

Global Prevalence of Long COVID, Its Subtypes, and Risk Factors: An Updated Systematic Review and Meta-analysis

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Background. This mega-systematic review evaluated the global prevalence of long COVID and its subtypes and symptoms, and assessed the effects of risk factors for long COVID.

Methods. Studies published from 5 July 2021 to 29 May 2024 were searched in PubMed, Embase, and Web of Science, with supplemental updates on 23 July 2024. Data were pooled using a random-effects framework with DerSimonian-Laird estimator. Risk of bias analysis was conducted.

Results. A total of 429 studies were meta-analyzed. The global pooled long COVID prevalence was 36% (95% confidence interval [CI], 33%–40%) with 144 contributing studies. The highest prevalence rates were observed in South America (51% [95% CI, 35%–66%]). The prevalence of long COVID persisted over time, with 35% (95% CI, 31%–39%) at <1 year of follow-up and 46% (95% CI, 37%–57%) at 1–2 years. The most prevalent subtypes were respiratory (20% [95% CI, 14%–28%]) estimated from 31 studies, general fatigue (20% [95% CI, 18%–23%]) from 119 studies, psychological (18% [95% CI, 11%–28%]) from 10 studies, and neurological (16% [95% CI, 8%–30%]) from 23 studies. The 3 strongest risk factors were being unvaccinated for COVID-19 (pooled odds ratio [OR], 2.09 [95% CI, 1.55–2.81]) meta-analyzed from 7 studies, infections from pre-Omicron variants (OR, 1.74 [95% CI, 1.40–2.17]) from 6 studies, and female sex (OR, 1.56 [95% CI, 1.32–1.84]) from 33 studies.

Conclusions. Long COVID is globally prevalent after a severe acute respiratory syndrome coronavirus 2 infection, highlighting a continuing health challenge. The heterogeneity of estimates across populations argues the need for well-designed follow-up studies that use consistent measures and are globally representative.

Keywords. epidemiology; infectious disease; long COVID; postacute sequelae of COVID-19.

The coronavirus disease 2019 (COVID-19) pandemic has posed unprecedented challenges to public health worldwide over the past 5 years. COVID-19 is an airborne infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). As of 16 February 2024, >777 million COVID-19 cases were reported [1]. COVID-19 survivors are at risk for long COVID, a complex multisystemic syndrome [2] that likely represents a disease with many subtypes [3]. This condition is termed postacute sequelae of COVID-19 (PASC) [4] and long COVID in the United States (US) [5].

Among varying terminologies and definitions for long COVID [6–9], the World Health Organization (WHO) first presented the term “post-COVID-19 condition” through a Delphi consensus in October 2021, defining it as “the continuation or development of new symptoms 3 months after the initial SARS-CoV-2 infection, with these symptoms lasting for at least 2 months with no other explanation” [10]. In 2024, the National Academies of Sciences, Engineering, and Medicine developed an updated definition of long COVID in the US, which is concisely described as “an infection-associated chronic condition that occurs after SARS-CoV-2 infection and is present for at least 3 months as a continuous, relapsing and remitting, or progressive disease state that affects 1 or more organ systems” [11, 12].

In this systematic review, we will use “long COVID” to describe the presence of at least 1 new or persistent symptom at a follow-up time of at least 2 months since a SARS-CoV-2 infection, as different studies included in the review follow different nomenclatures and definitions. We also want to clarify that our estimate reflects the proportion of individuals who met our definition of long COVID at the follow-up timepoint(s) considered in each meta-analyzed study regardless of whether they had symptoms persisting at a common future date. Thus, our

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estimate captures the prevalence of “ever” experiencing long COVID. This differs from “current” prevalence estimates, such as those from the Household Pulse Survey [13], which reported the proportion of individuals who not only had symptoms lasting 3 months or more but also had symptoms at the specific time of the survey.

Existing reviews focus either on specific symptoms or the broad long COVID phenotype. For example, in a *Nature* review article, Davis et al [14] explored current literature on long COVID subtypes, such as neurological [15–17], cardiovascular [18, 19], pulmonary, and immune symptoms [20, 21], and their risk factors [22]. However, the underlying prevalence of long COVID subtypes with consideration of a large set of symptoms and long COVID–related risk factors has not been examined in a unified manner. Building on our prior global study [23], this updated systematic review and meta-analysis examines global prevalence of long COVID, the prevalence of 8 subtypes and 41 symptoms, and the 11 most common risk factors.

METHODS

Search Strategy

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [24] framework (Supplementary Table 1). Three literature databases (PubMed, Embase, and Web of Science Core Collection) were searched on 29 May 2024, with a second and supplementary search conducted on 23 July 2024. The full search strategy is presented in Supplementary Methods 1.

Screening Procedure

Two screeners independently conducted title/abstract and full-text screenings, resolving conflicts through reexamination. Our inclusion criteria are as follows: human study population with confirmed COVID-19 diagnosis through polymerase chain reaction test, antibody test, or a clinical diagnosis; outcome including long COVID prevalence, risk factors, subtypes, or symptoms; and follow-up time of at least 2 months after the appropriate index diagnosis date. We defined long COVID as the presence of at least 1 new or persistent symptom at the follow-up time of at least 2 months. Detailed inclusion and exclusion criteria are listed in Supplementary Methods 1.

Data Extraction, Outcome, and Measures

We manually extracted data from eligible studies, including study design, sample size, and outcome of interest (full list in Supplementary Table 2). The primary endpoint was long COVID prevalence, including 8 subtypes and 41 symptoms (initial list in Supplementary Tables 3 and 4). Secondary endpoints were odds/risk ratios of 11 long COVID–related risk factors.

Statistical Analysis

We used a random-effects model with inverse variance weighting to meta-analyze the prevalence of long COVID, its subtypes, and symptoms. The between-study variance was estimated by the DerSimonian-Laird estimator (Supplementary Methods 2). For studies reporting overall long COVID prevalence, we applied a minimum sample size threshold to ensure a margin of error of $\pm 5\%$ or less, calculated by assuming an expected prevalence of 30% based on our previous meta-analysis [23]. Details of sample size calculation with specified margin of errors for each subtype and symptom are reported in Supplementary Methods 3. We did not report subtypes or symptoms with <3 eligible studies. Heterogeneity between studies was assessed by the I^2 statistic, with I^2 between 75% and 100% indicating considerable heterogeneity.

Although long COVID manifestations can occur across multiple organ systems, we calculated subtype- and symptom-specific prevalences independently. For each subtype, individuals who reported at least 1 symptom within that subtype at least 2 months after infection were included in the numerator. The denominator for all estimates was the total number of individuals with confirmed COVID-19 diagnosis. Consequently, a single individual could contribute to several subtype and symptom prevalence estimates.

The risk of bias analysis was conducted following a checklist-based tool for prevalence studies from the Joanna Briggs Institute [25], and publication bias was evaluated by funnel plot for asymmetry and Egger’s and Begg’s test of association (Supplementary Figure 1). Analysis was conducted in R software (version 4.3.2) using packages *meta* [26, 27] and *metafor* [28].

RESULTS

Search Results

Our initial literature search in May 2024 identified 8515 unique publications for title/abstract screening, followed by full-text screening for 1414 eligible studies. A total of 429 studies were included in the meta-analysis after initial and supplementary searches. The PRISMA flow diagrams for these searches are presented in Supplementary Figures 2 and 3. Details for the 13 studies included in the systematic review but excluded from the meta-analysis due to overlap are reported in Supplementary Methods 2 and Supplementary Results 1.

Study Characteristics

The studies covered 6 continents: Africa (9 studies), Asia (126 studies), Europe (195 studies), North America (61 studies), Oceania (3 studies), and South America (31 studies). Additionally, 4 studies included populations from multiple continents. We present the global distribution of studies from our previous 2021 meta-analysis [23] in Figure 1A and the current study pool in Figure 1B. Comparison of the panels showed

an increase in the number of studies across the world from 2021 to 2024, with still limited information from Africa and Oceania. The specific countries and their study numbers covered among the 429 studies included in our meta-analysis are reported in [Supplementary Table 5](#). This meta-analysis included data from >2 million individuals with confirmed COVID-19 diagnosis. Details of the included studies are summarized in [Supplementary Table 2](#).

Pooled Prevalence of Long COVID

As illustrated in [Figure 2](#), we conducted a meta-analysis of 144 studies that reported an overall prevalence of long COVID. The pooled global prevalence of long COVID was estimated to be 36% (95% confidence interval [CI], 33%–40%) in individuals with confirmed COVID-19 diagnosis. Studies varied substantially ($I^2 = 100\%$, $P < .001$), possibly due to heterogeneity in definition of long COVID, study designs and populations, evolution of SARS-CoV-2 and its variants from Alpha to Omicron subvariants, and testing and prevention/treatment strategies over a wide time span from 2021 to 2024.

When observing the stratified meta-analyses on publication year ([Supplementary Figure 4](#)), the estimated pooled global prevalence of long COVID was 38% (95% CI, 28%–50%), ranging from 10% to 62% for publications in 2021; 37% (95% CI, 26%–49%), ranging from 1% to 92% for publications in 2022; and 37% (95% CI, 30%–45%), ranging from 6% to 87% for publications in 2023. The prevalence reduced marginally to 34% (95% CI, 29%–41%), ranging from 3% to 80% for publications in 2024.

Prevalence of Long COVID by Hospitalization Status, Geographic Regions, Follow-up Time, Biological Sex, and Age

When stratified by hospitalization status, the estimated pooled prevalence of long COVID for studies including a mix of hospitalized and nonhospitalized patients was 35% (95% CI, 31%–40%). Studies with only hospitalized patients showed a higher pooled prevalence of 44% (95% CI, 38%–51%), while studies with only nonhospitalized patients showed a lower pooled prevalence of 29% (95% CI, 14%–50%). The estimated prevalence varied widely in all 3 groups: 1%–89% in the mixed group, 17%–92% in the hospitalized group, and 3%–56% in the nonhospitalized group ([Supplementary Figure 5](#)).

When stratifying studies by continent, South America had a higher estimated pooled prevalence of 51% (95% CI, 35%–66%), while Asia and Europe had estimates of 35% (95% CI, 25%–46%) and 39% (95% CI, 31%–48%), respectively. Note that there were <5 studies from Africa included in the analysis, so the estimate of 53% (95% CI, 38%–67%) for Africa should be interpreted with caution. Among studies from North America, the estimated pooled prevalence was 30% (95% CI, 24%–38%). Furthermore, a meta-analysis of 19 studies conducted only in the US showed an estimate of 29% (95% CI, 21%–37%).

When stratifying the studies by follow-up time, we categorized the time from index date as follows: <1 year, 1–2 years, or >2 years. The estimated pooled prevalence was 35% (95% CI, 31%–39%) at <1 year of follow-up, 46% (95% CI, 37%–57%) at 1–2 years of follow-up, and 43% (95% CI, 24%–64%) at >2 years of follow-up. When the follow-up duration was further stratified by hospitalization status, there were no statistically significant differences noted over follow-up time ([Supplementary Figure 6](#)).

Based on 7 studies that reported prevalence stratified by biological sex, the estimated pooled prevalence was higher in the female group (45% [95% CI, 33%–58%]) than in the male group (37% [95% CI, 27%–48%]). Categorizing the study population by age, the estimated pooled prevalence was 35% (95% CI, 31%–40%) in adults >18 years old, 23% (95% CI, 14%–34%) in nonadults, and 41% (95% CI, 32%–50%) in studies including any age group.

Prevalence of Specific Long COVID Subtypes and Symptoms

We assessed prevalence of 8 subtypes of long COVID among individuals with confirmed COVID-19 diagnosis based on the reported measures from 429 studies and stratified each study into <1 year or at least 1 year of follow-up time (1 to >2 years). As shown in [Table 1](#), the 5 most prevalent subtypes by estimated pooled subtype prevalence were respiratory at 20% (95% CI, 14%–28%) estimated from 31 studies, general fatigue at 20% (95% CI, 18%–23%) estimated from 119 studies, psychological at 18% (95% CI, 11%–28%) estimated from 10 studies, neurological at 16% (95% CI, 8%–30%) estimated from 23 studies, and dermatological at 12% (95% CI, 8%–17%) estimated from 10 studies.

Furthermore, we summarized 41 symptoms of long COVID pooled from our studies and analysis, listed within each subtype in [Table 1](#). The most common symptoms, based on estimated prevalence among individuals with confirmed COVID-19 diagnosis, were memory problems with an estimated prevalence of 11% (95% CI, 7%–19%) meta-analyzed by 12 studies, followed by muscle weakness of 11% (95% CI, 5%–23%) by 5 studies, breathlessness or discomfort in breathing of 8% (95% CI, 3%–22%) by 4 studies, dyspnea or observable breathing difficulties of 7% (95% CI, 6%–10%) by 31 studies, joint pain of 7% (95% CI, 4%–11%) by 14 studies, and cough of 6% (95% CI, 4%–8%) by 44 studies. Variations in subtype- and symptom-specific prevalences across studies are shown in the forest plots ([Supplementary Figure 7](#)) and further detailed in [Supplementary Results 2](#). We note that subtype and symptom prevalence estimates should be interpreted with caution, as individuals may have experienced multiple subtypes and symptoms simultaneously. These estimates are not mutually exclusive and should not be summed to derive an overall prevalence.

Risk of Bias and Sensitivity Analysis for 442 Included Papers

The risk of bias among 442 studies was assessed, with a lower score out of 9 representing a higher risk of bias in the study

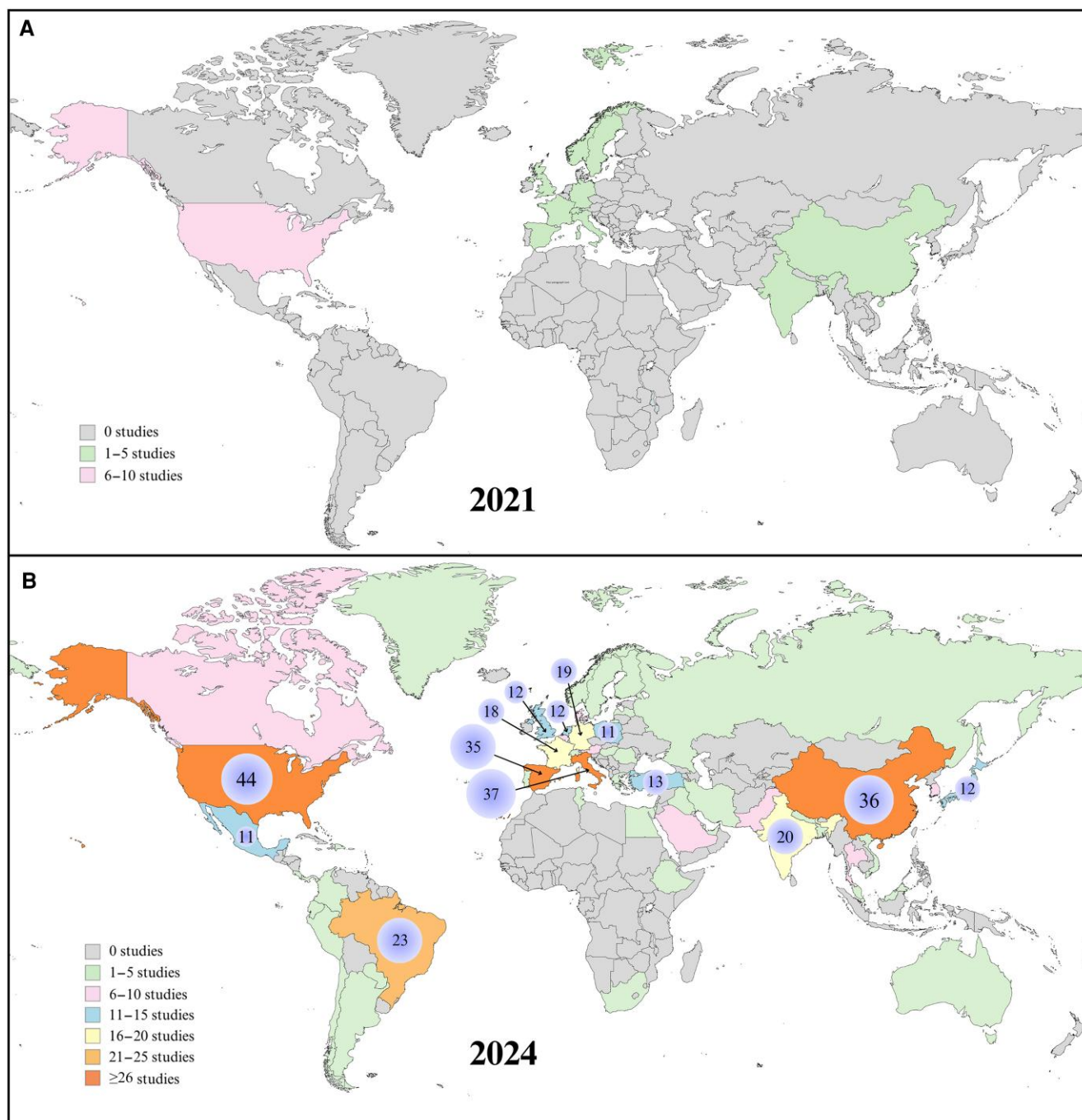


Figure 1. A, Global coverage among the 33 studies included in the meta-analysis by Chen et al [23]. B, Global coverage among the 429 studies included in the current meta-analysis. Countries with >10 studies are marked with circles indicating the exact number of studies. The lack of studies in the gray areas shows the lack of representation in global datasets and the information gap. The change from A to B shows that except for Africa and Oceania, considerable literature has emerged in the past 3 years in other parts of the world.

[25]. Within these studies, 4.1% (18 studies) scored a 4/9, and 13.8% (61 studies) scored a 5/9. We conducted a sensitivity analysis by removing these 79 studies with a higher risk of bias. The pooled global long COVID prevalence was estimated to be 35% (95% CI, 32%–39%) using 127 studies, and the estimated pooled subtype and symptom prevalence remained

consistent. Detailed results from this sensitivity analysis are provided in [Supplementary Figure 8](#) and [Supplementary Table 6](#). Reports on the risk of bias are provided in [Supplementary Methods 4](#).

Outcome	Pooled Prevalence [95% CI]; (# of studies)
Long COVID	
Overall long COVID	36 [33–40]%; (144)
Hospitalization Status	
Hospitalized and nonhospitalized mix	35 [31–40]%; (104)
Hospitalized	44 [38–51]%; (27)
Nonhospitalized	29 [14–50]%; (13)
Geographical Region	
Africa	53 [38–67]%; (3)
Asia	35 [25–46]%; (45)
Europe	39 [31–48]%; (59)
North America	30 [24–38]%; (24)
United States	29 [21–37]%; (19)
South America	51 [35–66]%; (10)
Oceania	18 [18–19]%; (1)
Multiregional	10 [4–24]%; (2)
Follow-up Time	
<1 year	35 [31–39]%; (122)
1–2 years	46 [37–57]%; (18)
>2 years	43 [24–64]%; (4)
Biological Sex	
Female	45 [33–58]%; (7)
Male	37 [27–48]%; (7)
Age Group	
Adults	35 [31–40]%; (87)
Nonadults	23 [14–34]%; (8)
Adults and nonadults mix	41 [32–50]%; (49)

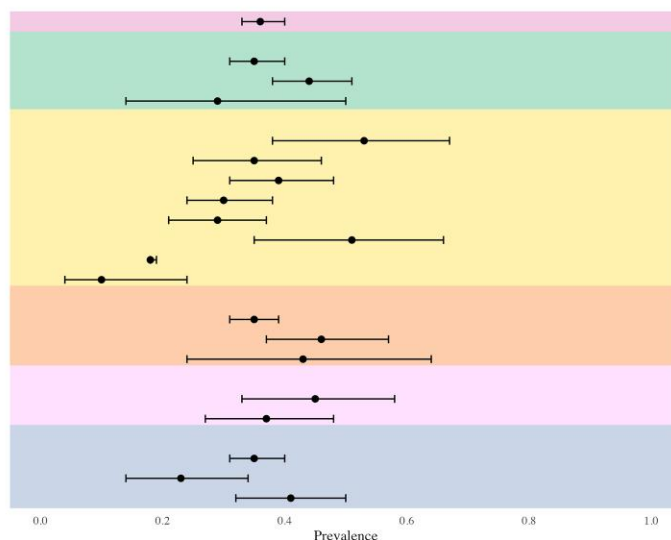


Figure 2. Forest plot for pooled long COVID prevalence, corresponding 95% confidence intervals (CIs), and number of contributing studies stratified by hospitalization status, geographical region, follow-up time, biological sex, and age group.

Meta-analysis of Association Parameters Corresponding to Risk Factors for Long COVID

After our review of studies reporting risk factors, we identified 11 risk factors that were reported in at least 5 studies (Figure 3). Those who were unvaccinated for COVID-19 have significantly higher odds of having long COVID compared to those with any vaccination with pooled estimated odds ratios (ORs) of 2.09 (95% CI, 1.55–2.81) from 7 studies. Those who were infected with any pre-Omicron variants of SARS-CoV-2, including either Alpha or Delta variants or both, have higher odds of having long COVID compared to those infected with the Omicron variant with a pooled estimated OR of 1.74 (95% CI, 1.40–2.17) based on 6 studies. Those with at least 1 comorbidity, those with preexisting cardiovascular disease, and those with preexisting hypertension have higher odds of having long COVID with pooled estimated ORs of 1.52 (95% CI, 1.27–1.82) from 17 studies, 1.50 (95% CI, 1.24–1.81) from 5 studies, and 1.37 (95% CI, 1.08–1.74) from 9 studies, respectively (Supplementary Figure 9). Different studies considered different comorbidities, listed in Supplementary Results 3. In addition, females and those who had intensive care unit admission had higher odds of having long COVID, with pooled estimated ORs of 1.56 (95% CI, 1.32–1.84) from 33 studies and 1.43 (95% CI, 1.02–2.02) from 8 studies. We did not consider reinfections or different strains of SARS-CoV-2 as a risk factor due to the limited number of studies available for meta-analysis as described in Supplementary Results 4.

DISCUSSION

We synthesized information from 442 studies, with 429 contributing to the meta-analysis. Our findings suggest a global long COVID prevalence of approximately 36% among individuals with confirmed COVID-19 diagnosis, with large heterogeneity across studies. Thus, as a precaution, these results should be compared with national benchmark estimates when available. We estimated the prevalence of long COVID at 29% (95% CI, 21%–37%) among individuals with confirmed COVID-19 diagnosis in the US. Our result is strikingly similar to the report by the Household Pulse Survey conducted by the US Census Bureau, in which the most proximal survey in phase 4.2 (20 August to 16 September 2024) estimated 29.8% (95% CI, 28.7%–30.8%) among adults who had ever experienced COVID-19 symptoms lasting ≥ 3 months [13].

We caution that our pooled prevalence estimates represent the percentage of individuals who *ever* experienced long COVID symptoms during study follow-up, rather than those who are *currently* experiencing symptoms at a specific point in time, among those with a history of COVID-19. Therefore, our pooled estimates may overstate the clinical burden of long COVID. For comparison, the same Household Pulse Survey mentioned in the previous paragraph reported that 8.7% (95% CI, 8.1%–9.3%) of US adults who have ever had COVID-19 currently experience long COVID symptoms. However, only 24.3% of adults who currently experience long COVID symptoms in phase 4.2 reported significant activity limitations, indicating that for most, the clinical burden of long COVID does not interfere with daily activities [13].

Table 1. Pooled Inverse Variance–Weighted Estimate of the Prevalence of Long COVID Subtypes and Symptoms Among Individuals With Confirmed COVID-19 Diagnosis, With Corresponding 95% Confidence Intervals Obtained by Random-Effects Meta-analysis

Subtype/Symptom	Pooled Estimate, % (95% CI)	No. of Studies
Neurological	16 (8–30)	23
<1 y	13 (5–27)	16
1 to >2 y	27 (15–44)	7
Concentration/confusion/brain fog	4 (3–6)	27
Headache	6 (5–7)	56
Malaise	8 (3–20)	5
Memory problems	11 (7–19)	12
Sleep problems	7 (5–10)	16
Loss of/change in smell	5 (4–7)	43
Loss of/change in smell or taste	4 (1–12)	7
Loss of/change in taste	4 (3–7)	30
Tinnitus	1 (1–2)	17
Tremors/chills	2 (1–3)	11
Vision problems	2 (1–3)	12
Cardiovascular	10 (4–25)	16
<1 y	8 (2–22)	11
1 to >2 y	20 (11–33)	5
Arrhythmia	2 (0–17)	3
Hypertension	2 (1–5)	5
Palpitations	3 (2–5)	31
Tachycardia	4 (2–7)	9
Musculoskeletal	9 (5–16)	13
<1 y	8 (5–14)	12
1 to >2 y	30 (29–32)	1
Joint pain	7 (4–11)	14
Muscle weakness	11 (5–23)	5
Myalgia	5 (4–7)	24
Gastrointestinal	5 (5–7)	34
<1 y	6 (5–7)	28
1 to >2 y	4 (1–10)	6
Abdominal pain	1 (1–2)	14
Constipation	1 (0–3)	5
Diarrhea	1 (1–3)	15
Stomach pain	2 (1–4)	3
Psychological	18 (11–28)	10
<1 y	10 (5–20)	5
1 to >2 y	29 (14–51)	5
Anxiety	6 (4–9)	26
Depression	8 (5–13)	17
Insomnia	6 (4–9)	29
Mood swings	7 (3–16)	6
PTSD symptoms	14 (2–52)	6
Respiratory	20 (14–28)	31
<1 y	20 (14–29)	25
1 to >2 y	19 (14–26)	6
Breathlessness	8 (3–22)	4
Chest pain	4 (3–6)	46
Chest tightness	2 (1–3)	7
Cough	6 (4–8)	44
Dyspnea	7 (6–10)	31
Nasal congestion	2 (1–4)	9
Dermatological	12 (8–17)	10
<1 y	11 (7–19)	7
1 to >2 y	12 (5–24)	3

Table 1. Continued

Subtype/Symptom	Pooled Estimate, % (95% CI)	No. of Studies
Hair loss	5 (3–8)	26
Skin rash	2 (1–3)	19
General fatigue	20 (18–23)	119
<1 y	19 (16–22)	93
1 to >2 y	26 (20–33)	26
Constant, severe, or unusual fatigue	7 (2–26)	3
Miscellaneous symptoms		
Dizziness	3 (2–4)	37
Fever	2 (1–3)	39
Loss of appetite	2 (2–3)	29
Sore throat	4 (2–6)	25
Sweats	2 (1–5)	10

Abbreviations: CI, confidence interval; PTSD, posttraumatic stress disorder.

The prevalence of long COVID remained consistent across time since diagnosis, with 35% (95% CI, 31%–39%) at <1 year of follow-up and 46% (95% CI, 37%–57%) at 1–2 years, suggesting a sustained burden of symptoms over longer follow-up durations. This difference could also be due to delays in getting diagnosed. Thus, longer follow-up time (≥ 1 year) may artificially yield a higher prevalence of long COVID compared to shorter follow-up time (<1 year of follow-up) due to delayed diagnosis. Additionally, differences in the populations sampled across follow-up durations—often associated with the severity of initial SARS-CoV-2 infection—likely contributed to the observed pattern of long COVID prevalence over time since individuals with more severe infection were more likely to be hospitalized and thus were more likely to be included in studies with longer follow-up. In [Supplementary Figure 5](#), we observed that among the 122 studies with <1 year of follow-up, 13% of the studies had hospitalized-only cohorts. By contrast, among the 18 studies with 1–2 years of follow-up, 44% of the studies had hospitalized-only cohorts. For the 4 studies with >2 years of follow-up (43% [95% CI, 24%–64%]), 75% of the studies had hospitalized-only cohorts. In general, studies suggest that individual burdens of long COVID symptoms abate over time [29–32]. However, the consistent presence of long COVID symptoms at extended follow-up also suggests a sustained burden for hospitalized individuals [33, 34]. Consequently, it is difficult to discern the effects from the severity of COVID-19 and follow-up time on prevalence outcome.

A unique strength of the current study is its evaluation of the prevalence of 8 subtypes and 41 symptoms associated with long COVID. Among these, neurological symptoms emerge as a detrimental long-term problem for individuals with a history of COVID-19 [35], which is uncommonly seen in common respiratory viral infection such as seasonal influenza [36, 37] and the common cold [37]. Analyses conducted by Hauptert et al [38] identified multiple symptoms specific to COVID-19, such as

Risk Factors	Pooled Odds Ratio [95% CI]; (# of studies)
Age, per 5-year increase	1.06 [.99–1.14]; (14)
Obesity	1.28 [.99–1.66]; (6)
History of COPD	1.37 [1.03–1.82]; (6)
Hypertension	1.37 [1.08–1.74]; (9)
Intensive care unit admission	1.43 [1.02–2.02]; (8)
Cardiovascular disease	1.50 [1.24–1.81]; (5)
At least 1 comorbidity	1.52 [1.27–1.82]; (17)
Female sex	1.56 [1.32–1.84]; (33)
Infected with any pre-Omicron variants of SARS-CoV-2	1.74 [1.40–2.17]; (6)
Diabetes	1.77 [.78–4.01]; (12)
Unvaccinated for COVID-19	2.09 [1.55–2.81]; (7)

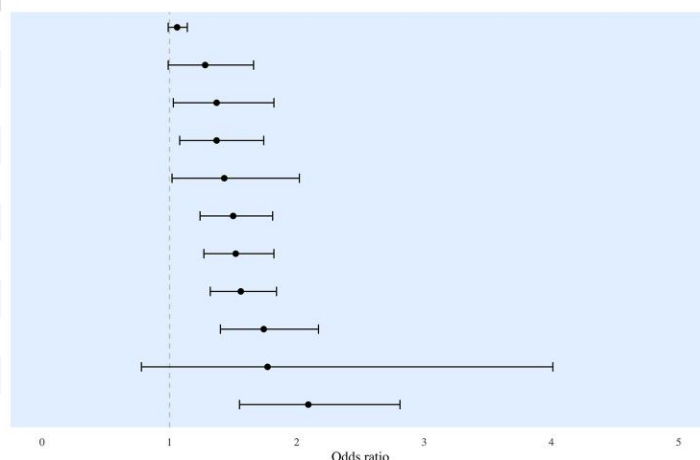


Figure 3. Forest plot for pooled odds ratio estimates for long COVID associated with 11 risk factors with corresponding 95% confidence intervals and the number of contributing studies. Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disease; COVID-19, coronavirus disease 2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

depression and sleep apnea, whereas ischemic heart disease was the only significant post-flu manifestation. The neurological subtype has an estimated pooled prevalence of 16% among confirmed COVID-19 cases, closely following the respiratory subtype (20%). The prevalence of specific symptoms within the neurological subtypes, such as memory problems (11%) and brain fog (4%), highlight the cognitive impact of long COVID among the global COVID-19 population. These findings highlight the need for heightened attention to neurological complications within long COVID care and research.

Our evaluation of effect sizes for 11 risk factors indicates that vaccination status is the strongest risk factor: Unvaccinated COVID-19 individuals face significantly higher odds of developing long COVID than those who received any vaccination. Some studies have reported subtype-specific risk factors and categorized version of age as additional long COVID-related risk factors, which is discussed in [Supplementary Results 5](#).

While considering the risk factor as “infected with any pre-Omicron variants of SARS-CoV-2,” the definition of the pre-Omicron and Omicron periods varied across our included studies. Thi Khanh et al [39] and Morello et al [40] assigned participants the variant that was dominant at the time of infection, whereas Babicki et al [41] treated all infections from January 2020 to December 2021 as the pre-Omicron period. Hernández-Aceituno et al [42] defined the periods as congruent with the COVID-19 pandemic waves of Alpha (from 17 January to 18 July 2021), Delta (from 4 July 2021 to 9 January 2022), and Omicron (from 15 December 2021 to 24 May 2022). Because year is also a proxy for vaccine rollout, as most adults were vaccinated by 2022, variant effects on long COVID can be confounded by vaccination status. It would be more appropriate to study the effect of variants stratified by

vaccination status. For instance, Maier et al [43] found that vaccinated individuals infected with Omicron had a lower risk of any long COVID symptom at 90 days. However, Gottlieb et al [44] reported that severe fatigue and at least 3 long COVID symptoms were no longer significant across variants after adjusting for vaccination.

Although we reported pooled prevalence with relatively narrow 95% CIs, additional between-study heterogeneity estimates and 95% predictive intervals are reported in [Supplementary Tables 7 and 8](#). Smaller between-study heterogeneity estimates and narrower prediction intervals in [Supplementary Table 9](#) suggest less variability in ORs (except the risk factor of diabetes) compared to prevalence estimates.

Our study builds on the growing body of research on the prevalence of and risk factors associated with long COVID, aligning with recent findings by Al-Aly et al [45], emphasizing the substantial and lasting impact of long COVID on public health policy. By evaluating its various subtypes and symptoms, we provide quantitative insights into the diverse manifestations of long COVID in the global population. Our results highlight the need for long COVID subtype- and symptom-specific research. Furthermore, these findings support the call for improvement in data inequities and standardization of well-developed studies within the global medical community as evidenced by the paucity of studies from Africa and Oceania and the substantial heterogeneity between studies.

Limitations

Potential limitations in our search strategy and inclusion/exclusion criteria are summarized in [Supplementary Methods 5](#). Although we aimed to capture a broad spectrum of long COVID subtypes and symptoms, some may have been missed.

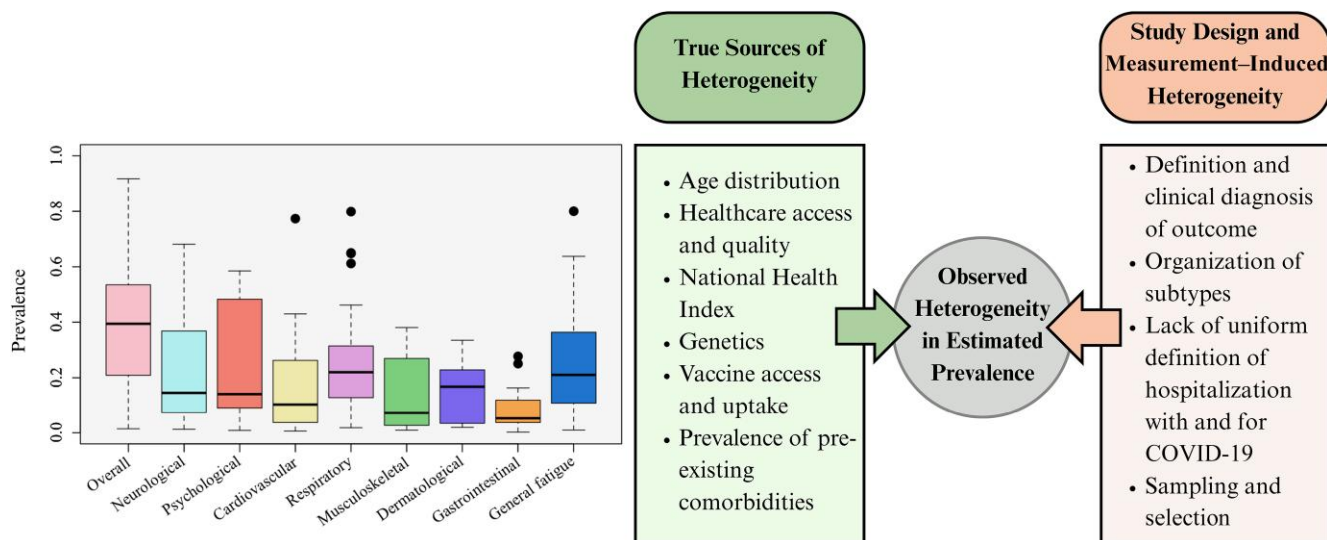


Figure 4. Examination of heterogeneity by boxplot of overall long COVID prevalence and neurological, psychological, cardiovascular, respiratory, musculoskeletal, dermatological, gastrointestinal, and general fatigue subtype prevalence. Potential sources of true etiological heterogeneity versus study-induced heterogeneity are listed. Abbreviation: COVID-19, coronavirus disease 2019.

The selection of symptoms reflects both what was reported in the included studies and our methodological criteria, including sample size thresholds to ensure a minimum margin of error and the requirement that each subtype or symptom must be reported by at least 3 studies. These steps reduced the number of subtypes and symptoms ultimately included in the analysis. Another major limitation is not including downstream long COVID outcomes, such as quality of life [46–50], functional status [51], mortality, and survival, which have been documented in the literature and summarized in [Supplementary Table 10](#). Although these outcomes were not the focus of our meta-analysis, they are crucial for understanding the full spectrum of long COVID and warrant further investigation, with additional discussion in [Supplementary Results 6](#).

The proportions of estimated subtype and symptom prevalence attributable specifically to SARS-CoV-2 infection may differ between symptoms. While some symptoms, such as memory problems and loss of taste or smell, are more COVID-19-specific, other symptoms such as fatigue and psychological symptoms are common in the general population and may be associated with preexisting health conditions. The general symptom categories used in many studies limit the ability to draw COVID-19-specific clinical inferences for such chronic conditions, and it is hard to attribute them specifically to COVID-19. In fact, using a case-crossover study design comparing pre- and post-COVID-19 phenomes with pre- and post-flu phenomes, a study by our team found similar occurrences of fatigue and anxiety in a post-flu period [38]. The term “phenome” refers to the omnibus set of disease conditions present in health records. Future analyses would benefit from stratifying symptoms by severity score using validated

instruments such as the Fatigue Assessment Scale (FAS) [52, 53] and the Functional Assessment of Chronic Illness Therapy (FACIT) Fatigue Score [54] to better interpret the health implications of persistent symptoms. In our analysis, when we stratify the prevalence estimates for fatigue by pooling the 3 studies that considered constant/severe/unusual fatigue, we note that the prevalence estimate changed from 20% (95% CI, 18%–23%) to 7% (95% CI, 2%–26%). Variations of estimates across studies for general fatigue and constant/severe/unusual fatigue are shown in the forest plots ([Supplementary Figure 7](#)).

Furthermore, measured and unmeasured confounders, such as preexisting conditions and access to testing, and variation in the definition of long COVID phenotype across studies, may have influenced prevalence differences between studies and subgroups within studies. Hospitalized individuals were more likely to receive follow-up referrals for long COVID symptoms, whereas nonhospitalized individuals were more likely to self-assess their health status through follow-up surveys, leading to a diagnosis bias. Underresourced communities may also be missed due to limited accessibility of testing and referrals. Future research should investigate how healthcare access and socioeconomic determinants contribute to differences in long COVID prevalence.

One major observation from this meta-analysis is variation in estimates. To visualize the considerable amount of heterogeneity across the prevalence estimates, we created boxplots for overall and subtype prevalence estimates in [Figure 4](#). There are several potential sources of this heterogeneity. Some of these were induced by study design and varying definitions of outcomes. Vast variation in how people were labeled as those with long COVID, given the absence of any diagnostic

biomarkers, contributes to between-study heterogeneity and uncertainties in our prevalence estimates (Supplementary Results 7). Within the hospitalized COVID-19 population, the definition of hospitalization was not consistent, with further discussion in Supplementary Results 8. True population heterogeneity due to differences in age structure, healthcare infrastructure, access to vaccines, and biological and genetic differences may also exist, but currently we do not have the tools to distinguish between the 2 sources.

Since long COVID subtypes are not yet standardized, differences between subtype definitions across studies contribute to heterogeneity in estimating subtype prevalence. In this meta-analysis, we grouped symptoms into 8 subtypes based on the primary anatomical or physical system involved (eg, neurological, respiratory, cardiovascular). The mapping of individual symptoms to these domains is described in Supplementary Methods 1A and Supplementary Table 3, and the common subtype- or domain-specific labels found in studies are reported in Supplementary Table 11. The Researching COVID to Enhance Recovery (RECOVER-Adult) study [55] updated its subtype classification in 2024, in which 5 symptom subtypes were defined by prominent symptoms: change in smell or taste (subtype 1), chronic cough (subtype 2), brain fog (subtype 3), palpitations (subtype 4), and postexertional soreness, dizziness, and gastrointestinal symptoms (subtype 5). Several symptoms such as fatigue and postexertional malaise span across each subtype. We retained physiology-based subtype grouping instead of adopting distinct clinical phenotypes of long COVID. Within our subtypes, some individual symptoms can be shared between different subtypes (eg, chest pain can be placed under either cardiovascular subtype or respiratory subtype), depending on the clinical question under study.

Finally, with such heterogeneity in estimates across and within geography, one could argue that pooling such a large number of studies across the world is meaningless. We also observe considerable heterogeneity (I^2 statistics between 99% and 100%) across geographical regions. A lack of consensus definition and standardization of long COVID symptoms implies that populations and outcomes are heterogeneous across prevalence studies, and possibly within studies, making meaningful evidence synthesis challenging. While we recognize the challenges of a common effect meta-analysis model in the face of such wide between-study variability [56], the inverse variance-weighted pooled estimate across the globe provides a precision weighted average of available estimates and displays the variation through the forest plots (Supplementary Figures 5 and 7). Despite these limitations, the agreement of the pooled US estimate with a nationally representative estimate from the Household Pulse Survey, the consistency of the prevalence estimates over the years, and the robustness of estimate when studies with a high risk of bias were eliminated gives us some confidence in the legitimacy of the pooled estimates and the analysis.

CONCLUSIONS

This systematic review and meta-analysis provide a comprehensive overview of empirical estimates of the prevalence of long COVID, its subtypes and symptoms, and associated risk factors after a confirmed COVID-19 diagnosis. Importantly, the identification of long COVID subtypes and symptoms is shaped by symptom selection of the included studies and our methodology and analysis. Our findings reveal significant regional variation and heterogeneity in prevalence estimates, emphasizing the need for representative samples and well-designed data collection to reduce heterogeneity within and across geographies and produce more precise estimates of long COVID prevalence. The study also emphasizes global data inequity, with underrepresentation of data from certain parts of the world. Finally, the persistence of long COVID symptoms across varying follow-up durations highlights the long-term burden of these conditions and the need to better understand long COVID physiology, identify diagnostic biomarkers, develop effective treatments, and address its impacts on healthcare systems and workforce participation.

Supplementary Data

Supplementary materials are available at [Open Forum Infectious Diseases](https://academic.oup.com/ofid/article/12/9/ofaf533/8244677) online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Author contributions. Conceptualization and methodology: B. M. Investigation: Y. H. (Screener 1), Z. N. (Screener 2), and B. M. Supervision: B. M. and T. G. Writing—original draft: Y. H., T. G., Z. N., and B. M. Writing—review & editing: Y. H., T. G., X. S., M. L. R., and B. M. The authors take full responsibility for the integrity of the data and the accuracy of the analysis. All authors had access to the data used in this study and have reviewed and approved the final manuscript.

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Data availability. Data used in this meta-analysis were derived from previously published studies, which are publicly available through databases such as PubMed, Embase, and Web of Science. No new or proprietary data were generated or collected in this study. A summary of the papers used can be found in the Supplementary Material.

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