobility issues that were more frequent in adults than in the other ages. Since mobility issues are often a precursor to disability, our meta-analysis further indicates the need to approach long COVID with non-pharmacological approaches, such as promoting physical activity.[28] When stratifying patients for mean age, it is interesting that children and adolescents presented long COVID symptoms, particularly respiratory and general symptoms: taken together, these significant findings encourage follow-up of children previously affected by COVID-19 for better understanding of the long-term sequalae of this condition.

In the opinion of the present authors, long COVID represents a major public-health problem, both because of its incidence in patients with SARS-CoV-2 infection and because of the lack of effective therapeutic strategies to date. Published literature regarding the possible treatment is still limited, and studies published until now were limited by lack of homogeneity owing to varying study designs, settings, populations, follow-up period and symptoms description. Potentially, mass vaccination and the use of new therapies aimed at rapidly reducing viral load and limiting disease progression could play a crucial role in preventing long COVID and long-term symptoms persistence, but future studies are urgently needed. In addition to characteristics of patients, the SARS-CoV-2 variant of concern involved in acute infection is often missing, but it may also play an important role in the type of symptoms that occur in long COVID.

The results of our systematic review with meta-analysis must be interpreted within its limitations. First, some long COVID symptoms may be missing because they were not identified and not investigated in patient questionnaires. This limitation determines the need to standardize questionnaires and to better define some symptoms: for example, the symptom "fatigue" may be exaggerated by some patients or underestimated by others. The use of objective and precise scales,

such as, the Visual Analogue Scale for pain or the Fatigue Assessment Scale for fatigue would facilitate harmonization of symptom descriptions. The studies included in this meta-analysis often used only self-reported information or physical examination. Second, all the outcomes were characterized by a high heterogeneity, only partly explained by our meta-regression or sensitivity analyses. These findings suggest that other factors are probably important in determining a higher or lower incidence of long COVID. Unfortunately, we were not able to explore the role of vaccinations on the incidence of long COVID: further studies are urgently needed in this sense. Another important problem is the presence of publication bias in our findings, likely owing to the choice to screen papers written only in English and the fact that only two databases were screened.[29] Finally, the maximum follow-up reported by the studies included in our systematic review was only one year. Future studies are needed regarding long-term consequences of COVID-19.

In conclusion, our systematic review and meta-analysis indicates that long COVID is a common condition in patients who have been infected with SARS-CoV-2 and often regardless of the severity of the acute illness. Therefore, more long-term studies are needed to understand the real long-term impact on quality of life, but also to develop optimal therapeutic and long COVID prevention strategies.

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Author Contributions

F.D.G. and N.V. conceived the study topic and design. A.B., L.D., D.F.B., F.D.G, O.T., V.G. and R.B. carried out the study selection and data extraction. The data were analysed by N.V. and the manuscript drafted by F.D.G, A.B. and N.V.

L.S., M.T., O.B., L.M., C.C., M.B., L.J.D., A.S. contributed significantly to the revision of the manuscript. All authors approved the final version of the text. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

1. Organization WH (2022) Weekly Operational Update on COVID-19; Issue No. 97. https://www.who.int/publications/m/item/weekly-operational-update-on-covid-19---30-march-2022#.YkwrvaHCh8g.link Accessed 03/30/2022

2. Sanchez-Ramirez DC, Normand K, Zhaoyun Y, Torres-Castro R (2021) Long-term impact of COVID-19: A systematic review of the literature and meta-analysis. Biomedicines 9:900

3. Lopez-Leon S, Wegman-Ostrosky T, Perelman C, Sepulveda R, Rebolledo PA, Cuapio A, Villapol S (2021) More than 50 long-term effects of COVID-19: a systematic review and meta-analysis. Scientific reports 11:1-12

4. Baig AM (2020) Chronic COVID syndrome: Need for an appropriate medical terminology for long-COVID and COVID long-haulers. Journal of medical virology

5. Organization WH (2021) A clinical case definition of post COVID-19 condition by a Delphi consensus, 6 October 2021. World Health Organization,

6. Chen C, Haupert SR, Zimmermann L, Shi X, Fritsche LG, Mukherjee B (2022) Global Prevalence of Post COVID-19 Condition or Long COVID: A Meta-Analysis and Systematic Review. The Journal of Infectious Diseases

7. Stavem K, Ghanima W, Olsen MK, Gilboe HM, Einvik G (2021) Prevalence and determinants of fatigue after COVID-19 in non-hospitalized subjects: a population-based study. International Journal of Environmental Research and Public Health 18:2030

8. Natarajan A, Shetty A, Delanerolle G, Zeng Y, Zhang Y, Raymont V, Rathod S, Halabi S, Elliot K, Phiri P (2022) A systematic review and meta-analysis of Long COVID symptoms. medRxiv : the preprint server for health sciences

9. Han Q, Zheng B, Daines L, Sheikh A (2022) Long-Term sequelae of COVID-19: A systematic review and meta-analysis of one-year follow-up studies on post-COVID symptoms. Pathogens 11:269

10. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (2019) Cochrane handbook for systematic reviews of interventions. John Wiley & Sons,

11. Sarkis-Onofre R, Catalá-López F, Aromataris E, Lockwood C (2021) How to properly use the PRISMA Statement. Systematic Reviews 10:1-3

12. Luchini C, Stubbs B, Solmi M, Veronese N (2017) Assessing the quality of studies in meta-analyses: Advantages and limitations of the Newcastle Ottawa Scale. World Journal of Meta-Analysis 5:80-84

13. Luchini C, Veronese N, Nottegar A, Shin JI, Gentile G, Granziol U, Soysal P, Alexinschi O, Smith L (2021) Assessing the quality of studies in meta-research: Review/guidelines on the most important quality assessment tools. 20:185-195

14. DerSimonian R, Laird N (1986) Meta-analysis in clinical trials. Controlled clinical trials 7:177-188

15. Dyussenbayev A (2017) Age periods of human life. Advances in Social Sciences Research Journal 4:

16. Higgins JP, Thompson SG (2002) Quantifying heterogeneity in a meta-analysis. Statistics in medicine 21:1539-1558

17. Egger M, Smith GD, Schneider M, Minder C (1997) Bias in meta-analysis detected by a simple, graphical test. Bmj 315:629-634

18. Michelen M, Manoharan L, Elkheir N, Cheng V, Dagens A, Hastie C, O'Hara M, Suett J, Dahmash D, Bugaeva P (2021) Characterising long COVID: a living systematic review. BMJ global health 6:e005427

19. Groff D, Sun A, Ssentongo AE, Ba DM, Parsons N, Poudel GR, Lekoubou A, Oh JS, Ericson JE, Ssentongo P (2021) Short-term and long-term rates of postacute sequelae of SARS-CoV-2 infection: a systematic review. JAMA network open 4:e2128568-e2128568

20. Veronese N, Bonica R, Cotugno S, Tulone O, Camporeale M, Smith L, Trott M, Bruyere O, Mirarchi L, Rizzo G (2022) Interventions for Improving Long COVID-19 Symptomatology: A Systematic Review. Viruses 14:1863

21. Herridge MS, Cheung AM, Tansey CM, Matte-Martyn A, Diaz-Granados N, Al-Saidi F, Cooper AB, Guest CB, Mazer CD, Mehta S (2003) One-year outcomes in survivors of the acute respiratory distress syndrome. New England Journal of Medicine 348:683-693

22. Ahmed H, Patel K, Greenwood DC, Halpin S, Lewthwaite P, Salawu A, Eyre L, Breen A, O'Connor R, Jones A (2020) Long-term clinical outcomes in survivors of severe acute respiratory syndrome and Middle East respiratory syndrome coronavirus outbreaks after hospitalisation or ICU admission: a systematic review and meta-analysis. Journal of rehabilitation medicine 52:

23. Ngai JC, Ko FW, Ng SS, TO KW, Tong M, Hui DS (2010) The long-term impact of severe acute respiratory syndrome on pulmonary function, exercise capacity and health status. Respirology 15:543-550

24. Moldofsky H, Patcai J (2011) Chronic widespread musculoskeletal pain, fatigue, depression and disordered sleep in chronic post-SARS syndrome; a case-controlled study. BMC neurology 11:1-7

25. Stewart S, Newson L, Briggs TA, Grammatopoulos D, Young L, Gill P (2021) Long COVID risk-a signal to address sex hormones and women's health. The Lancet Regional Health–Europe 11:

26. Sudre C, Murray B, Varsavsky T, Graham M, Penfold R, Bowyer R, Pujol JC, Klaser K, Antonelli M, Canas L (2020) Attributes and predictors of Long-COVID: analysis of COVID cases and their symptoms collected by the Covid Symptoms Study App.

27. Jovanoski N, Chen X, Becker U, Zalocusky K, Chawla D, Tsai L, Borm M, Neighbors M, Yau V (2021) Severity of COVID-19 and adverse long-term outcomes: a retrospective cohort study based on a US electronic health record database. BMJ open 11:e056284

28. Fernández-Lázaro D, González-Bernal JJ, Sánchez-Serrano N, Navascués LJ, Ascaso-del-Río A, Mielgo-Ayuso J (2020) Physical exercise as a multimodal tool for COVID-19: could it be used as a preventive strategy? International journal of environmental research and public health 17:8496

29. Gilbody SM, Song F, Eastwood AJ, Sutton A (2000) The causes, consequences and detection of publication bias in psychiatry. Acta Psychiatrica Scandinavica 102:241-249

Figure 1 Incidence of long COVID signs and symptoms

Table 1. Cumulative incidence of long COVID signs and symptoms

System	Number of cohorts	Total sample size	Cumulative incidence	95% CI
Any	**196**	**120970**	**56.9**	**52.2-61.6**
Neurological	**156**	**106284**	**19.7**	**17.4-22.1**
Headache	104	87599	12.4	10.5-14.4
Taste disorder (ageusia or dysgeusia)	116	62510	12.8	10.7-15.0
Smell disorder (anosmia)	117	93929	13.1	11.1-15.3
Cognitive impairment	44	21300	13.5	10.5-16.8
Memory deficits	48	18348	13.5	10.5-16.9
Difficulty concentrating	58	30380	14.6	11.7-17.9
Dizziness	46	27737	10.8	8.3-13.7
Tremors	8	4078	3.4	1.4-6.2
Seizures	4	9325	0.6	0.0-2.1
Cramps	6	790	12.0	5.2-21.0
Visual impairment	16	9963	4.6	2.5-7.2
Psychiatric	**117**	**65156**	**20.3**	**17.4-23.3**
PTSD	26	13167	13.6	8.9-19.3
Depression	74	43789	16.1	12.8-19.8
Sleep disorders	81	50757	17.8	14.8-21.0
Anxiety	85	46762	18.9	15.2-22.2
Respiratory	**154**	**101849**	**24.5**	**21.3-27.9**
Cough	108	86809	13.1	11.0-15.5
Dyspnea	142	97065	24.1	20.5-27.9
Oxygen use	4	400	4.3	2.4-6.7
Nasal congestion	36	48592	6.3	5.0-7.7
Voice change	14	10352	3.7	2.0-5.9
Mobility impairment	**34**	**19747**	**13.7**	**10.6-17.2**
Decreased exercise tolerance	12	6431	16.6	11.2-22.8
Mobility decline	19	13177	11.3	7.7-15.6
Functional impairment	10	6544	7.6	3.1-13.9
Heart	**95**	**54056**	**11.0**	**8.9-13.3**
Palpitations	55	32784	11.2	8.7-14.1
Chest pain	71	45894	10.6	8.2-13.3
Flushing	3	2349	3.1	0-11.2
Hypertension (new onset)	4	2136	6.4	1.5-14.3
Digestive	**99**	**80701**	**7.7**	**6.4-9.1**
Abdominal pain	47	61445	5.2	4.0-6.5
Diarrhea	77	72024	5.9	4.9-7.1
Vomit	40	28238	3.0	2.0-4.0
Loss of appetite	52	27034	7.1	5.2-9.4
Skin	**63**	**34224**	**8.5**	**6.8-10.3**
Rash	34	25796	4.1	2.9-5.5
Hair loss	52	28816	8.8	6.8-11.1
General	**166**	**113802**	**31.0**	**27.1-35.1**
Weight loss	16	11234	7.2	5.1-9.6

System	Number of cohorts	Total sample size	Cumulative incidence	95% CI
Myalgia	103	84678	15.5	13.0-18.3
Pain	48	28230	19.9	14.7-25.6
Flulike symptoms	1	97	16.5	9.7-25.4
Fever	45	55310	7.9	5.2-11.0
Fatigue	142	104766	31.4	27.1-35.8
Arthralgia	64	34941	15.0	11.6-18.9
Sore throat	49	63400	7.6	6.2-9.2
Sweats	9	9079	5.8	4.4-7.4
Poor QoL	7	3995	16.0	9.0-24.7
Conjunctivitis	14	7256	3.1	1.1-6.0

Data are reported as cumulative incidence with their 95% confidence intervals.

PTSD= Post-traumatic stress disorder, QoL= Quality of Life

Supplementary Table 1. List of references included in the systematic review and meta-analysis

1. Abdelrahman MM, Abd-Elrahman NM, Bakheet TM (2021) Persistence of symptoms after improvement of acute COVID19 infection, a longitudinal study. J Med Virol 93:5942-5946

2. Agergaard J, Leth S, Pedersen TH, Harbo T, Blicher JU, Karlsson P, Ostergaard L, Andersen H, Tankisi H (2021) Myopathic changes in patients with long-term fatigue after COVID-19. Clin Neurophysiol 132:1974-1981

3. Albu S, Zozaya NR, Murillo N, Garcia-Molina A, Chacon CAF, Kumru H (2021) What's going on following acute covid-19? Clinical characteristics of patients in an out-patient rehabilitation program. NeuroRehabilitation 48:469-480

4. Anastasio F, Barbuto S, Scarnecchia E, Cosma P, Fugagnoli A, Rossi G, Parravicini M, Parravicini P (2021) Medium-term impact of COVID-19 on pulmonary function, functional capacity and quality of life. Eur Respir J 58:

5. Aranda J, Oriol I, Martin M, et al. (2021) Long-term impact of COVID-19 associated acute respiratory distress syndrome. J Infect 83:581-588

6. Arnold DT, Hamilton FW, Milne A, et al. (2021) Patient outcomes after hospitalisation with COVID-19 and implications for follow-up: results from a prospective UK cohort. Thorax 76:399-401

7. Asadi-Pooya AA, Akbari A, Emami A, et al. (2021) Risk Factors Associated with Long COVID Syndrome: A Retrospective Study. Iran J Med Sci 46:428-436

8. Attauabi M, Dahlerup JF, Poulsen A, et al. (2021) Outcomes and long-term effects of COVID-19 in patients with inflammatory bowel diseases - a Danish prospective population-based cohort study with individual-level data. J Crohns Colitis

9. August D, Stete K, Hilger H, Götz V, Biever P, Hosp J, Wagner D, Köhler TC, Gerstacker K, Seufert J (2021) Persistierende Beschwerden 6 Monate nach COVID-19–Erfahrungen aus der COVID-19-Nachsorgeambulanz des Universitätsklinikums Freiburg. DMW-Deutsche Medizinische Wochenschrift 146:e65-e73

10. Augustin M, Schommers P, Stecher M, et al. (2021) Post-COVID syndrome in non-hospitalised patients with COVID-19: a longitudinal prospective cohort study. Lancet Reg Health Eur 6:100122

11. Bates TA, Leier HC, Lyski ZL, Goodman JR, Curlin ME, Messer WB, Tafesse FG (2021) Age-Dependent Neutralization of SARS-CoV-2 and P.1 Variant by Vaccine Immune Serum Samples. JAMA

12. Becker C, Beck K, Zumbrunn S, Memma V, Herzog N, Bissmann B, Gross S, Loretz N, Mueller J, Amacher SA (2021) Long COVID 1 year after hospitalisation for COVID-19: A prospective bicentric cohort study. Swiss Medical Weekly

13. Bellan M, Baricich A, Patrucco F, et al. (2021) Long-term sequelae are highly prevalent one year after hospitalization for severe COVID-19. Sci Rep 11:22666

14. Bellan M, Soddu D, Balbo PE, et al. (2021) Respiratory and Psychophysical Sequelae Among Patients With COVID-19 Four Months After Hospital Discharge. JAMA Netw Open 4:e2036142

15. Bertlich M, Stihl C, Lusebrink E, et al. (2021) The course of subjective and objective chemosensory dysfunction in hospitalized patients with COVID-19: a 6-month follow-up. Eur Arch Otorhinolaryngol 278:4855-4861

16. Betschart M, Rezek S, Unger I, Ott N, Beyer S, Boni A, Gisi D, Shannon H, Spruit MA, Sieber C (2021) One year follow-up of physical performance and quality of life in patients surviving COVID-19: a prospective cohort study. Swiss Med Wkly 151:w30072

17. Blomberg B, Mohn KG, Brokstad KA, et al. (2021) Long COVID in a prospective cohort of home-isolated patients. Nat Med 27:1607-1613

18. Boari GEM, Bonetti S, Braglia-Orlandini F, et al. (2021) Short-Term Consequences of SARS-CoV-2-Related Pneumonia: A Follow Up Study. High Blood Press Cardiovasc Prev 28:373-381

19. Boscolo-Rizzo P, Menegaldo A, Fabbris C, Spinato G, Borsetto D, Vaira LA, Calvanese L, Pettorelli A, Sonego M, Frezza D (2021) Six-month psychophysical evaluation of olfactory dysfunction in patients with COVID-19. Chemical senses 46:

20. Bottemanne H, Gouraud C, Hulot JS, Blanchard A, Ranque B, Lahlou-Laforet K, Limosin F, Gunther S, Lebeaux D, Lemogne C (2021) Do Anxiety and Depression Predict Persistent Physical Symptoms After a Severe COVID-19 Episode? A Prospective Study. Front Psychiatry 12:757685

21. Bozzetti S, Ferrari S, Zanzoni S, et al. (2021) Neurological symptoms and axonal damage in COVID-19 survivors: are there sequelae? Immunol Res 69:553-557

22. Bussiere N, Mei J, Levesque-Boissonneault C, Blais M, Carazo S, Gros-Louis F, De Serres G, Dupre N, Frasnelli J (2021) Chemosensory Dysfunctions Induced by COVID-19 Can Persist up to 7 Months: A Study of Over 700 Healthcare Workers. Chem Senses 46:

23. Buttery S, Philip KEJ, Williams P, et al. (2021) Patient symptoms and experience following COVID-19: results from a UK-wide survey. BMJ Open Respir Res 8:

24. Bylicki O, Delarbre D, Mayet A, et al. (2021) Neutralizing antibody response to SARS-CoV-2 persists 9 months post symptom onset in mild and asymptomatic patients. Int J Infect Dis 112:8-12

25. Capelli M, Gatti P (2021) Anosmia in the first coronavirus disease 2019 outbreak in Europe: functional recovery after eight months. J Laryngol Otol 135:224-228

26. Caruso D, Guido G, Zerunian M, et al. (2021) Post-Acute Sequelae of COVID-19 Pneumonia: Six-month Chest CT Follow-up. Radiology 301:E396-E405

27. Cassar MP, Tunnicliffe EM, Petousi N, et al. (2021) Symptom Persistence Despite Improvement in Cardiopulmonary Health - Insights from longitudinal CMR, CPET and lung function testing post-COVID-19. EClinicalMedicine 41:101159

28. Catalan IP, Marti CR, Sota DP, et al. (2022) Corticosteroids for COVID-19 symptoms and quality of life at 1 year from admission. J Med Virol 94:205-210

29. Chand S, Kapoor S, Naqvi A, Thakkar J, Fazzari MJ, Orsi D, Dieiev V, Lewandowski DC, Dicpinigaitis PV (2021) Long-Term Follow up of Renal and Other Acute Organ Failure in Survivors of Critical Illness Due to Covid-19. Journal of Intensive Care Medicine 08850666211062582

30. Chaumont H, Meppiel E, Roze E, Tressières B, de Broucker T, Lannuzel A (2022) Long-term outcomes after NeuroCOVID: A 6-month follow-up study on 60 patients. Revue neurologique

31. Chen X, Li Y, Shao TR, et al. (2022) Some characteristics of clinical sequelae of COVID-19 survivors from Wuhan, China: A multi-center longitudinal study. Influenza Other Respir Viruses 16:395-401

32. Clavario P, De Marzo V, Lotti R, et al. (2021) Cardiopulmonary exercise testing in COVID-19 patients at 3 months follow-up. Int J Cardiol 340:113-118

33. Cristillo V, Pilotto A, Cotti Piccinelli S, Bonzi G, Canale A, Gipponi S, Bezzi M, Leonardi M, Padovani A, Neuro Covid Next Study g (2022) Premorbid vulnerability and disease severity impact on Long-COVID cognitive impairment. Aging Clin Exp Res 34:257-260

34. Cristillo V, Pilotto A, Cotti Piccinelli S, et al. (2021) Age and subtle cognitive impairment are associated with long-term olfactory dysfunction after COVID-19 infection. J Am Geriatr Soc 69:2778-2780

35. Dai S, Zhao B, Liu D, Zhou Y, Liu Y, Lan L, Li Y, Luo W, Zeng Y, Li W (2021) Follow-Up Study of the Cardiopulmonary and Psychological Outcomes of COVID-19 Survivors Six Months After Discharge in Sichuan, China. Int J Gen Med 14:7207-7217

36. Darcis G, Bouquegneau A, Maes N, et al. (2021) Long-term clinical follow-up of patients suffering from moderate-to-severe COVID-19 infection: a monocentric prospective observational cohort study. Int J Infect Dis 109:209-216

37. Darley DR, Dore GJ, Byrne AL, Plit ML, Brew BJ, Kelleher A, Matthews GV (2021) Limited recovery from post-acute sequelae of SARS-CoV-2 at 8 months in a prospective cohort. ERJ Open Res 7:

38. Deetz S, Mumby DK (1990) Power, discourse, and the workplace: Reclaiming the critical tradition. Annals of the International Communication Association 13:18-47

39. Del Brutto OH, Rumbea DA, Recalde BY, Mera RM (2022) Cognitive sequelae of long COVID may not be permanent: A prospective study. European journal of neurology 29:1218-1221

40. Dennis A, Wamil M, Alberts J, et al. (2021) Multiorgan impairment in low-risk individuals with post-COVID-19 syndrome: a prospective, community-based study. BMJ Open 11:e048391

41. Diaz-Fuentes G, Roa-Gomez G, Reyes O, Singhal R, Venkatram S (2021) Coronavirus Pneumonia: Outcomes and Characteristics of Patients in an Inner-City Area after 3 Months of Infection. J Clin Med 10:

42. Du YY, Zhao W, Zhou XL, et al. (2022) Survivors of COVID-19 exhibit altered amplitudes of low frequency fluctuation in the brain: a resting-state functional magnetic resonance imaging study at 1-year follow-up. Neural Regen Res 17:1576-1581

43. Elkan M, Dvir A, Zaidenstein R, Keller M, Kagansky D, Hochman C, Koren R (2021) Patient-Reported Outcome Measures After Hospitalization During the COVID-19 Pandemic: A Survey Among COVID-19 and Non-COVID-19 Patients. Int J Gen Med 14:4829-4836

44. Eloy P, Tardivon C, Martin-Blondel G, et al. (2021) Severity of self-reported symptoms and psychological burden 6-months after hospital admission for COVID-19: a prospective cohort study. Int J Infect Dis 112:247-253

45. Evans RA, McAuley H, Harrison EM, et al. (2021) Physical, cognitive, and mental health impacts of COVID-19 after hospitalisation (PHOSP-COVID): a UK multicentre, prospective cohort study. The Lancet Respiratory Medicine 9:1275-1287

46. Fang X, Ming C, Cen Y, Lin H, Zhan K, Yang S, Li L, Cao G, Li Q, Ma X (2022) Post-sequelae one year after hospital discharge among older COVID-19 patients: A multi-center prospective cohort study. J Infect 84:179-186

47. Fernandez-de-Las-Penas C, Gomez-Mayordomo V, Cuadrado ML, Palacios-Cena D, Florencio LL, Guerrero AL, Garcia-Azorin D, Hernandez-Barrera V, Arendt-Nielsen L (2021) The presence of headache at onset in SARS-CoV-2 infection is associated with long-term post-COVID headache and fatigue: A case-control study. Cephalalgia 41:1332-1341

48. Fernandez-de-Las-Penas C, Gomez-Mayordomo V, Garcia-Azorin D, Palacios-Cena D, Florencio LL, Guerrero AL, Hernandez-Barrera V, Cuadrado ML (2021) Previous History of Migraine Is Associated With Fatigue, but Not Headache, as Long-Term Post-COVID Symptom After

Severe Acute Respiratory SARS-CoV-2 Infection: A Case-Control Study. Front Hum Neurosci 15:678472

49. Fernandez-de-Las-Penas C, Guijarro C, Plaza-Canteli S, Hernandez-Barrera V, Torres-Macho J (2021) Prevalence of Post-COVID-19 Cough One Year After SARS-CoV-2 Infection: A Multicenter Study. Lung 199:249-253

50. Fernandez-de-Las-Penas C, Martin-Guerrero JD, Cancela-Cilleruelo I, Moro-Lopez-Menchero P, Rodriguez-Jimenez J, Pellicer-Valero OJ (2022) Trajectory curves of post-COVID anxiety/depressive symptoms and sleep quality in previously hospitalized COVID-19 survivors: the LONG-COVID-EXP-CM multicenter study. Psychol Med 1-2

51. Fernandez-de-Las-Penas C, Martin-Guerrero JD, Navarro-Pardo E, Cancela-Cilleruelo I, Moro-Lopez-Menchero P, Pellicer-Valero OJ (2022) Exploring Trajectory Curves from Loss of Smell and Taste in Previously Hospitalized COVID-19 Survivors: the LONG-COVID-EXP-CM Multicenter Study. J Gen Intern Med

52. Fernandez-de-Las-Penas C, Martin-Guerrero JD, Pellicer-Valero OJ, Navarro-Pardo E, Gomez-Mayordomo V, Cuadrado ML, Arias-Navalon JA, Cigaran-Mendez M, Hernandez-Barrera V, Arendt-Nielsen L (2022) Female Sex Is a Risk Factor Associated with Long-Term Post-COVID Related-Symptoms but Not with COVID-19 Symptoms: The LONG-COVID-EXP-CM Multicenter Study. J Clin Med 11:

53. Fernandez-de-Las-Penas C, Palacios-Cena D, Gomez-Mayordomo V, et al. (2022) Fatigue and Dyspnoea as Main Persistent Post-COVID-19 Symptoms in Previously Hospitalized Patients: Related Functional Limitations and Disability. Respiration 101:132-141

54. Fernandez-de-Las-Penas C, Pellicer-Valero OJ, Navarro-Pardo E, Palacios-Cena D, Florencio LL, Guijarro C, Martin-Guerrero JD (2022) Symptoms Experienced at the Acute Phase of SARS-CoV-2 Infection as Risk Factor of Long-term Post-COVID Symptoms: The LONG-COVID-EXP-CM Multicenter Study. Int J Infect Dis 116:241-244

55. Fernandez-de-Las-Penas C, Pellicer-Valero OJ, Navarro-Pardo E, Rodriguez-Jimenez J, Martin-Guerrero JD, Cigaran-Mendez M (2021) The number of symptoms at the acute COVID-19 phase is associated with anxiety and depressive long-term post-COVID symptoms: A multicenter study. J Psychosom Res 150:110625

56. Fernandez-de-Las-Penas C, Torres-Macho J, Elvira-Martinez CM, Molina-Trigueros LJ, Sebastian-Viana T, Hernandez-Barrera V (2021) Obesity is associated with a greater number of long-term post-COVID symptoms and poor sleep quality: A multicentre case-control study. Int J Clin Pract 75:e14917

57. Ferrucci R, Dini M, Rosci C, Capozza A, Groppo E, Reitano MR, Allocco E, Poletti B, Brugnera A, Bai F (2022) One-Year Cognitive Follow-Up of COVID-19 Hospitalized Patients. European Journal of Neurology

58. Fink TT, Marques HHS, Gualano B, et al. (2021) Persistent symptoms and decreased health-related quality of life after symptomatic pediatric COVID-19: A prospective study in a Latin American tertiary hospital. Clinics (Sao Paulo) 76:e3511

59. Förster C, Colombo MG, Wetzel A-J, Martus P, Joos S (2022) Persisting Symptoms After COVID-19-Prevalence and Risk Factors in a Population-Based Cohort. Deutsches Arzteblatt International

60. Fortini A, Rosso A, Cecchini P, et al. (2022) One-year evolution of DLCO changes and respiratory symptoms in patients with post COVID-19 respiratory syndrome. Infection 50:513-517

61. Fortini A, Torrigiani A, Sbaragli S, Lo Forte A, Crociani A, Cecchini P, Innocenti Bruni G, Faraone A (2021) COVID-19: persistence of symptoms and lung alterations after 3-6 months from hospital discharge. Infection 49:1007-1015

62. Fortunato F, Martinelli D, Iannelli G, et al. (2022) Self-reported olfactory and gustatory dysfunctions in COVID-19 patients: a 1-year follow-up study in Foggia district, Italy. BMC Infect Dis 22:77

63. Froidure A, Mahsouli A, Liistro G, et al. (2021) Integrative respiratory follow-up of severe COVID-19 reveals common functional and lung imaging sequelae. Respir Med 181:106383

64. Frontera JA, Yang D, Lewis A, et al. (2021) A prospective study of long-term outcomes among hospitalized COVID-19 patients with and without neurological complications. J Neurol Sci 426:117486

65. Fumagalli C, Zocchi C, Tassetti L, et al. (2022) Factors associated with persistence of symptoms 1 year after COVID-19: A longitudinal, prospective phone-based interview follow-up cohort study. Eur J Intern Med 97:36-41

66. Gaber TAK, Ashish A, Unsworth A (2021) Persistent post-covid symptoms in healthcare workers. Occup Med (Lond) 71:144-146

67. Galal I, Hussein AARM, Amin MT, et al. (2021) Determinants of persistent post-COVID-19 symptoms: value of a novel COVID-19 symptom score. The Egyptian Journal of Bronchology 15:

68. Gamberini L, Mazzoli CA, Prediletto I, et al. (2021) Health-related quality of life profiles, trajectories, persistent symptoms and pulmonary function one year after ICU discharge in invasively ventilated COVID-19 patients, a prospective follow-up study. Respir Med 189:106665

69. Garcia-Abellan J, Padilla S, Fernandez-Gonzalez M, Garcia JA, Agullo V, Andreo M, Ruiz S, Galiana A, Gutierrez F, Masia M (2021) Antibody Response to SARS-CoV-2 is Associated with Long-term Clinical Outcome in Patients with COVID-19: a Longitudinal Study. J Clin Immunol 41:1490-1501

70. Garrigues E, Janvier P, Kherabi Y, et al. (2020) Post-discharge persistent symptoms and health-related quality of life after hospitalization for COVID-19. J Infect 81:e4-e6

71. Gautam N, Madathil S, Tahani N, et al. (2022) Medium-Term Outcomes in Severely to Critically Ill Patients With Severe Acute Respiratory Syndrome Coronavirus 2 Infection. Clin Infect Dis 74:301-308

72. Gerard M, Mahmutovic M, Malgras A, Michot N, Scheyer N, Jaussaud R, Nguyen-Thi PL, Quilliot D (2021) Long-Term Evolution of Malnutrition and Loss of Muscle Strength after COVID-19: A Major and Neglected Component of Long COVID-19. Nutrients 13:

73. Gherlone EF, Polizzi E, Tete G, De Lorenzo R, Magnaghi C, Rovere Querini P, Ciceri F (2021) Frequent and Persistent Salivary Gland Ectasia and Oral Disease After COVID-19. J Dent Res 100:464-471

74. Ghosn J, Piroth L, Epaulard O, Le Turnier P, Mentre F, Bachelet D, Laouenan C, French Ccs, investigators g (2021) Persistent COVID-19 symptoms are highly prevalent 6 months after hospitalization: results from a large prospective cohort. Clin Microbiol Infect 27:1041 e1041-1041 e1044

75. Gluck V, Grobecker S, Tydykov L, et al. (2021) SARS-CoV-2-directed antibodies persist for more than six months in a cohort with mild to moderate COVID-19. Infection 49:739-746

76. Godeau D, Petit A, Richard I, Roquelaure Y, Descatha A (2021) Return-to-work, disabilities and occupational health in the age of COVID-19. Scand J Work Environ Health 47:408-409

77. Goertz YMJ, Van Herck M, Delbressine JM, et al. (2020) Persistent symptoms 3 months after a SARS-CoV-2 infection: the post-COVID-19 syndrome? ERJ Open Res 6:

78. González J, Benítez ID, Carmona P, Santisteve S, Monge A, Moncusí-Moix A, Gort-Paniello C, Pinilla L, Carratalá A, Zuil M (2021) Pulmonary function and radiologic features in survivors of critical COVID-19: a 3-month prospective cohort. Chest 160:187-198

79. Gonzalez-Hermosillo JA, Martinez-Lopez JP, Carrillo-Lampon SA, Ruiz-Ojeda D, Herrera-Ramirez S, Amezcua-Guerra LM, Martinez-Alvarado MDR (2021) Post-Acute COVID-19 Symptoms, a Potential Link with Myalgic Encephalomyelitis/Chronic Fatigue Syndrome: A 6-Month Survey in a Mexican Cohort. Brain Sci 11:

80. Graham EL, Clark JR, Orban ZS, et al. (2021) Persistent neurologic symptoms and cognitive dysfunction in non-hospitalized Covid-19 "long haulers". Ann Clin Transl Neurol 8:1073-1085

81. Gramaglia C, Gambaro E, Bellan M, et al. (2021) Mid-term Psychiatric Outcomes of Patients Recovered From COVID-19 From an Italian Cohort of Hospitalized Patients. Front Psychiatry 12:667385

82. Gudziol H, Kirschstein T, Pletz MW, Weis S, Guntinas-Lichius O, Bitter T, Co NANsg (2022) High prevalence of long-term olfactory dysfunction confirmed by olfactory testing after a community COVID-19 outbreak. HNO 70:224-231

83. Han X, Fan Y, Alwalid O, et al. (2021) Six-month Follow-up Chest CT Findings after Severe COVID-19 Pneumonia. Radiology 299:E177-E186

84. Heightman M, Prashar J, Hillman TE, et al. (2021) Post-COVID-19 assessment in a specialist clinical service: a 12-month, single-centre, prospective study in 1325 individuals. BMJ Open Respir Res 8:

85. Hodgson CL, Higgins AM, Bailey MJ, et al. (2021) The impact of COVID-19 critical illness on new disability, functional outcomes and return to work at 6 months: a prospective cohort study. Crit Care 25:382

86. Hopkins C, Surda P, Vaira LA, Lechien JR, Safarian M, Saussez S, Kumar N (2021) Six month follow-up of self-reported loss of smell during the COVID-19 pandemic. Rhinology 59:26-31

87. Horwitz LI, Garry K, Prete AM, Sharma S, Mendoza F, Kahan T, Karpel H, Duan E, Hochman KA, Weerahandi H (2021) Six-Month Outcomes in Patients Hospitalized with Severe COVID-19. J Gen Intern Med 36:3772-3777

88. Hossain MA, Hossain KMA, Saunders K, et al. (2021) Prevalence of Long COVID symptoms in Bangladesh: a prospective Inception Cohort Study of COVID-19 survivors. BMJ Glob Health 6:

89. Houben-Wilke S, Goertz YM, Delbressine JM, et al. (2022) The Impact of Long COVID-19 on Mental Health: Observational 6-Month Follow-Up Study. JMIR Ment Health 9:e33704

90. Huang L, Xu X, Zhang L, et al. (2021) Post-traumatic Stress Disorder Symptoms and Quality of Life of COVID-19 Survivors at 6-Month Follow-Up: A Cross-Sectional Observational Study. Front Psychiatry 12:782478

91. Huang L, Yao Q, Gu X, et al. (2021) 1-year outcomes in hospital survivors with COVID-19: a longitudinal cohort study. The Lancet 398:747-758

92. Ishiyama H, Ishii J, Yoshimura H, et al. (2021) Neurological Manifestations and Long-term Sequelae in Hospitalized Patients with COVID-19. Intern Med 60:3559-3567

93. Jacobson KB, Rao M, Bonilla H, Subramanian A, Hack I, Madrigal M, Singh U, Jagannathan P, Grant P (2021) Patients with uncomplicated COVID-19 have long-term persistent symptoms and functional impairment similar to patients with severe COVID-19: a cautionary tale during a global pandemic. Clinical Infectious Diseases

94. Karaarslan F, Guneri FD, Kardes S (2022) Long COVID: rheumatologic/musculoskeletal symptoms in hospitalized COVID-19 survivors at 3 and 6 months. Clin Rheumatol 41:289-296

95. Kariisa M, Scholl L, Wilson N, Seth P, Hoots B (2019) Drug Overdose Deaths Involving Cocaine and Psychostimulants with Abuse Potential - United States, 2003-2017. MMWR Morb Mortal Wkly Rep 68:388-395

96. Kayaaslan B, Eser F, Kalem AK, Kaya G, Kaplan B, Kacar D, Hasanoglu I, Coskun B, Guner R (2021) Post-COVID syndrome: A single-center questionnaire study on 1007 participants recovered from COVID-19. J Med Virol 93:6566-6574

97. Kim Y, Bitna H, Kim SW, Chang HH, Kwon KT, Bae S, Hwang S (2022) Post-acute COVID-19 syndrome in patients after 12 months from COVID-19 infection in Korea. BMC Infect Dis 22:93

98. Kim Y, Kim SW, Chang HH, Kwon KT, Bae S, Hwang S (2021) Significance and Associated Factors of Long-Term Sequelae in Patients after Acute COVID-19 Infection in Korea. Infect Chemother 53:463-476

99. Klein H, Asseo K, Karni N, Benjamini Y, Nir-Paz R, Muszkat M, Israel S, Niv MY (2021) Onset, duration and unresolved symptoms, including smell and taste changes, in mild COVID-19 infection: a cohort study in Israeli patients. Clin Microbiol Infect

100. Knight DRT, Munipalli B, Logvinov, II, Halkar MG, Mitri G, Dabrh AMA, Hines SL (2022) Perception, Prevalence, and Prediction of Severe Infection and Post-acute Sequelae of COVID-19. Am J Med Sci 363:295-304

101. Kozak R, Armstrong SM, Salvant E, Ritzker C, Feld J, Biondi MJ, Tsui H (2021) Recognition of Long-COVID-19 Patients in a Canadian Tertiary Hospital Setting: A Retrospective Analysis of Their Clinical and Laboratory Characteristics. Pathogens 10:

102. Kyzar EJ, Purpura LJ, Shah J, Cantos A, Nordvig AS, Yin MT (2021) Anxiety, depression, insomnia, and trauma-related symptoms following COVID-19 infection at long-term follow-up. Brain Behav Immun Health 16:100315

103. LaVergne SM, Stromberg S, Baxter BA, et al. (2021) A longitudinal SARS-CoV-2 biorepository for COVID-19 survivors with and without post-acute sequelae. BMC Infect Dis 21:677

104. Leftin Dobkin SC, Collaco JM, McGrath-Morrow SA (2021) Protracted respiratory findings in children post-SARS-CoV-2 infection. Pediatr Pulmonol 56:3682-3687

105. Lemhofer C, Sturm C, Loudovici-Krug D, Best N, Gutenbrunner C (2021) The impact of Post-COVID-Syndrome on functioning - results from a community survey in patients after mild and moderate SARS-CoV-2-infections in Germany. J Occup Med Toxicol 16:45

106. Leth S, Gunst JD, Mathiasen V, Hansen K, Sogaard O, Ostergaard L, Jensen-Fangel S, Storgaard M, Agergaard J (2021) Persistent Symptoms in Patients Recovering From COVID-19 in Denmark. Open Forum Infect Dis 8:ofab042

107. Li Y, Han X, Huang J, et al. (2021) Follow-up study of pulmonary sequelae in discharged COVID-19 patients with diabetes or secondary hyperglycemia. Eur J Radiol 144:109997

108. Liang L, Yang B, Jiang N, Fu W, He X, Zhou Y, Ma WL, Wang X (2020) Three-month Follow-up Study of Survivors of Coronavirus Disease 2019 after Discharge. J Korean Med Sci 35:e418

109. Liao T, Meng D, Xiong L, et al. (2022) Long-Term Effects of COVID-19 on Health Care Workers 1-Year Post-Discharge in Wuhan. Infect Dis Ther 11:145-163

110. Logue JK, Franko NM, McCulloch DJ, McDonald D, Magedson A, Wolf CR, Chu HY (2021) Sequelae in adults at 6 months after COVID-19 infection. JAMA network open 4:e210830-e210830

111. Lombardo MDM, Foppiani A, Peretti GM, Mangiavini L, Battezzati A, Bertoli S, Martinelli Boneschi F, Zuccotti GV (2021) Long-Term Coronavirus Disease 2019 Complications in Inpatients and Outpatients: A One-Year Follow-up Cohort Study. Open Forum Infect Dis 8:ofab384

112. Lu Y, Li X, Geng D, et al. (2020) Cerebral Micro-Structural Changes in COVID-19 Patients - An MRI-based 3-month Follow-up Study. EClinicalMedicine 25:100484

113. Maestre-Muniz MM, Arias A, Mata-Vazquez E, Martin-Toledano M, Lopez-Larramona G, Ruiz-Chicote AM, Nieto-Sandoval B, Lucendo AJ (2021) Long-Term Outcomes of Patients with Coronavirus Disease 2019 at One Year after Hospital Discharge. J Clin Med 10:

114. Malinowska A, Muchlado M, Slizien Z, Biedunkiewicz B, Heleniak Z, Debska-Slizien A, Tylicki L (2021) Post-COVID-19 Sydrome and Decrease in Health-Related Quality of Life in Kidney Transplant Recipients after SARS-COV-2 Infection-A Cohort Longitudinal Study from the North of Poland. J Clin Med 10:

115. Mantovani E, Mariotto S, Gabbiani D, et al. (2021) Chronic fatigue syndrome: an emerging sequela in COVID-19 survivors? J Neurovirol 27:631-637

116. Martinez AE, Banderet F, Labhardt ND, Battegay M (2021) Long-term outcome after SARS-CoV-2 infection in healthcare workers: a single centre cohort study. Swiss Med Wkly 151:w30094

117. Mazza MG, Palladini M, De Lorenzo R, Bravi B, Poletti S, Furlan R, Ciceri F, group C-BOCS, Rovere-Querini P, Benedetti F (2021) One-year mental health outcomes in a cohort of COVID-19 survivors. J Psychiatr Res 145:118-124

118. Mazza MG, Palladini M, De Lorenzo R, Magnaghi C, Poletti S, Furlan R, Ciceri F, group C-BOCS, Rovere-Querini P, Benedetti F (2021) Persistent psychopathology and neurocognitive impairment in COVID-19 survivors: Effect of inflammatory biomarkers at three-month follow-up. Brain Behav Immun 94:138-147

119. McCue C, Cowan R, Quasim T, Puxty K, McPeake J (2021) Long term outcomes of critically ill COVID-19 pneumonia patients: early learning. Intensive Care Med 47:240-241

120. McGroder CF, Zhang D, Choudhury MA, Salvatore MM, D'Souza BM, Hoffman EA, Wei Y, Baldwin MR, Garcia CK (2021) Pulmonary fibrosis 4 months after COVID-19 is associated with severity of illness and blood leucocyte telomere length. Thorax 76:1242-1245

121. McPeake J, Shaw M, MacTavish P, et al. (2021) Long-term outcomes following severe COVID-19 infection: a propensity matched cohort study. BMJ Open Respir Res 8:

122. Mechi A, Al-Khalidi A, Al-Darraji R, Al-Dujaili MN, Al-Buthabhak K, Alareedh M, Shaghee F, Nafakhi H (2021) Long-term persistent symptoms of COVID-19 infection in patients with diabetes mellitus. Int J Diabetes Dev Ctries 1-4

123. Meije Y, Duarte-Borges A, Sanz X, et al. (2021) Long-term outcomes of patients following hospitalization for coronavirus disease 2019: a prospective observational study. Clin Microbiol Infect 27:1151-1157

124. Mendez R, Balanza-Martinez V, Luperdi SC, et al. (2022) Long-term neuropsychiatric outcomes in COVID-19 survivors: A 1-year longitudinal study. J Intern Med 291:247-251

125. Menges D, Ballouz T, Anagnostopoulos A, Aschmann HE, Domenghino A, Fehr JS, Puhan MA (2021) Burden of post-COVID-19 syndrome and implications for healthcare service planning: A population-based cohort study. PLoS One 16:e0254523

126. Messin L, Puyraveau M, Benabdallah Y, Lepiller Q, Gendrin V, Zayet S, Klopfenstein T, Toko L, Pierron A, Royer PY (2021) COVEVOL: Natural Evolution at 6 Months of COVID-19. Viruses 13:

127. Mirfazeli FS, Sarabi-Jamab A, Pereira-Sanchez V, Kordi A, Shariati B, Shariat SV, Bahrami S, Nohesara S, Almasi-Dooghaee M, Faiz SHR (2022) Chronic fatigue syndrome and cognitive deficit are associated with acute-phase neuropsychiatric manifestations of COVID-19: A 9-month follow-up study. Neurol Sci 43:2231-2239

128. Miwa M, Nakajima M, Kaszynski RH, Hamada S, Ando H, Nakano T, Shirokawa M, Goto H (2021) Abnormal pulmonary function and imaging studies in critical COVID-19 survivors at 100 days after the onset of symptoms. Respir Investig 59:614-621

129. Mohamed-Hussein A, Amin M, Makhlouf H, Makhlouf N, Galal I, Abd-Elaal H, Abdeltawab D, Kholief K, Hashem M (2021) Non-hospitalised COVID-19 patients have more frequent long COVID-19 symptoms. The International Journal of Tuberculosis and Lung Disease 25:732-737

130. Mohiuddin Chowdhury ATM, Karim MR, Ali MA, Islam J, Li Y, He S (2021) Clinical Characteristics and the Long-Term Post-recovery Manifestations of the COVID-19 Patients-A Prospective Multicenter Cross-Sectional Study. Front Med (Lausanne) 8:663670

131. Moreno-Perez O, Merino E, Leon-Ramirez JM, et al. (2021) Post-acute COVID-19 syndrome. Incidence and risk factors: A Mediterranean cohort study. J Infect 82:378-383

132. Munblit D, Bobkova P, Spiridonova E, et al. (2021) Incidence and risk factors for persistent symptoms in adults previously hospitalized for COVID-19. Clin Exp Allergy 51:1107-1120

133. Naik S, Haldar SN, Soneja M, et al. (2021) Post COVID-19 sequelae: A prospective observational study from Northern India. Drug Discov Ther 15:254-260

134. Nehme M, Braillard O, Chappuis F, Courvoisier DS, Guessous I, CoviCare Study T (2021) Prevalence of Symptoms More Than Seven Months After Diagnosis of Symptomatic COVID-19 in an Outpatient Setting. Ann Intern Med 174:1252-1260

135. Nguyen NN, Hoang VT, Dao TL, Meddeb L, Cortaredona S, Lagier JC, Million M, Raoult D, Gautret P (2022) Long-Term Persistence of Olfactory and Gustatory Disorders in COVID-19 Patients. Front Med (Lausanne) 9:794550

136. Nguyen NN, Hoang VT, Dao TL, Meddeb L, Lagier JC, Million M, Raoult D, Gautret P (2022) Long-term persistence of symptoms of dyspnoea in COVID-19 patients. Int J Infect Dis 115:17-23

137. Noviello D, Costantino A, Muscatello A, Bandera A, Consonni D, Vecchi M, Basilisco G (2022) Functional gastrointestinal and somatoform symptoms five months after SARS-CoV-2 infection: A controlled cohort study. Neurogastroenterol Motil 34:e14187

138. Nune A, Durkowski V, Titman A, Gupta L, Hadzhiivanov M, Ahmed A, Musat C, Sapkota HR (2021) Incidence and risk factors of long COVID in the UK: a single-centre observational study. JR Coll Physicians Edinb 51:338-343

139. Och A, Tylicki P, Polewska K, Puchalska-Reglinska E, Parczewska A, Szabat K, Biedunkiewicz B, Debska-Slizien A, Tylicki L (2021) Persistent Post-COVID-19 Syndrome in Hemodialyzed Patients-A Longitudinal Cohort Study from the North of Poland. J Clin Med 10:

140. Ong SWX, Fong SW, Young BE, et al. (2021) Persistent Symptoms and Association With Inflammatory Cytokine Signatures in Recovered Coronavirus Disease 2019 Patients. Open Forum Infect Dis 8:ofab156

141. Orru G, Bertelloni D, Diolaiuti F, Mucci F, Di Giuseppe M, Biella M, Gemignani A, Ciacchini R, Conversano C (2021) Long-COVID Syndrome? A Study on the Persistence of Neurological, Psychological and Physiological Symptoms. Healthcare (Basel) 9:

142. Osmanov IM, Spiridonova E, Bobkova P, et al. (2022) Risk factors for post-COVID-19 condition in previously hospitalised children using the ISARIC Global follow-up protocol: a prospective cohort study. Eur Respir J 59:

143. Otte MS, Bork ML, Zimmermann PH, Klussmann JP, Luers JC (2021) Persisting olfactory dysfunction improves in patients 6 months after COVID-19 disease. Acta Otolaryngol 141:626-629

144. Parente-Arias P, Barreira-Fernandez P, Quintana-Sanjuas A, Patino-Castineira B (2021) Recovery rate and factors associated with smell and taste disruption in patients with coronavirus disease 2019. Am J Otolaryngol 42:102648

145. Parry AH, Wani AH, Shah NN, Jehangir M (2021) Medium-term chest computed tomography (CT) follow-up of COVID-19 pneumonia patients after recovery to assess the rate of resolution and

determine the potential predictors of persistent lung changes. Egyptian Journal of Radiology and Nuclear Medicine 52:

146. Pasquini J, Maremmani C, Salvadori S, Silani V, Ticozzi N (2021) Testing olfactory dysfunction in acute and recovered COVID-19 patients: a single center study in Italy. Neurol Sci 42:2183-2189

147. Peghin M, Palese A, Venturini M, et al. (2021) Post-COVID-19 symptoms 6 months after acute infection among hospitalized and non-hospitalized patients. Clin Microbiol Infect 27:1507-1513

148. Pela G, Goldoni M, Cavalli C, et al. (2021) Long-Term Cardiac Sequelae in Patients Referred into a Diagnostic Post-COVID-19 Pathway: The Different Impacts on the Right and Left Ventricles. Diagnostics (Basel) 11:

149. Peluso MJ, Lu S, Tang AF, et al. (2021) Markers of Immune Activation and Inflammation in Individuals With Postacute Sequelae of Severe Acute Respiratory Syndrome Coronavirus 2 Infection. J Infect Dis 224:1839-1848

150. Pérez-González A, Araújo-Ameijeiras A, Fernández-Villar A, Crespo M, Poveda E (2021)

151. Petersen MS, Kristiansen MF, Hanusson KD, Danielsen ME, B AS, Gaini S, Strom M, Weihe P (2021) Long COVID in the Faroe Islands: A Longitudinal Study Among Nonhospitalized Patients. Clin Infect Dis 73:e4058-e4063

152. Petrocelli M, Cutrupi S, Salzano G, Maglitto F, Salzano FA, Lechien JR, Saussez S, Boscolo-Rizzo P, De Riu G, Vaira LA (2021) Six-month smell and taste recovery rates in coronavirus disease 2019 patients: a prospective psychophysical study. J Laryngol Otol 135:436-441

153. Pilotto A, Cristillo V, Cotti Piccinelli S, et al. (2021) Long-term neurological manifestations of COVID-19: prevalence and predictive factors. Neurol Sci 42:4903-4907

154. Qu G, Zhen Q, Wang W, et al. (2021) Health-related quality of life of COVID-19 patients after discharge: A multicenter follow-up study. J Clin Nurs 30:1742-1750

155. Rass V, Beer R, Schiefecker AJ, et al. (2021) Neurological outcome and quality of life 3 months after COVID-19: A prospective observational cohort study. Eur J Neurol 28:3348-3359

156. Rass V, Beer R, Schiefecker AJ, et al. (2022) Neurological outcomes 1 year after COVID-19 diagnosis: A prospective longitudinal cohort study. Eur J Neurol

157. Rauch B, Kern-Matschilles S, Haschka SJ, et al. (2021)

158. Rivera-Izquierdo M, Lainez-Ramos-Bossini AJ, de Alba IG, Ortiz-Gonzalez-Serna R, Serrano-Ortiz A, Fernandez-Martinez NF, Ruiz-Montero R, Cervilla JA (2022) Long COVID 12 months after discharge: persistent symptoms in patients hospitalised due to COVID-19 and patients hospitalised due to other causes-a multicentre cohort study. BMC Med 20:92

159. Roge I, Smane L, Kivite-Urtane A, Pucuka Z, Racko I, Klavina L, Pavare J (2021) Comparison of Persistent Symptoms After COVID-19 and Other Non-SARS-CoV-2 Infections in Children. Front Pediatr 9:752385

160. Romero-Duarte A, Rivera-Izquierdo M, Guerrero-Fernandez de Alba I, et al. (2021) Sequelae, persistent symptomatology and outcomes after COVID-19 hospitalization: the ANCOHVID multicentre 6-month follow-up study. BMC Med 19:129

161. Sakurada Y, Sunada N, Honda H, Tokumasu K, Otsuka Y, Nakano Y, Hanayama Y, Furukawa M, Hagiya H, Otsuka F (2022) Serial Changes of Long COVID Symptoms and Clinical Utility of Serum Antibody Titers for Evaluation of Long COVID. J Clin Med 11:

162. Schambeck SE, Crowell CS, Wagner KI, et al. (2021) Phantosmia, Parosmia, and Dysgeusia Are Prolonged and Late-Onset Symptoms of COVID-19. J Clin Med 10:

163. Seang S, Itani O, Monsel G, et al. (2022) Long COVID-19 symptoms: Clinical characteristics and recovery rate among non-severe outpatients over a six-month follow-up. Infect Dis Now

164. Seessle J, Waterboer T, Hippchen T, Simon J, Kirchner M, Lim A, Muller B, Merle U (2022) Persistent Symptoms in Adult Patients 1 Year After Coronavirus Disease 2019 (COVID-19): A Prospective Cohort Study. Clin Infect Dis 74:1191-1198

165. Shoucri SM, Purpura L, DeLaurentis C, et al. (2021) Characterising the long-term clinical outcomes of 1190 hospitalised patients with COVID-19 in New York City: a retrospective case series. BMJ Open 11:e049488

166. Simani L, Ramezani M, Darazam IA, Sagharichi M, Aalipour MA, Ghorbani F, Pakdaman H (2021) Prevalence and correlates of chronic fatigue syndrome and post-traumatic stress disorder after the outbreak of the COVID-19. J Neurovirol 27:154-159

167. Sonnweber T, Sahanic S, Pizzini A, et al. (2021) Cardiopulmonary recovery after COVID-19: an observational prospective multicentre trial. Eur Respir J 57:

168. Soraas A, Kalleberg KT, Dahl JA, et al. (2021) Persisting symptoms three to eight months after non-hospitalized COVID-19, a prospective cohort study. PLoS One 16:e0256142

169. Suárez-Robles M, del Rosario Iguaran-Bermúdez M, García-Klepizg JL, Lorenzo-Villalba N, Méndez-Bailón M (2020) Ninety days post-hospitalization evaluation of residual COVID-19 symptoms through a phone call check list. The Pan African Medical Journal 37:

170. Sykes DL, Holdsworth L, Jawad N, Gunasekera P, Morice AH, Crooks MG (2021) Post-COVID-19 Symptom Burden: What is Long-COVID and How Should We Manage It? Lung 199:113-119

171. Szekely Y, Lichter Y, Sadon S, et al. (2021) Cardiorespiratory Abnormalities in Patients Recovering from Coronavirus Disease 2019. J Am Soc Echocardiogr 34:1273-1284 e1279

172. Tabacof L, Tosto-Mancuso J, Wood J, et al. (2022) Post-acute COVID-19 Syndrome Negatively Impacts Physical Function, Cognitive Function, Health-Related Quality of Life, and Participation. Am J Phys Med Rehabil 101:48-52

173. Taboada M, Moreno E, Carinena A, et al. (2021) Quality of life, functional status, and persistent symptoms after intensive care of COVID-19 patients. Br J Anaesth 126:e110-e113

174. Taquet M, Dercon Q, Luciano S, Geddes JR, Husain M, Harrison PJ (2021) Incidence, co-occurrence, and evolution of long-COVID features: A 6-month retrospective cohort study of 273,618 survivors of COVID-19. PLoS Med 18:e1003773

175. Terlizzi K, Kutscher E, Yoncheva Y (2021) Monitoring New Symptoms After COVID-19 Infection Among Primary Care Patients in New York City. J Am Board Fam Med 34:1014-1016

176. Titze-de-Almeida R, da Cunha TR, Dos Santos Silva LD, et al. (2022) Persistent, new-onset symptoms and mental health complaints in Long COVID in a Brazilian cohort of non-hospitalized patients. BMC Infect Dis 22:133

177. Tleyjeh IM, Saddik B, AlSwaidan N, AlAnazi A, Ramakrishnan RK, Alhazmi D, Aloufi A, AlSumait F, Berbari E, Halwani R (2021) Prevalence and predictors of Post-Acute COVID-19 Syndrome (PACS) after hospital discharge: A cohort study with 4 months median follow-up. PLoS One 16:e0260568

178. Tleyjeh IM, Saddik B, Ramakrishnan RK, AlSwaidan N, AlAnazi A, Alhazmi D, Aloufi A, AlSumait F, Berbari EF, Halwani R (2022) Long term predictors of breathlessness, exercise intolerance, chronic fatigue and well-being in hospitalized patients with COVID-19: A cohort study with 4 months median follow-up. J Infect Public Health 15:21-28

179. Todt BC, Szlejf C, Duim E, et al. (2021) Clinical outcomes and quality of life of COVID-19 survivors: A follow-up of 3 months post hospital discharge. Respir Med 184:106453

180. Tosato M, Carfi A, Martis I, et al. (2021) Prevalence and Predictors of Persistence of COVID-19 Symptoms in Older Adults: A Single-Center Study. J Am Med Dir Assoc 22:1840-1844

181. Trunfio M, Venuti F, Alladio F, et al. (2021) Diagnostic SARS-CoV-2 Cycle Threshold Value Predicts Disease Severity, Survival, and Six-Month Sequelae in COVID-19 Symptomatic Patients. Viruses 13:

182. Ugurlu BN, Akdogan O, Yilmaz YA, Yapar D, Aktar Ugurlu G, Yerlikaya HS, Aslan Felek S (2021) Quantitative evaluation and progress of olfactory dysfunction in COVID-19. Eur Arch Otorhinolaryngol 278:2363-2369

183. Ungaro RC, Brenner EJ, Gearry RB, et al. (2021) Effect of IBD medications on COVID-19 outcomes: results from an international registry. Gut 70:725-732

184. Vaes AW, Goertz YMJ, Van Herck M, et al. (2021) Recovery from COVID-19: a sprint or marathon? 6-month follow-up data from online long COVID-19 support group members. ERJ Open Res 7:

185. Vaira LA, Gessa C, Deiana G, et al. (2022) The Effects of Persistent Olfactory and Gustatory Dysfunctions on Quality of Life in Long-COVID-19 Patients. Life (Basel) 12:

186. van den Borst B, Peters JB, Brink M, et al. (2021) Comprehensive Health Assessment 3 Months After Recovery From Acute Coronavirus Disease 2019 (COVID-19). Clin Infect Dis 73:e1089-e1098

187. Vassalini P, Serra R, Tarsitani L, et al. (2021) Depressive Symptoms among Individuals Hospitalized with COVID-19: Three-Month Follow-Up. Brain Sci 11:

188. Walle-Hansen MM, Ranhoff AH, Mellingsaeter M, Wang-Hansen MS, Myrstad M (2021) Health-related quality of life, functional decline, and long-term mortality in older patients following hospitalisation due to COVID-19. BMC Geriatr 21:199

189. Weber B, Siddiqi H, Zhou G, et al. (2022) Relationship Between Myocardial Injury During Index Hospitalization for SARS-CoV-2 Infection and Longer-Term Outcomes. J Am Heart Assoc 11:e022010

190. Wisnivesky JP, Govindarajulu U, Bagiella E, Goswami R, Kale M, Campbell KN, Meliambro K, Chen Z, Aberg JA, Lin JJ (2022) Association of Vaccination with the Persistence of Post-COVID Symptoms. J Gen Intern Med

191. Writing Committee for the CSG, Morin L, Savale L, et al. (2021) Four-Month Clinical Status of a Cohort of Patients After Hospitalization for COVID-19. JAMA 325:1525-1534

192. Wynberg E, van Willigen HDG, Dijkstra M, et al. (2021) Evolution of COVID-19 symptoms during the first 12 months after illness onset. Clin Infect Dis

193. Xiong Q, Xu M, Li J, Liu Y, Zhang J, Xu Y, Dong W (2021) Clinical sequelae of COVID-19 survivors in Wuhan, China: a single-centre longitudinal study. Clin Microbiol Infect 27:89-95

194. Yin X, Xi X, Min X, Feng Z, Li B, Cai W, Fan C, Wang L, Xia L (2021) Long-term chest CT follow-up in COVID-19 Survivors: 102-361 days after onset. Ann Transl Med 9:1231

195. Zayet S, Zahra H, Royer PY, et al. (2021) Post-COVID-19 Syndrome: Nine Months after SARS-CoV-2 Infection in a Cohort of 354 Patients: Data from the First Wave of COVID-19 in Nord Franche-Comte Hospital, France. Microorganisms 9:

196. Zhao Y, Yang C, An X, et al. (2021) Follow-up study on COVID-19 survivors one year after discharge from hospital. Int J Infect Dis 112:173-182

Supplementary Table 2. Descriptive characteristics of the studies included

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Abdelrahman,2021	172	Egypt	PCR	Hospital and non-hospital	No	10	Phone	65.7	42	7
Agergaard,2021	20	Denmark	PCR	Hospital and non-hospital	Yes	7	Outpatient visit	81.0	53	9
Albu,2021	41	Spain	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	58.0	54	7
Anastasio,2021	379	Italy	PCR	Yes	Yes	4	Outpatient visit	54.0	56	7
Aranda, 2021	113	Spain	PCR	Yes	Yes	7	Outpatient visit	30.1	64	7
Arnold,2021	110	UK	PCR	Yes	No	4	Outpatient visit	40.0	55	7
Asadi-Pooya,2021	4681	Iran	PCR	Yes	Yes	6	Phone	47.1	52	7
Attuabi,2021	516	Denmark	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	52.0	44	7

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
August,2021	353	Germany	PCR	Yes	NA	6	Outpatient visit	56.0	54	8
Augustin, 2021	90	Germany	PCR	No	No	7	Outpatient visit	57.0	49	8
Becker, 2021	136	Switzerland	PCR	Yes	Yes	12	Outpatient visit	38.0	60	8
Bellan,2021	200	Italy	PCR	Yes	Yes	4	Outpatient visit	38.5	61	7
Bellan,2021	57	Italy	PCR	Yes	Yes	12	Outpatient visit	39.0	62	7
Bertlich,2021	43	Germany	PCR	Yes	No	6	Outpatient visit	34.0	65	7
Betschart,2021	247	Switzerland	PCR	Yes	NA	12	Outpatient visit	30.0	60	8
Blomberg,2021	91	Norway	PCR	Hospital and non-hospital	No	6	NA	53.0	46	8
Boari, 2021	183	Italy	PCR	Yes	Yes	4	Outpatient visit	41.0	58	8
Boscolo-Rizzo,2021	84	Italy	PCR	Yes	No	6	Phone	55.2	55	8
Bottemanne,2021	107	France	PCR	Yes	No	3	Outpatient visit	27.4	60	8
Bozzetti, 2021	704	Italy	PCR	Yes	Yes	6	Outpatient visit	32.0	63	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Bussiere,2021	1865	Canada	PCR	Yes	NA	4.8	in person interview	84.2	42	8
Buttery,2021	86	UK	PCR	Hospital and non-hospital	Yes	3	eletronic survey	77.0	46	6
Bylicki,2021	55	France	PCR	No	No	9	Outpatient visit	22.7	31	6
Capelli,2021	160	Italy	PCR	No	No	8	Phone	51.0	49	8
Caruso,2021	118	Italy	PCR	Yes	Yes	6	Outpatient visit	53.0	65	8
Cassar,2021	46	UK	PCR	Yes	Yes	6	Outpatient visit	41.0	55	8
Catalán,2021	76	Spain	PCR	Yes	Yes	12	Outpatient visit	38.0	62	6
Chand,2021	105	USA	PCR	Yes	Yes	7	Phone	52.0	54	6
Chaumont,2022	50	France	PCR	Yes	NA	6	Outpatient visit	40.0	66	8
Chen, 2021	715	China	PCR	Yes	Yes	7.5	Phone	48.7	69	8
Chowdhury,2021	313	Bangladesh	PCR	Yes	No	7	Phone	19.8	38	8
Clavario,2021	200	Italy	PCR	Yes	No	3	Outpatient visit	43.0	59	6

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Cristillo, 2021	18	Italy	PCR	Yes	No	6	Outpatient visit	26.7	65	8
Cristillo, 2022	106	Italy	PCR	Yes	No	6	Outpatient visit	27.7	63	8
Dai,2021	1415	China	PCR	Yes	No	6	Outpatient visit	50.0	48	8
Darcis, 2021	1697	Belgium	PCR	Yes	Yes	6	Outpatient visit	36.7	60	8
Darley, 2021	50	Australia	PCR	Yes	NA	8	Outpatient visit	39.0	47	7
De las Penas, 2021	199	Spain	PCR	Yes	Yes	7	Outpatient visit	39.8	52	8
De las Penas, 2021	97	Spain	PCR	Yes	Yes	7	Phone	37.9	70	8
De las Penas, 2021	435	Spain	PCR	Yes	Yes	8.5	Phone	46.5	60	8
De las Penas, 2021	264	Spain	PCR	Yes	Yes	8	Outpatient visit	46.5	61	8
De las Penas, 2021	1969	Spain	PCR	Yes	Yes	7.3	Phone	67.0	56	7
De las Penas, 2021	1593	Spain	PCR	Yes	Yes	8.4	Phone	46.5	61	8
De las Penas, 2021	1593	Spain	PCR	Yes	Yes	7	Phone	48.0	61	8
De las Penas, 2022	1969	Spain	PCR	Yes	Yes	8	Phone	45.0	61	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
De las Penas, 2022	161	Spain	PCR	Yes	Yes	8	Phone	45.0	61	9
Del Brutto, 2021	1969	Ecuador	PCR	NA	NA	18	Outpatient visit	63.0	63	6
Dennis, 2021	1142	UK	PCR	Hospital and non-hospital	No	5	Outpatient visit	70.6	44	6
Diaz Fuentes, 2021	50	USA	PCR	Yes	Yes	3	Outpatient visit	53.0	60	8
D'souza,2021 (only abstract)	201	India	PCR	Yes	NA	6	Outpatient visit	NA	NA	6
Du,2022	111	China	PCR	Yes	No	6	Outpatient visit	38.0	54	8
Elkan, 2021	132	Israel	PCR	Yes	No	9	eletronic survey	56.0	58	8
Eloy,2021	19	France	PCR	Yes	Yes	6	eletronic survey	37.0	61	8
Evans,2021	66	UK	PCR	Yes	Yes	6	mixed	69.0	58	9
Fang, 2021	3060	China	PCR	Yes	Yes	12	Phone	52.1	68	6

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Ferrucci, 2022	767	Italy	PCR	Yes	Yes	5	Outpatient visit	26.3	56	6
Fink, 2021	1233	Brazil	PCR	Yes	No	4.4	Outpatient visit	58.0	15	8
Forster, 2022 (abstract)	76	German	PCR	Hospital and non-hospital	NA	3	NA	NA	NA	8
Fortini, 2021	53	Italy	PCR	Yes		4	Outpatient visit	47.5	68	7
Fortini, 2022	1459	Italy	PCR	Yes	No	12	Outpatient visit	53.0	71	8
Fortunato, 2022	46	Italy	PCR	No	No	12	Phone	53.9	43	8
Froidure, 2021	17	Belgium	PCR	Yes	Yes	3	Outpatient visit	31.0	60	6
Frontera, 2021	178	USA	PCR	Yes	Yes	6	Phone	35.0	69	8
Fumagalli, 2022	126	Italy	PCR	Yes	No	12	Phone	40.0	62	8
Gaber, 2021	382	UK	PCR	No	No	4	eletronic survey	83.0	NA	7
Galal,2021	402	Egypt	PCR	Yes	Yes	6	Outpatient visit	63.7	37	8
Gamberini, 2021	138	Italy	PCR	Yes	Yes	12	Outpatient visit	27.5	64	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Garcia-Abellan,2021	430	Spain	PCR	Yes	No	6	Outpatient visit	40.0	64	6
Garrigues,2021	178	France	PCR	Yes	Yes	4	Phone	38.5	63	6
Gautam,2021	146	UK	PCR	Yes	Yes	5	Outpatient visit	37.5	56	8
Gerard,2021	120	France	PCR	Yes	Yes	6	Outpatient visit	45.8	59	6
Gherlone,2021	200	Italy	PCR	Yes	Yes	4	Outpatient visit	25.0	63	8
Ghosn,2021	288	France	PCR	Yes	Yes	6	Outpatient visit	37.0	61	8
Goertz, 2021	122	Nederland and Belgium	PCR	Hospital and non-Hospital	NO	3	Phone	85.0	47	8
Gonzales-Hermosillo, 2021	1137	Mexico	PCR	Yes	Yes	3	Phone	34.6	51	8
Gonzalez,2021	123	Spain	PCR	Yes	Yes	3	Outpatient visit	25.8	60	8
Graham,2021	2113	USA	PCR	No	No	4	mixed	70.0	43	7
Gramaglia,2021	130	Italy	PCR	Yes	Yes	4	Phone	43.6	56	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Gudziol, 2021	62	Germany	PCR	No	NA	4	Outpatient visit	58.1	62	8
Han,2021	100	China	PCR	Hospital and non-hospital	Yes	6	Outpatient visit	30.0	54	6
Haung,2022	237	China	PCR	Yes	Yes	7	Outpatient visit	60.6	57,67	6
Heightman,2022	24	UK	PCR	Yes	NA	12	mixed	56.5	50	8
Hodgson,2021	114	Australia	PCR	Yes	Yes	6	Phone	41.5	61	6
Hopkins,2021	1325	UK	Lab confirmed	No	No	6	other	74.9	40	8
Horwitz, 2021	193	USA	PCR	Yes	Yes	6	eletronic survey	40.0	62	8
Hossain, 2021	126	Bangladesh	PCR	Hospital and non-hospital	Yes	3	Phone	27.6	39	8
Houben-Wilken, 2022	2198	Netherlands	PCR	Hospital and non-hospital	No	6	eletronic survey	82.8	50	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Huang ,2021	239	Cina	Lab confirmed	Yes		6	in person interview	47.0	59	8
Huang,2021	2469	Cina	Lab confirmed	Yes	Yes	6	mixed	48.0	57	7
Ishiyama, 2021	461	Japan	PCR	Yes	Yes	3	mixed	40.0	53	8
Jacobson 2021	95	USA	PCR	Yes	NA	4	Outpatient visit	47.0	43	9
Janiri, 2021	118	Italy	PCR	Yes	Yes	3	Outpatient visit	43.6	55	6
Karaarsian,2022	381	Turkey	Lab confirmed	Yes	Yes	3	Phone	40.5	53	6
Kayaaslan, 2022	285	Turkey	PCR	Yes	Yes	5	eletronic survey	43.6	45	8
Kim, 2022	291	Korea	PCR	Hospital and non-hospital	Yes	12	eletronic survey	68.0	37	6
Kim,2021	1007	Korea	PCR	Yes		6	eletronic survey	69.7	30	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Klein, 2021	241	Israel	PCR	Yes	No	6	eletronic survey	38.0	35	8
Knight,2021	5252	USA	PCR	Yes	Yes	6	eletronic survey	47	44	8
Kozak, 2021	103	Canada	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	53.0	49	8
Kyzar, 2021	223	USA	PCR	Hospital and non-hospital	Yes	8	mixed	62.5	46	8
Lavergne SM, 2021	52	USA	PCR	Yes	No	6	in person interview	71.0	53	7
Leftin Dobkin, 2021	512	USA	PCR	Yes	No	3	Outpatient visit	58.6	13	8
Lemhofer, 2021	119	Germany	PCR	No	No	3	eletronic survey	59.2	50	9

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Leth, 2021	29	Denmark	PCR	Yes	Yes	3	mixed	57.0	58	6
Li, 2021	365	China	PCR	Yes	Yes	6	Outpatient visit	36.9	59	6
Liang,2020	365	China	PCR	Yes	Yes	3	Outpatient visit	72.0	41	8
Liao, 2022	49	China	PCR	Yes	Yes	12	Outpatient visit	80.5	39	6
Logue, 2021	236	USA	PCR	Hospital and non-hospital	Yes	6	mixed	57.1	48	8
Lombardo, 2021	141	Italy	PCR	Hospital and non-hospital	Yes	12	Phone	54.0	53	8
Lu, 2020	76	China	PCR	Yes	Yes	3	Outpatient visit	43.3	44	8
Maestre-Muniz, 2021	303	Spain	PCR	Hospital and non-hospital	Yes	12	Phone	49.3	65	8
Malinowska, 2021	1276	Poland	PCR	Hospital and non-hospital	No	6	Phone	43.3	53	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Mantovani, 2021	1276	Italy	PCR	Hospital and non-hospital	No	6	Outpatient visit	32.4	52	7
Martinez, 2021	177	Switzerland	PCR	Yes	No	3	eletronic survey	75.4	35	8
Mazza ,2022	303	italy	PCR	Yes	Yes	12	in person interview	32.0	59	9
Mazza, 2021	60	Italy	PCR	Yes	Yes	3	Outpatient visit	33.0	58	8
McCue, 2021	543	United Kingdom	PCR	Yes	Yes	3	other	23.0	57	8
McGroder, 2021	67	USA	PCR	Yes	Yes	4	Outpatient visit	39.0	54	8
McPeake, 2021	131	United Kingdom	PCR	Yes	Yes	5	Outpatient visit	34.4	59	8
Mechi, 2021	260	Iraq	PCR	Hospital and non-hospital	NA	9	Outpatient visit	64.0	52	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Meije, 2021	192	Spain	PCR	Yes	Yes	7	Phone			7
Mendez, 2022	226	Spain	PCR	Yes	Yes	12	Phone	42.1	58	8
Menges, 2021	24	Switzerland	PCR	Hospital and non-hospital		7	eletronic survey	49.7	47	8
Messin, 2021	76	France	PCR	Yes	Yes	6	Phone	59.5	52	6
Mirfazeli, 2022	93	Iran	PCR	Hospital and non-hospital	Yes	9	Phone	42.0	50	8
Miwa, 2021	112	Japan	PCR	Yes	Yes	3	Outpatient visit	17.6	63	8
Mohamed-Hussein, 2021	294	Egypt	PCR	Hospital and non-hospital	Yes	3	mixed	58.0	43	8
Moreno-Perez, 2021	171	Spain	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	47.3	62	8
Morin, 2021	431	France	PCR	Yes	Yes	4	mixed	42.1	61	8
Munblit, 2021	74	Russia	PCR	Yes	No	8.3	Phone	51.1	56	7

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Munblit, 2021	95	Russia	PCR	Yes	Yes	7	Phone	51.1	56	8
Naik, 2021	17	India	Lab confirmed	Yes	NA	6	Phone	30.6	42	8
Nehme, 2021	262	Switzerland	PCR	No	No	9	Phone	60.9	42	6
Nguyen, 2021	277	France	PCR	Yes	Yes	7	Phone	55.0	38	8
Nguyen, 2022	277	France	PCR	Yes	Yes	11	Phone	68.0	42	8
Noviello,2021	244	Italy	PCR	Hospital and non-hospital	NA	5	other	40.0	44	8
Nune,2021 (abstract)	2649	UK	Lab confirmed	Yes	NA	9	NA	NA	NA	8
Och, 2021	2649	Poland	PCR	Yes	Yes	6	Phone	50.6	70	8
Ong, 2021	2243	Singapore	PCR	Yes	Yes	6	Outpatient visit	24.6	44	7
Orrù,2021	629	Italy	PCR	NA	NA	3	eletronic survey	82.0	44	8
Osmanov, 2022	629	Russia	PCR	Yes	Yes	5	Phone	52.1	10	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Otte, 2021	125	Germany	PCR	No	No	6	Outpatient visit	42.3	45	6
Parente-Arias, 2021	496	Spain	PCR			3	Phone	65.0	55	8
Parry, 2021	347	India	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	38.3	52	6
Pasquini, 2021	271	Italy	PCR	Hospital and non-hospital	No	4	Outpatient visit	65.4	46	8
Peghin, 2021	73	Italy	PCR	Hospital and non-hospital	Yes	6	Phone	53.4	53	6
Pelà, 2021	183	Italy	PCR	Yes	Yes	5	Outpatient visit	40.0	60	8
Peluso, 2021	507	USA	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	54.5	44	8
Pérez-Gonzàlez,2022	518	Spain	PCR	Yes	No	6	other	40.0	57	8
Petersen,2020	26	Faroe Island	PCR	No	No	4	Phone	98.0	40	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Petrocelli,2021	151	Italy	PCR	No	No	6	mixed	75.0	44	8
Pilotto, 2021	81	Italy	PCR	Yes	Yes	6	Phone	30.3	65	7
Qu,2021	26	China	PCR	Yes	Yes	3	Outpatient visit	50.0	48	8
Radtke, 2021	599	USA	PCR	No	No	3	Outpatient visit	54.0	11	8
Rass, 2021	599	Austria	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	49.0	56	6
Rass,2022	160	Austria	Lab confirmed	Yes	Yes	12	other	33.0	54	6
Rauch, 2021	121	Germany	PCR	Hospital and non-hospital	Yes	6	Eletronic survey	68.5	NA	8
Rivera-Izquierdo, 2022	121	Spain	PCR	Yes	No	12	other	43.0	61	6
Roge, 2021	1583	Lettonia	PCR	Yes	NA	6	Outpatient visit	44.5	10	8
Romero-Duarte, 2021	248	Spain	PCR	Yes	Yes	6	Outpatient visit	46.3	63	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Romero-Duarte, 2021	187	SPAIN	PCR	Yes	Yes	5	In person interview	46.3	63	8
Sakurada, 2022	300	JAPAN	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	55.4	39	8
Schambeck, 2021	56	Switzerland	PCR	Hospital and non-hospital	NA	9	Outpatient visit	41		8
Seang, 2022	540	FRANCE	PCR	Hospital and non-hospital	NA	6	In person interview	78.0	48	7
SeeBle, 2021	1355	GERMANY	PCR	Hospital and non-hospital	Yes	12	Outpatient visit	55.2	57	8
Shoucri, 2021	135	USA	PCR	Yes	Yes	6	Outpatient visit	40.8	36	8
Simani, 2021	81	Iran	PCR	Yes	Yes	12	Phone	33.3	55	6
Sonnweber,2021	127	Austria	PCR	Yes	Yes	3	Outpatient visit	43.0	57	6

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Soraas, 2021	906	HONG KONG	PCR	No	No	12	In person interview	68.0	44	8
Suarez-Robles,2020	797	Spain	PCR	Yes	Yes	3	Phone	54.0	59	9
Sykes, 2021	797	UK	PCR	Yes	Yes	4	In person interview	34.3	58	6
Szekely, 2021	65	Israel	LAB CONFIRMED	Yes	NA	3	Outpatient visit	44.0	52	6
Tabacof, 2022	44	USA	PCR	Hospital and non-hospital	NA	12	In person interview	69.0	44	8
Taboada, 2021	63	Spain	PCR	Yes	Yes	6	Outpatient visit	41.0	66	6
Taquet, 2021	146	NETHERLANDS	PCR	Hospital and non-hospital	Yes	6	In person interview	55.6	46	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Terlizzi, 2021	96	USA	PCR	Yes	Yes	6	In person interview	57.3	56	8
Titze-de-Akmeida, 2022	1190	BRAZIL	PCR	Hospital and non-hospital	Yes	8	phone and in person interview	61.0	41	8
Tleyjeh,2021	267	Saudi Arabia	PCR	Yes	No	4	Phone	23.0	52	8
Tleyleh, 2021	145	USA	PCR	Hospital and non-hospital	Yes	6	phone and in person interview	33.0	52	8
Todt, 2021	31013	Brazil	PCR	Yes	Yes	3	Phone	40.2	53	7
Tosato, 2021	134	ITALY	PCR	Yes	NA	3	In person interview	38.2	73	8
Trunfio,2021	387	Italy	PCR	Hospital and non-hospital	Yes	6	Outpatient visit	44.0	56	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Ugurlu,2021	129	Turkey	PCR	Yes	NA	3	Outpatient visit	53.0		6
Vaes, 2021	386	Netherlands	PCR	Hospital and non-hospital	Yes	6	eletronic survey	82.8	50	6
Vaira, 202	91	Italy	PCR	No	No	6	eletronic survey	76.3	38	6
van der Borst, 2020	273	Netherlands	PCR	Yes	Yes	3	Outpatient visit	40.0	59	9
Vassallini, 2021	499	Italy	PCR	Yes	Yes	3	Phone	46.0	53	6
Walle-Hansen,2021	362	Norway	PCR	Yes	Yes	6	Outpatient visit	43.0	74	6
Weber, 2021	125	USA	Lab confirmed	Hospital and non-hospital	Yes	6	mixed	51.2	61	8
Weng,2021	251	China	PCR	Yes	Yes	3	Phone	44.4	NA	6
Wisnivesky, 2021	165	USA	Lab confirmed	Hospital and non-hospital	Yes	6	in person interview	54.9	50	8

Author, year	Sample size	Country	Methods for COVID19 diagnosis	Hospitalized	ICU	Follow-up (months)	Follow-up mode	Percentage females	Mean age	NOS
Wynberg, 2021	165	Netherlands	PCR	Hospital and non-hospital	Yes	3	Outpatient visit	46.0	51	8
Xiong, 2021	200	China	PCR	Yes	Yes	3	Phone	54.5	52	8
Yin,2021	104	China	PCR	Yes	Yes	6	Outpatient visit	49.6	53,51	8
Zayet, 2021	1005	France	PCR	Hospital and non-hospital	Yes	9	mixed	63.8	49	8
Zhao,2021	239	China	PCR	Yes	Yes	12	Outpatient visit	40.0	48	7

ICU= Intensive Care Unit, NA= Not Available, PCR= Polymerase chain reaction, USA = United Stades of America, NOS= Newcastle Ottawa Scale.

Supplementary Table 3. Meta-regression analysis of long COVID signs and symptoms

	Hospitalized (yes vs. no)	% of females	Mean age
Any	NS	B=0.02 (0.01) P=0.047 R2=2.2	NS
Neurological	NS	B=0.003 (0.0009) P=0.001 R2=9.2	NS
Psychiatric	NS	NS	B=0.003 (0.001) P=0.007 R2=6.7
Respiratory	NS	NS	B=0.004 (0.001) P=0.009 R2=6.0
Mobility issues	NS	NS	NS
General	NS	B= 0.02 (0.01) P=0.05 R2=2.0	B=0.004 (0.002) P=0.03 R2=3.0
Cardiovascular	NS	B=0.003 (0.0009) P=0.001 R2=14.1	NS
Digestive	NS	NS	B=0.002 (0.0009) P=0.04 R2=5.0
Skin	NS	NS	B=0.002 (0.0009) P=0.02 R2=12.6

Data are reported as Beta (B) and their standard error and correspondent p-values and adjusted R2.

NS: not significant.

Supplementary Table 4. Cumulative incidence of long COVID by continent, mean age and follow-up

	Continent						Mean age			Follow-up		
Cluster	**North America**	**Europe**	**Asia**	**South America**	**Africa**	**Oceania**	**Children Youth (0-18)**	**Adults (18-60)**	**Older (>=60)**	**3 months**	**3-6 months**	**6-12 months**
Any	48.5*** (32.2-65.0)	58.7 (53.1-64.2)	54.3 (42.3-66.1)	55.2 (31.2-78.0)	60.2 (56.9-63.4)	63.4 (57.4-69.2)	72.0 (20.0-100)	58.0 (51.8-64.1)	56.2 (47.2-65.0)	60.7 (49.5-71.4)	56.0 (48.8-63.0)	56.1 (47.5-64.5)
Neurological	15.4*** (8.8-23.4)	23.0 (20.0-26.2)	8.9 (6.8-11.2)	30.9 (22.2-40.3)	11.9 (9.4-14.7)	34.0 (18.9-49.4)	8.8* (4.0-15.1)	20.3 (17.4-23.4)	18.8 (14.5-23.6)	20.0** (13.8-26.0)	20.1 (16.4-24.2)	14.0 (12.4-15.6)
Psychiatric	19.0*** (9.8-30.4)	21.4 (17.8-25.3)	15.0 (9.2-22.0)	26.8 (15.3-40.0)	41.6 (37.8-45.6)	-	5.0** (0.0-16.1)	19.6 (16.1-23.4)	20.7 (14.8-27.3)	20.0 (12.7-28.4)	19.4 (14.9-24.2)	21.7 (18.1-25.6)
Respiratory	21.9*** (12.1-33.6)	27.0 (23.4-30.8)	17.3 (13.0-22.0)	17.3 (4.8-35.0)	26.8 (23.4-30.5)	23.3 (18.3-28.7)	17.0 (4.2-35.2)	23.6 (19.5-27.9)	26.9 (20.9-33.4)	32.6*** (23.0-43.0)	21.7 (17.3-26.4)	22.9 (17.8-28.4)
Mobility issues	17.7 (4.8-36.1)	14.2 (10.3-18.5)	9.5 (6.0-13.7)	-	-	-	4.9*** (0.9-11.5)	17.3 (13.2-21.8)	8.8 (4.3-14.6)	13.9* (5.5-25.2)	11.5 (7.0-16.8)	16.3 (12.5-20.6)
General	20.0*** (11.6-30.0)	33.6 (29.2-38.2)	28.2 (20.6-36.5)	21.6 (5.6-43.9)	53.5 (49.5-57.5)	19.6 (15.0-24.7)	10.6*** (8.5-12.8)	31.1 (26.2-36.3)	31.2 (23.7-39.3)	36.6 (27.3-46.3)*	27.8 (22.5-32.3)	32.9 (25.4-40.8)
Cardiovascular	8.6 (3.8-15.0)***	10.5 (8.3-12.9)	11.1 (7.4-15.5)	-	33.1 (29.4-36.9)	10.7 (8.9-13.3)	1.9** (0.0-5.9)	11.3 (8.6-14.3)	9.6 (6.7-12.7)	14.4 (7.3-23.4)	10.7 (7.7-13.9)	8.9 (6.8-11.2)
Digestive	6.6*** (3.3-11.0)	8.4 (6.5-10.5)	4.8 (3.2-6.6)	4.0 (2.3-6.3)	36.9 (33.1-40.8)	3.1 (0.6-8.8)	1.5 (0.0-4.2)	6.9 (5.6-8.3)	10.4 (5.7-16.3)	12.1*** (7.4-17.8)	8.4 (6.1-11.0)	4.2 (3.2-5.4)
Skin	6.2 (3.3-9.9)	8.0 (6.2-9.9)	12.5	-	8.9	-	2.1*** (1.2-3.3)	8.4 (6.3-10.8)	13.2	6.8*** (3.4-11.3)	7.9 (5.4-10.9)	10.6 (7.9-13.7)

			(6.5-20.0)		(6.5-11.1)				(7.9-19.6)			

Notes: data are reported as cumulative incidence with their 95% confidence intervals. *, **, *** indicate between sub-groups interaction with a p-value <0.05, <0.001 and <0.0001, respectively.

Supplementary Table 5. Cumulative incidence of long COVID by previous intensive care unit admission, hospitalization, follow-up mode and risk of bias.

	ICU admission		Hospitalized			Type of follow-up					Risk of bias	
Cluster	**Yes**	**No**	**Mixed**	**Yes**	**No**	**Outpatient visit**	**Mixed**	**Phone**	**Electronic survey**	**In person interview**	**Moderate**	**Low**
Any	53.6 (46.0-61.1)	51.0 (42.2-59.8)	55.7 (46.3-65.1)	51.5 (45.0-58.1)	53.0 (38.5-67.4)	53.7*** (47.8-59.7)	55.6 (44.0-67.2)	50.1 (41.6-58.6)	52.9 (34.2-71.6)	36.3 (25.7-46.8)	51.9 (43.0-60.7)	52.3 (45.6-59.0)
Neurological	18.1* (16.4-19.8)	28.2 (20.0-36.5)	25.8*** (20.6-31.0)	16.7 (15.4-18.0)	35.4 (15.5-55.4)	24.8*** (21.6-28.1)	18.7 (13.5-23.8)	17.4 (15.0-20.0)	22.1 (17.7-26.6)	14.3 (11.1-17.4)	23.9*** (21.1-26.7)	18.9 (17.4-20.5)
Psychiatric	23.9 (21.0-26.7)	20.9 (15.2-26.6)	28.6** (22.3-34.9)	19.3 (17.7-21.0)	38.5 (27.1-50.0)	23.3** (20.3-26.3)	16.9 (10.3-23.4)	22.9 (19.1-26.8)	22.9 (18.4-27.3)	16.8 (9.3-24.4)	23.9*** (21.1-26-7)	18.9 (17.4-20.5)
Respiratory	28.1 (25.1-31.0)	29.2 (20.5-38.0)	25.1 (18.3-31.9)	27.7 (25.5-29.9)	29.1 (19.5-38.7)	31.3*** (26.9-35.6)	18.4 (9.8-27.1)	25.7 (20.2-31.2)	17.9 (13.8-22.0)	19.1 (14.2-24.0)	31.4*** (26.8-35.9)	23.4 (21.7-25.2)
Mobility issues	13.6*** (10.0-17.2)	23.9 (20.4-27.3)	20.2** (15.1-25.3)	11.3 (8.9-22.7)	18.4 (14.7-22.7)	22.4*** (17.0-27.7)	20.6 (18.9-22.6)	7.3 (3.7-10.9)	13.9 (8.9-18.8)	8.7 (4.0-13.4)	28.0*** (18.6-37.3)	11.7 (9.7-13.7)
General	34.0 (30.1-37.8)	32.6 (20.0-45.1)	34.1 (23.2-45.0)	32.8 (29.8-35.8)	38.5 (26.8-50.2)	35.5 (27.9-43.1)	28.2 (16.2-40.2)	35.6 (28.2-43.0)	29.0 (23.1-34.7)	25.7 (18.4-33.0)	34.9 (27.8-42.0)	31.5 (28.4-34.6)
Cardiovascular	10.9 (9.2-12.5)	16.1 (10.5-21.7)	17.1** (13.3-20.8)	9.9 (8.7-11.1)	16.0 (2.5-29.4)	16.8*** (14.0-20.0)	8.5 (3.5-13.5)	7.9 (5.6-10.1)	11.8 (7.8-15.8)	10.7 (6.9-14.5)	14.3** (11.0-17.6)	9.5 (8.6-10.4)
Digestive	9.0 (7.6-10.4)	8.0	9.6	7.2	11.4	11.2*** (8.8-13.5)	5.6	5.6	5.7 (4.1-7.3)	7.4 (5.3-9.5)	9.6** (7.4-11.7)	6.4

	ICU admission		Hospitalized			Type of follow-up					Risk of bias	
		(6.0-9.9)	(7.2-11.9)	(6.3-8.1)	(6.2-16.5)		(3.4-7.8)	(4.4-6.8)				(5.7-7.0)
Skin	10.0 (7.9-12.0)	11.3 (7.3-15.2)	8.3 (5.9-10.6)	9.5 (7.8-11.2)	6.1 (1.1-11.2)	9.8*** (7.5-12.0)	5.1 (0.4-9.8)	9.2 (6.5-11.8)	9.7 (4.9-14.6)	7.7 (3.0-12.4)	13.7*** (10.2-17.2)	6.8 (5.4-8.2)

Notes: data are reported as cumulative incidence with their 95% confidence intervals. *, **, *** indicate between sub-groups interaction with a p-value <0.05, <0.001 and <0.0001, respectively.

Supplementary Figure 1. PRISMA flow-chart