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The Evolution of Long COVID Research, 2020 to 2025: A Bibliometric Analysis with Implications for Clinical Practice and Policy

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Abstract

Introduction/Background: Since the pandemic started, studies on long COVID have expanded significantly. This bibliometric analysis maps the field's evolution from January 2020 to March 2025, providing a macro-level understanding of research trends and informing clinical practice and health policy. **Methods:** We performed a systematic bibliometric review of 9729 publications indexed in the Scopus database. Utilising VOSviewer (version 1.6.20) and Biblioshiny (Bibliometrix R package, version 4.1), we analysed annual growth rates, country and institutional contributions, co-authorship networks, and thematic clusters. The study followed RIBA and GLOBAL reporting guidelines to ensure methodological transparency and clinical relevance. **Results:** We found 7867 articles and 1862 reviews, with an average document age of 2.13 years and 19.2 citations per document. Scientific output increased at an annual rate of 19.81%, reaching a definitive production peak in 2024, with 64,027 authors, 10.3 co-authors per document, and 24.97% international co-authorship. The United States, China, and the United Kingdom were the most significant contributors, with the University of California and Oxford University emerging as primary research hubs. Thematic mapping revealed 23,803 keywords plus and 13,991 author keywords. Key research gaps included limited interventional evidence, which represented less than 2% of the corpus; sparse paediatric-related research accounting for only 4.2%; and persistent geographic imbalance, particularly the underrepresentation of low- and middle-income countries. **Conclusions:** The long COVID research landscape is dynamic and collaborative but exhibits geographic and topical imbalances. To improve patient outcomes, stakeholders should pivot from observational mapping toward interventional trials. Priorities should include fostering inclusive international collaborations, addressing the paediatric research gap, and evaluating integrated service delivery models to manage this complex, multisystemic condition.

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1. Introduction

Long COVID has evolved from grassroots patient observations into a defining global health crisis of the 21st century. Formally termed post-acute sequelae of SARS-CoV-2 infection (PASC), this term describes symptoms that persist or emerge three months after the initial infection [1]. In June 2024, the National Academies of Sciences, Engineering, and Medicine (NASEM) solidified its status by defining it as an infection-associated chronic condition that affects multiple organ systems over a relapsing or continuous trajectory [1]. The scale of this condition is significant; current meta-analyses estimate a pooled global prevalence of 36%, with rates reaching 51% in South America [2]. This prevalence suggests that long COVID is not a transient post-viral state but a persistent clinical challenge.

The resultant morbidity exerts documented pressure on healthcare infrastructure and global labour markets [3,4]. Research indicates that long COVID contributes to significant workforce attrition and increased disability claims, extending the pandemic's economic impact well beyond the acute viral phase [4,5]. For healthcare systems, the condition necessitates specialised, multidisciplinary clinics and long-term management strategies for which many systems were unprepared [6]. As these socio-economic costs mount, the scientific community has responded with an unprecedented volume of research across immunology, neurology, and rehabilitation [3].

However, this rapid expansion has created a critical paradox: the sheer volume of data now hinders, rather than helps, the synthesis of actionable knowledge. As the field shifts from an acute emergency response to a period of long-term scientific consolidation, it has become increasingly fragmented. This fragmentation creates significant tension. While we have more data than ever before, it remains difficult for clinicians and policymakers to identify which research avenues are maturing and which remain critically underfunded. Essential questions regarding paediatric long COVID and the efficacy of specific interventions remain buried under a mountain of data noise [3]. Analysing this evolution is essential to distinguish between productive scientific growth and duplicative effort.

To resolve this tension, we analysed the field's intellectual structure. Bibliometric analysis provides the quantitative tools necessary to address this need. Unlike traditional reviews, bibliometric methods map the intellectual structure and historical trajectory of a research field by examining publication patterns, citation networks, and thematic clusters [7]. This approach allows us to visualise how different disciplines collaborate and to identify the influential hubs of knowledge that drive clinical practice. While general COVID-19 bibliometrics exist, this analysis focuses specifically on long COVID and explicitly links science mapping findings to implications for clinical practice, health policy, and future research prioritisation. Several bibliometric reviews have examined COVID-19 research broadly [8,9], yet few focus exclusively on the rapid evolution of long COVID. While earlier studies captured the field's initial emergence [9] and Honorato-Cia et al. utilised PubMed to map clinical output [8], our study provides a broader interdisciplinary perspective. By utilising the Scopus database, we capture essential literature from rehabilitation, social sciences, and psychology that is often omitted from PubMed-only searches. Furthermore, this study uniquely provides a quantitative gap analysis of paediatric and LMIC research during the field's transition into a consolidation phase.

This study evaluated the growth and trends of long COVID research from January 2020 to March 2025. We utilised data from the Scopus database, analysed through VOSviewer

and Biblioshiny, to answer four critical questions: How has publication volume shifted over time? Which authors and institutions lead the global discourse? What are the dominant thematic clusters? Finally, where are the thematic gaps in the literature that may indicate areas of clinical research that remain underexplored? By mapping this landscape, this study provides a roadmap for stakeholders to prioritise funding, foster international collaboration, and accelerate translation into integrated care models.

2. Methods

2.1. Study Design and Reporting Framework

This study utilised a systematic bibliometric design to map the global evolution of long COVID research. To ensure methodological rigour and reproducibility, the study adhered to the Reporting Items for Bibliometric Analysis (RIBA) and the Guidelines for Bibliometric Analysis (GLOBAL) [10,11]. These frameworks provide a structured approach to data collection, refinement, and visualisation in health-related bibliometrics. Additionally, the screening and selection process followed the PRISMA 2020 statement, with the full workflow documented in a data curation flow diagram.

2.2. Data Source and Search Strategy

Bibliographic data were retrieved from the Scopus database on 14 March 2025. Scopus was selected as the sole data source because it is recognised as a curated, high-quality database optimised for quantitative science studies, offering more consistent metadata for institutional and country-level mapping than alternative platforms [12,13]. The selection of Scopus as the singular data source was motivated by its comprehensive indexing of not only clinical medical literature but also the social science, rehabilitation, and psychology journals essential for capturing the multisystemic scope of long COVID. This approach ensures data integrity by avoiding the technical artefacts and potential deduplication errors often introduced when merging disparate bibliographic databases [12]. This approach is consistent with established bibliometric protocols that prioritise data integrity and interdisciplinary coverage [13,14]. The search was conducted using the TITLE-ABS-KEY (Title, Abstract, and Keywords) field to ensure a comprehensive capture of relevant literature. The search strategy utilised two primary blocks of terms combined with the AND operator: (i) a disease-specific block containing nomenclature variations such as "long COVID," "PASC," and "post-acute sequelae of SARS-CoV-2"; and (ii) a clinical/methodological block including terms such as "symptoms," "paediatrics," and "clinical trials." The full, verbatim advanced search query utilised in the Scopus interface is provided in Supplementary File S1 to ensure the full reproducibility of the analytical workflow. We restricted the search to original articles and reviews published in English between January 2020 and March 2025.

The search query included terms such as "long COVID", "post-COVID syndrome", "post-acute COVID-19", "chronic COVID", "long-haul COVID", and "PASC" (post-acute sequelae of SARS-CoV-2 infection). The search strings for this study were designed to capture the breadth of research on long COVID, including its various terminologies and manifestations. The search strategy employs Boolean operators (AND, OR) and truncation symbols (*) to ensure comprehensive coverage of the literature.

The search strings for the Scopus database were "("long COVID" OR "long-COVID" OR "long COVID-19" OR "long-haul COVID" OR "long-haul COVID-19" OR "post-COVID syndrome" OR "post-COVID-19 syndrome" OR "post-acute COVID" OR "post-acute COVID-19" OR "chronic COVID" OR "chronic COVID-19" OR "PASC" OR "post-acute sequelae of SARS-CoV-2" OR "post-COVID condition" OR "post-COVID-19 condition" OR "ongoing COVID" OR "living with COVID" OR "long-tail COVID") AND ("symptoms" OR "fatigue" OR "brain fog" OR "respiratory symptoms" OR "cardiovascular symptoms"

OR "neurological symptoms" OR "cognitive dysfunction" OR "mental health" OR "multi-system inflammation" OR "children" OR "adults" OR "elderly" OR "healthcare workers" OR "comorbidities" OR "immunocompromised" OR "vaccination" OR "reinfection" OR "clinical trials" OR "cohort studies" OR "longitudinal studies" OR "qualitative research" OR "systematic reviews" OR "meta-analysis" OR "bibliometric analysis")". The inclusion of diverse terminologies related to the disease ensures that the search captures the full scope of research on the topic. The search was limited to articles published between January 2020 and March 2025, providing coverage of the entire period since the emergence of the COVID-19 pandemic. Only articles and reviews in English were included, while editorials, letters, and non-scientific publications were excluded to maintain the quality and relevance of the dataset.

2.3. Eligibility Criteria and Data Extraction

The analysis included only original research articles and reviews published in English. Editorials, letters, notes, and conference papers were excluded to maintain the quality and peer-reviewed integrity of the dataset [15]. All identified records, including titles, abstracts, keywords, and citation counts, were exported in BibTeX and CSV formats for processing.

2.4. Data Cleaning and Refinement

Data refinement was performed to ensure the accuracy of the visualisations, a critical step mandated by the BIBLIO guidelines [7]. We utilised a conceptual grouping strategy via a manual thesaurus file (provided as Supplementary File S2) to facilitate term standardisation. This process was essential to address the nomenclatural evolution of the field, which transitioned rapidly from early patient-coined terms (e.g., "long-haul COVID," "long-tail COVID") to formal clinical designations (e.g., "PASC" and "post-COVID-19 condition"). By consolidating over 120 synonym variations into the representative node "long COVID," we ensured that the analysis reflected conceptual density rather than fragmented literal word counts. This methodological rationale was employed to prevent node dilution, a phenomenon where the intellectual weight of a single concept is artificially weakened by being split across multiple synonymous labels. Consequently, the resulting science maps provide a more robust representation of the field's actual thematic priorities. We also applied noise reduction to exclude over 50 non-informative terms. This ensured that the science maps reflected clinical and thematic concepts rather than database metadata. Additionally, we manually disambiguated author names to merge different spellings of the same researcher.

2.5. Bibliometric Analysis and Visualisation

The cleaned dataset was analysed using two specialised software tools: Biblioshiny (Bibliometrix R package, version 4.1) and VOSviewer (version 1.6.20). Biblioshiny was used to calculate descriptive statistics, including annual growth rates, most productive countries, and the most influential journals. VOSviewer was employed for science mapping and network visualisation. To ensure reproducibility, keyword co-occurrence analysis was restricted to terms with a minimum of 10 occurrences, ensuring that the resulting maps reflect established scientific themes rather than idiosyncratic observations [11,16]. Clusters were generated using the VOS clustering algorithm at a resolution of 1.0. This technique utilises a modularity-based optimisation to group nodes that exhibit higher-than-average link strengths, ensuring clinical and conceptual coherence across the identified research pillars [17,18]. To ensure a nuanced evaluation of the research landscape, the analysis distinguished between three primary dimensions of scholarly activity: (i) Productivity, defined as the total volume of documents published by a specific entity (country, institution, or author); (ii) Scientific Impact, measured through cumulative citation counts and average

citations per document; and (iii) Network Centrality, determined by the "total link strength" in VOSviewer, which quantifies the degree of influence and collaborative reach an entity maintains within the global research ecosystem [11,16].

To ensure methodological fairness, all network construction in VOSviewer utilised a "fractional counting" method. Unlike the full counting method, which attributes a weight of one to every contributor, fractional counting assigns a proportional weight to each author or institution based on the total number of contributors per document. For example, a publication with ten co-authors results in a weight of 0.1 being assigned to each contributor, ensuring the total weight of any single document remains 1.0. This approach was implemented across all co-authorship and institutional networks to prevent large-scale clinical trial consortia—which are highly prevalent in COVID-19 research—from disproportionately inflating the network centrality and productivity metrics of specific entities [11,16].

We performed network normalisation using the Association Strength method [17]. We set the clustering resolution to 1.0, following established defaults for science mapping. To ensure the robustness and stability of the identified thematic clusters, we performed a sensitivity analysis by testing alternative resolutions of 0.8 and 1.2. The baseline resolution of 1.0 was maintained for the final analysis, as it yielded the most stable and clinically coherent structures, successfully avoiding both the over-aggregation of distinct disciplines and the excessive fragmentation of core research pillars. Additionally, 10 random starts were utilised to confirm that the identified network layouts were reproducible and not an artefact of a single algorithmic iteration [17].

We selected specific technical parameters to maximise the stability and interpretability of the findings. For the keyword co-occurrence analysis, a minimum threshold of 10 occurrences was established. This setting follows the 'pruning rule' in bibliometrics, which eliminates idiosyncratic or low-frequency terms that introduce scientific noise, ensuring the resulting thematic map remains readable and relevant for a general medical audience.

3. Results

3.1. Descriptive Overview of the Research Corpus

The systematic search of the Scopus database yielded an initial total of 12,525 records. To ensure the scientific rigour of the analysis, we applied a stringent screening process to exclude non-peer-reviewed or informal document types. Consequently, 2796 records—comprising editorials, letters, notes, and conference papers—were removed from the dataset. The final analytical corpus consisted of 9729 documents. This refined dataset was composed of 7867 original research articles (80.9%) and 1862 review articles (19.1%), as summarised in Table 1. The data curation flow diagram in Supplementary Figure S1 illustrates the identification, screening, and inclusion workflow.

The average document age was 2.13 years, with an average of 19.2 citations per document, reflecting strong contemporary scholarly engagement. The authorship data revealed a highly collaborative landscape. A total of 64,027 authors contributed to the field, with only 325 documents being single-authored. The average number of co-authors per document was 10.3, and the international co-authorship rate was 24.97%. Keyword analysis identified 23,803 keywords plus (ID) and 13,991 author keywords (DE), indicating a broad thematic diversity.

Table 1. Overview of the long COVID research landscape from 2020 to March 2025.

Description	Results
Main information about data	
Timespan	2020:2025 (March)
Documents	9729
Annual growth rate %	19.81
Document average age	2.13
Average citations per doc	19.2
Document contents	
Keywords plus (ID)	23,803
Author's keywords (DE)	13,991
Authors	
Authors	64,027
Authors of single-authored docs	325
Authors collaboration	
Single-authored docs	359
Co-authors per doc	10.3
International co-authorships %	24.97
Document types	
Article	7867
Review	1862

DE: the frequency distribution of authors' keywords; ID: the frequency distribution of keywords associated with the manuscript by Scopus.

3.2. Publication Trends and Growth Trajectory

The research field exhibited a consistent upward trajectory with an annual growth rate of 19.81%. Publication volume rose sharply from 2020, reaching a peak in 2024 (Figure 1). Crucially, the 2025 data (n = 512) only encompasses the period through March 14, representing approximately 20% of the year's potential output. Consequently, the apparent plateau and subsequent decline observed in the final stage of Figure 1 represent a potential 'data artifact' of the partial year collection window rather than a definitive shift in scientific focus or a reduction in research interest. A coefficient of determination (R^2 = 0.86) confirmed a strong correlation between time and the increase in publication output over the five-year period. It is critical to note that the apparent plateau and subsequent decline observed in the final stage of Figure 1 represent a potential artefact of the data collection window rather than a definitive shift in scientific focus or a reduction in research interest. The 2025 data should not be used for annual comparative growth analysis.

3.3. Leadership in Global Discourse: Geographical Dominance, Authors, and Institutions

The United States was the most productive nation in the field, with approximately 4550 documents, followed by China, the United Kingdom, and Italy (Figure 2a). Its position at the centre of the collaboration network (Figure 2b) indicates that it also has the highest degree centrality, acting as the primary hub for global scientific impact.

Beyond individual country rankings, an analysis of productivity by economic status reveals a stark disparity in global knowledge production. High-income countries (HICs), based on World Bank 2024–2025 classifications, accounted for 78% of the total research output. In contrast, low-income countries (LICs) contributed less than 1% of the identified publications. The remaining output was distributed among middle-income countries, with prominent contributions from India and Turkey. This concentration of scientific activity in high-resource settings indicates that the current global research trajectory remains heavily weighted toward the clinical realities of the Global North, potentially leaving the unique health system constraints of the Global South unaddressed.

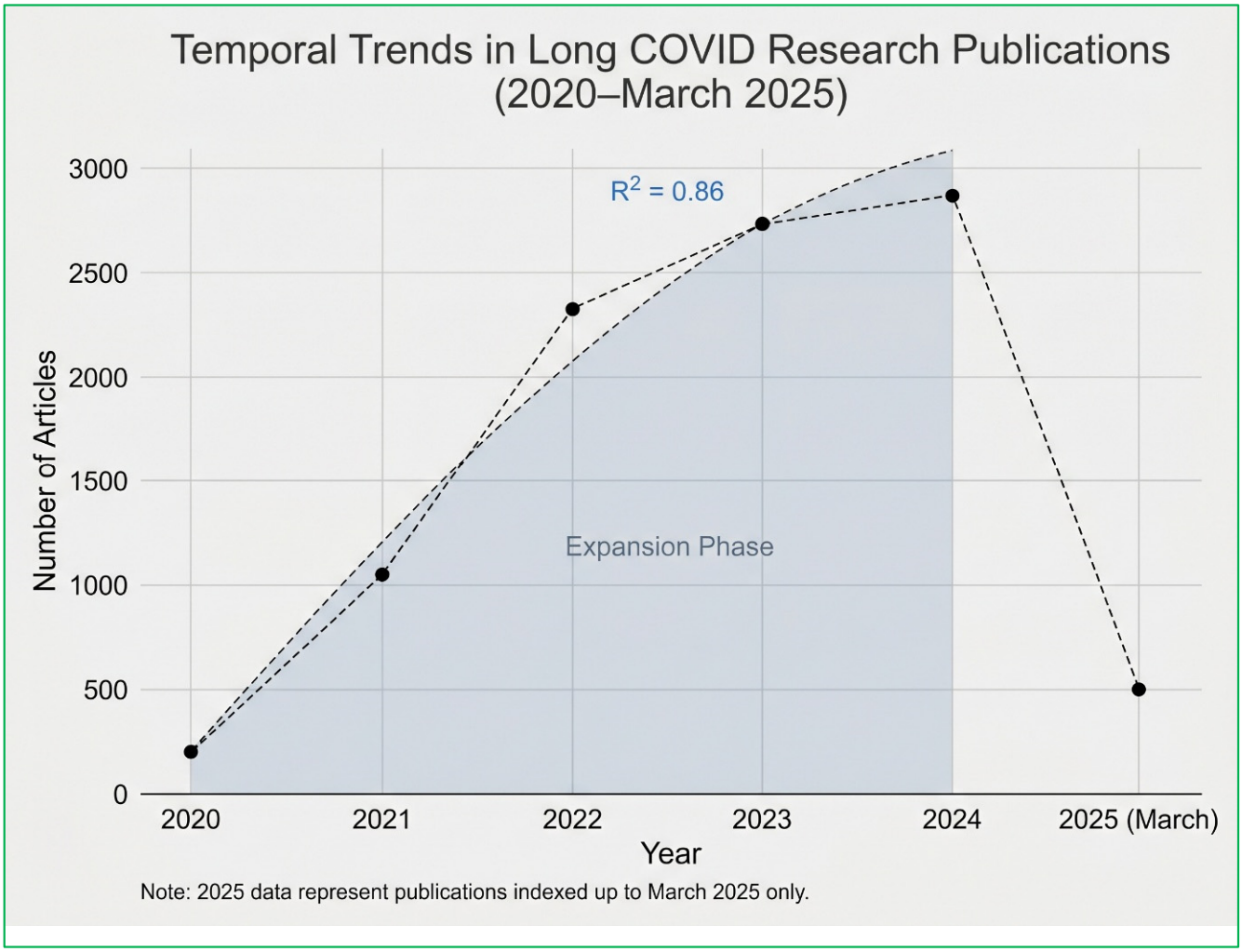
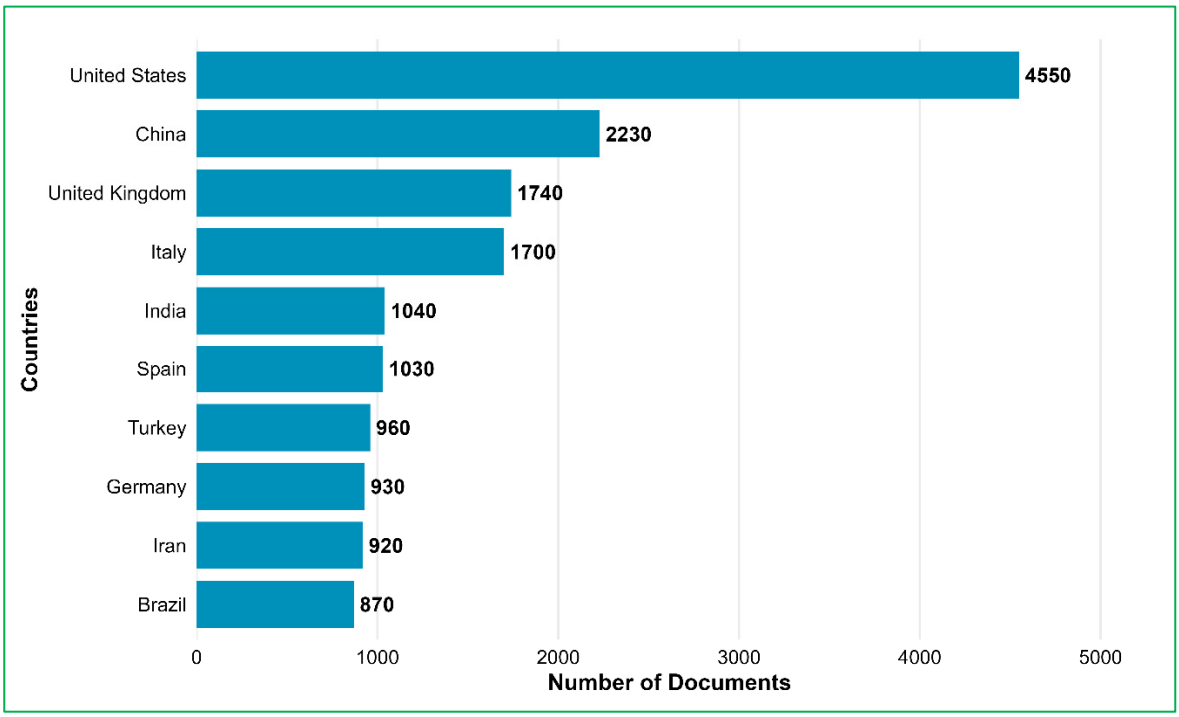


Figure 1. Annual publication trends and growth trajectory of long COVID research (2020–2025). Note: Data for 2025 represent only the first quarter (retrieved through 14 March 2025) and do not constitute a full calendar year. The apparent decline in 2025 is a data artefact of the search cutoff and should not be interpreted as a decrease in scholarly interest or research output. Accordingly, the 2025 data should not be used for annual comparative growth analysis.

In addition, the global discourse was driven by a small number of highly productive authors and prestigious academic medical centres. Wang Y emerged as the most prolific researcher with 82 publications, followed by Zhang Y (72) and Li Y (60) (Supplementary Figure S2). However, network centrality analysis (Supplementary Figure S3) identified César Fernández-de-las-Peñas as the most influential collaborator, serving as the primary link between disparate research communities. The intellectual foundation of the field was anchored by highly cited works from Nalbandian (2021), Xie (2022b), and Davis (2023) (Figure 3a).

Figure 3b shows that the University of California led global institutional output with 577 publications, followed by Oxford University (498), the Icahn School of Medicine at Mount Sinai (464), and University College London (452). These institutions act as intellectual hubs.

(**a**)



(**b**)

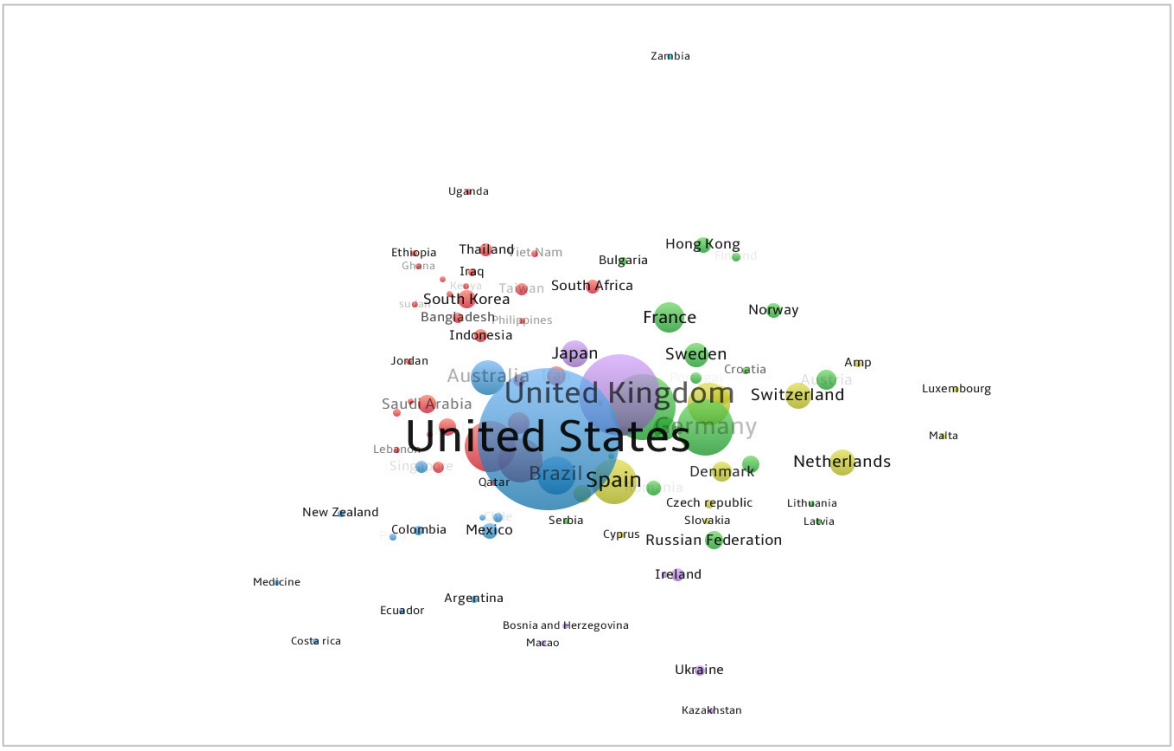
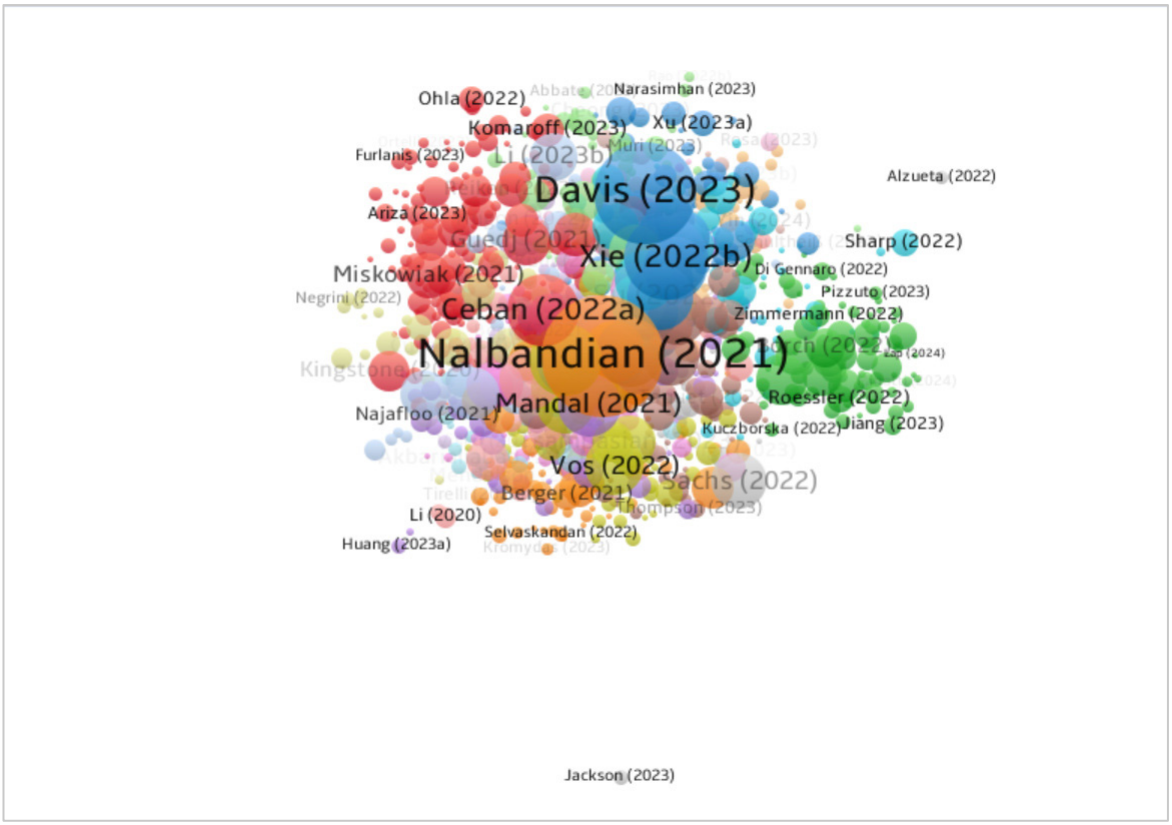


Figure 2. Leadership in global discourse by geographical dominance. The bar chart (panel (**a**)) illustrates the top 10 countries contributing to long COVID research publications, ranked according to productivity (total publication output). Bar length represents the number of documents produced by each country. The collaboration network map (panel (**b**)) visualises international research collaboration patterns in long COVID studies, where node size reflects publication volume and link thickness indicates the strength of collaborative relationships between countries. Colours represent distinct collaboration clusters identified through bibliometric network analysis. We analysed and visualised the data using Bibliometrix/Biblioshiny.

(**a**)



(**b**)

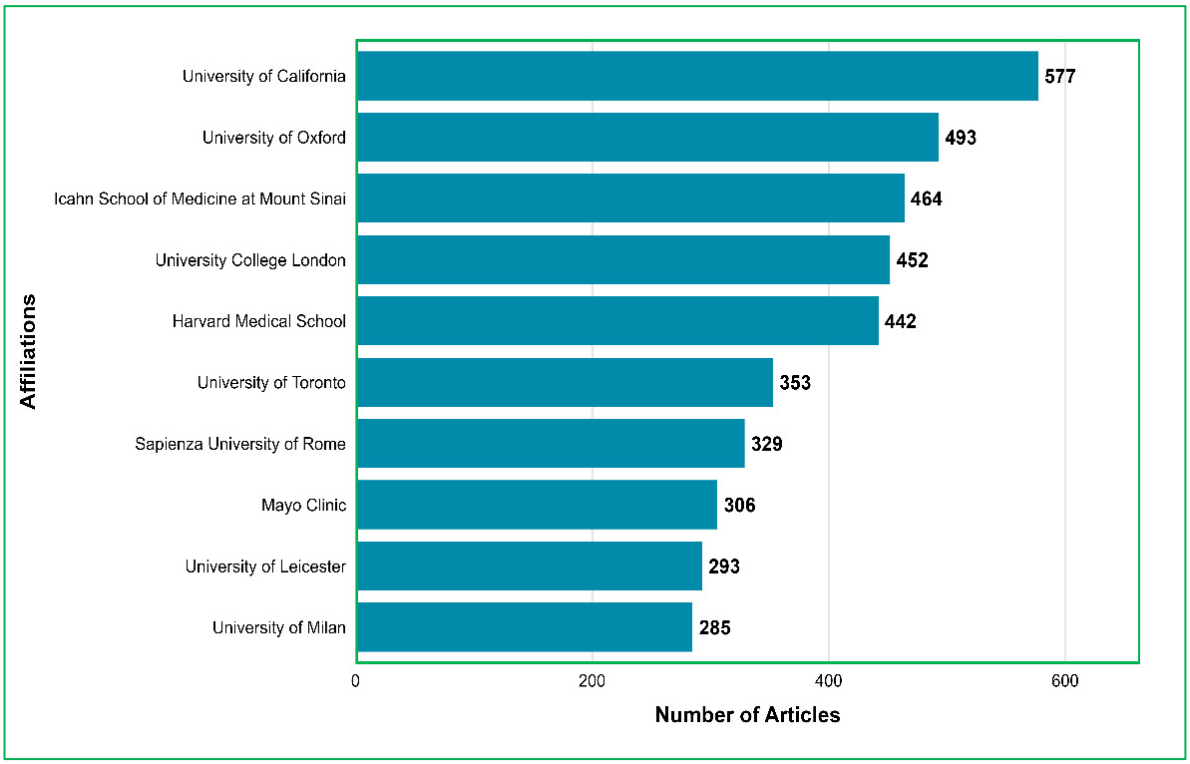


Figure 3. Leadership in global discourse by authors and institutions. Node size represented the number of publications produced by each institution or author within the long COVID research landscape. In the collaboration network map (panel (**a**)), nodes represented authors, and connecting lines indicated co-authorship relationships and the strength of collaborative links. Colours denote different research collaboration clusters identified through bibliometric network analysis. In the institutional contribution chart (panel (**b**)), institutions were ranked by total publication output, with larger, darker nodes indicating higher scholarly productivity.

The journal network analysis (Supplementary Figure S4) identified the primary hubs of knowledge dissemination in long COVID research. The field was characterised by a high degree of interdisciplinarity, with multidisciplinary journals such as PLOS ONE and Scientific Reports serving as central bridges between specialised clusters. The network revealed three distinct communities: a clinical medicine cluster anchored by the *Journal of Clinical Medicine*, an immunological/basic science cluster centred on *Frontiers in Immunology*, and a public health/environmental cluster led by the *International Journal of Environmental Research and Public Health*. The high centrality of these nodes suggested they were the most influential platforms for reaching a broad, cross-disciplinary audience (Supplementary Figure S4).

3.4. Dominant Thematic Clusters (Science Mapping)

Co-word analysis of 23,803 keywords plus and 13,991 author keywords meeting the n = 10 threshold identified 134 high-frequency terms distributed across four distinct research pillars (Figure 4). The map was anchored by the central "coronavirus disease 2019" node, which served as the primary bridge between foundational epidemiological data and specialised clinical investigations.

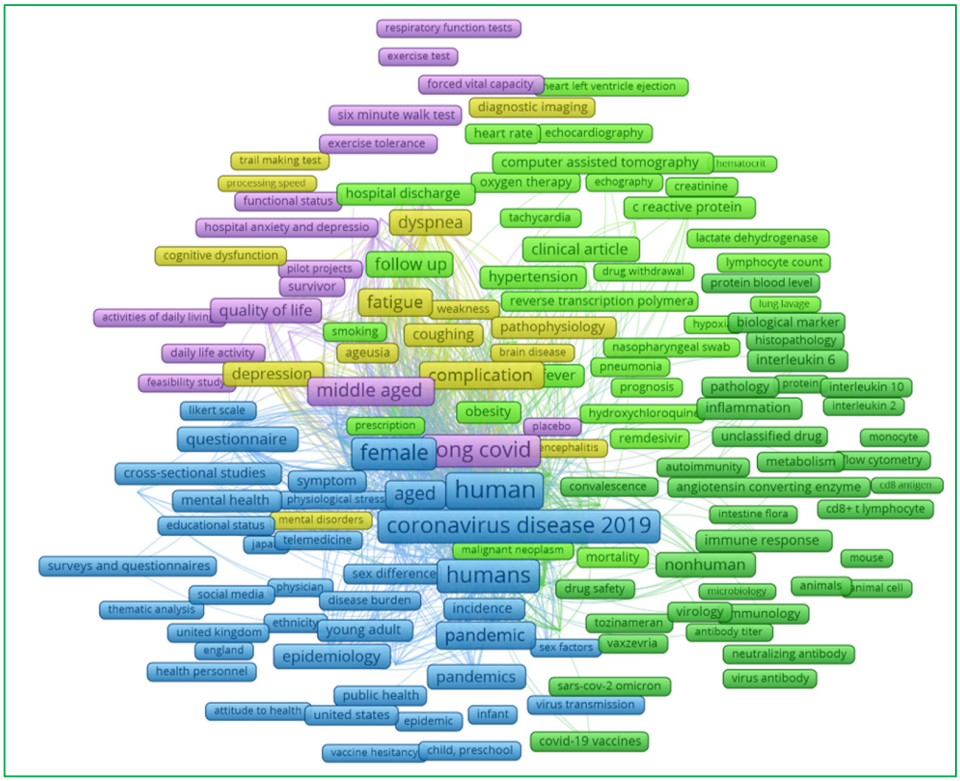


Figure 4. Keyword co-occurrence map generated using VOSviewer. The size of each node reflects keyword frequency, the distance between nodes indicates the degree of relatedness, and the connecting lines represent co-occurrence links. Colours identified distinct thematic clusters within the COVID-19 and long COVID research landscape.

Cluster 1: Epidemiology and public health (Blue; n = 42 keywords): This foundational pillar focused on macro-level pandemic surveillance. It was defined by the largest nodes, including "coronavirus disease 2019" (n = 8142), "humans" (n = 7550), "human," "pandemic," and "epidemiology (n = 2410). This cluster emphasised the use of "surveys and questionnaires" to assess "disease burden" and "mental health" across populations. Geographic nodes such as the "United States" and "United Kingdom" indicated that these regions had been the primary drivers of large-scale population studies.

Cluster 2: Functional status and rehabilitation (Purple; n = 31 keywords): This cluster represented the transition from acute care to long-term recovery management. It was anchored by the "long COVID" (n = 4210) node and specialised assessment terms such as "quality of life" (n = 1840), "six-minute walk test," "exercise tolerance," and "respiratory function tests." This cluster underscored the multidisciplinary effort to quantify "functional status" after "hospital discharge," focusing on the longitudinal "follow-up" (n = 1230) of survivors to determine their capacity for "daily life activity."

Cluster 3: Immunology and pathophysiology (Green; n = 36 keywords): This pillar focused on the biological and mechanistic underpinnings of the disease. It featured high-frequency nodes for "immune response" (n = 980), "inflammation" (n = 850), "virology" (n = 720), and "immunology." Critical biomarkers such as "C-reactive protein," "interleukin 6," and "lymphocyte count" appeared prominently. Furthermore, this cluster linked basic science to pharmacological interventions, including "remdesivir," "hydroxychloroquine," and "COVID-19 vaccines," reflecting the search for biological targets and the impact of immunisation on long-term outcomes.

Cluster 4: Clinical symptoms and complications (Yellow; n = 25 keywords): This cluster delineated the specific symptomatic phenotypes of the condition. It was centred on the most frequently reported manifestations, including "fatigue" (n = 1420), "dyspnoea" (n = 1150), and "complication" (n = 940). Notable clinical focuses included "cognitive dysfunction" and "brain disease," as well as "obesity" as a key risk factor. The nodes "female" and "middle-aged" served as critical connectors between this symptomatic cluster and the broader epidemiological data, identifying the primary demographic phenotypes observed in clinical practice.

The dense interconnectedness between these clusters revealed a maturing research landscape. Specifically, the strong links between "immune response" (green) and "fatigue" (yellow) suggested a scientific thematic co-occurrence toward understanding the biological drivers of chronic symptoms. Additionally, the proximity of "mental health" (blue) to "quality of life" (purple) emphasised the integrated approach required to manage the psychosocial and functional sequelae of long COVID.

3.5. Identified Gaps in Research Progress

Quantitative analysis of the research landscape identified three critical gaps. Keywords directly associated with interventional evidence—such as "clinical trial" and "randomised controlled trial"—appeared in less than 2% (n < 195) of the total documents, while paediatric-related terms accounted for only 4.2% of the corpus. Furthermore, nations in the Global South contributed less than 19% of the total output.

It is critical to acknowledge that these percentages represent thematic visibility within metadata (the "proxy" nature of keywords) rather than an exhaustive clinical census of all ongoing activity. To validate the reliability of these metrics, we performed a manual document-level audit of a random 5% sample (n = 486) of the corpus. Screening of titles and abstracts confirmed that keyword-based identification was a robust proxy for study classification, yielding a 92% agreement rate for interventional studies and a 95% agreement rate for paediatric research. This validation step confirms that while the absence of a specific keyword does not definitively exclude a study's relevance, the identified frequencies accurately reflect the structural imbalances and priorities currently dominating the global long COVID research trajectory.

4. Discussion

The evolution of long COVID research from 2020 to early 2025 represents one of the most rapid disciplinary expansions in the history of medicine. Our findings, showing an

annual growth rate of nearly 20% and a peak in 2024, indicate that the field has transitioned from an emergency observational phase to a period of scientific consolidation [1,5]. This maturation is evidenced by the shift from broad epidemiological surveys to specialised investigations into the disease's biological underpinnings and functional consequences.

The delineation of four distinct research clusters (Figure 4) reveals a high degree of complexity and multidisciplinary effort to understand long COVID. The epidemiological pillar established the scale of the crisis, while the immunological pillar has begun to uncover deep mechanistic drivers, such as viral persistence and chronic inflammation [5,19]. Critically, the dense interconnectedness between the symptomatic and rehabilitative clusters suggests a growing alignment in researcher interest, namely that long COVID is a multisystemic condition. The research trajectory suggests a thematic shift toward integrated care models rather than siloed biomedical treatments [8]. The prominence of terms like "quality of life" and "exercise tolerance" reflects a shift toward patient-centred outcomes [6,19,20]. However, a significant interventional lag remains. While our data show thousands of papers describing the "what" and "why" of long COVID, there is a disproportionately low volume of literature, as evidenced by the small size of the randomised controlled trial nodes, which detail the "how" of treatment. As shown in our quantitative analysis (Section 3.5), the less than 2% frequency of clinical trial keywords reveals a persistent 'interventional lag'. While the field has successfully mapped the mechanisms of the disease, it has yet to pivot toward validating therapeutic solutions [21,22]."

The dominance of the United States, China, and the United Kingdom (Figure 2) reflects substantial targeted funding, including the NIH RECOVER initiative. While this has provided the field with high-quality foundational data, it has also created a "Global North hegemony" that threatens the universal applicability of clinical guidelines.

Our analysis highlights a significant disparity: regions like South America and Africa, which report high prevalence rates, remain on the periphery of the global collaboration network [2,8]. If clinical evidence is derived almost exclusively from high-income settings, it may fail to account for the genetic diversity, disparate healthcare capacities, and unique socio-economic barriers of the Global South. This imbalance risks creating a scientific echo chamber that overlooks the realities of long COVID in low-resource settings. Diversifying the global research network is not merely an ethical priority; it is a clinical necessity for developing globally relevant treatments [23–25].

Despite the volume of literature, two critical gaps emerge. The 4.2% representation of paediatric-related research in the corpus (Section 3.5) underscores a significant demographic gap. This lack of data threatens to leave the long-term developmental impacts of PASC in children unaddressed [26]. Second, there is a scarcity of rigorous evaluations concerning service delivery models. While the literature identifies the symptoms, it provides little evidence on which integrated care pathways, such as multidisciplinary clinics, actually improve functional status [6]. Without evidence-based models of care, healthcare systems will remain ill-equipped to manage the "long tail" of the pandemic [27–29].

4.1. Implications of the Findings for Clinical Practices, Policy, and Future Research

The rapid expansion of the long COVID evidence base, characterised by a 19.81% annual growth rate, identifies a clear scientific priority toward interdisciplinary research. The dense thematic links between immunology and functional outcomes (Figure 4) suggest that the research trajectory is prioritising the integration of biological and psychosocial datasets. Rather than providing specific clinical mandates, these findings identify critical areas for research prioritisation. Specifically, the identified 2% interventional lag suggests that the scientific community must prioritise the transition from observational mapping toward the rigorous evaluation of service delivery models. Furthermore, the identified

geographic imbalances highlight an urgent need for research efforts to be prioritised in LMICs to ensure that the global evidence base accounts for diverse health system constraints and socio-economic realities.

For clinicians, this expanding evidence base indicates a research priority toward interdisciplinary care. The prominence of these research hubs suggests they will likely be the source of future consensus statements and landmark trial data [22]. The strong interconnectedness between immunological markers and functional symptoms in our maps suggests that management should integrate medical interventions such as long COVID rehabilitation with psychological support and social care [6,24]. The identification of leading academic centres—such as the University of California, Oxford University, and the Icahn School of Medicine—as primary contributors (Figure 3b) provides a roadmap for where the field's intellectual weight is currently situated. These institutions represent established centres of expertise where future consensus-building efforts are likely to be concentrated. Clinicians and researchers should monitor the outputs of these hubs for emerging high-impact data while acknowledging that the concentration of expertise in these specific high-resource settings may influence the thematic direction of the international research agenda. Furthermore, given the long COVID/patient outcomes cluster's focus on exercise tolerance and quality of life, clinicians should prioritise longitudinal, patient-centred assessments over acute symptomatic relief [30].

The concentration of research output in the United States, China, and the United Kingdom creates a significant risk of geographic hegemony in health policy. Currently, global guidelines are heavily weighted toward high-income settings, which may not reflect the clinical realities of low- and middle-income countries (LMICs).

Policymakers in LMICs should exercise caution when adopting Western-centric care models that assume a level of resource availability, such as advanced diagnostic imaging, that may not exist locally. Instead, national health strategies should prioritise targeted funding for contextually relevant research that accounts for local demographics and health system constraints. The identified trends suggest that policymakers should view long COVID as a long-term public health challenge. The expansion of the evidence base provides an objective basis for integrating emerging knowledge into national health strategies. Our analysis identifies a critical tension between data volume and practical utility. While the field has successfully mapped the disease's pathophysiology, there is a documented lag in interventional research. Future funding should be strategically diverted to address the specific gaps identified in this study. Specifically, the 98% deficit in interventional literature (Section 3.5) indicates that research priorities must shift from observational mapping to large-scale clinical trials. Furthermore, the minimal (4.2%) focus on paediatric populations signals an urgent need for age-specific longitudinal studies. In addition, the area that evaluates which multidisciplinary clinic models provide the highest value for care and improved patient functional status [31].

4.2. Limitations of the Study

While this study utilises established bibliometric protocols to ensure data integrity and reproducibility, several inherent limitations must be acknowledged. First, the exclusive reliance on the Scopus database, while justified by its high-quality metadata and interdisciplinary breadth [10], may omit regional journals not indexed on this platform. This likely reinforces the geographic bias toward high-income nations identified in our results. The exclusive reliance on the Scopus database represents a significant methodological boundary. While Scopus was selected for its superior metadata consistency and its documented 80–90% overlap with Web of Science [12], this approach may introduce a "high-impact bias." Because Scopus primarily indexes established, peer-reviewed journals

with international reach, it may underrepresent specialised or regional clinical journals that are indexed in databases like Embase or PubMed but do not meet Scopus's specific indexing thresholds. Consequently, localised clinical observations, particularly those published in native languages or in smaller regional medical journals, may be omitted from this analysis. This limitation suggests that the intellectual structure mapped in this study primarily reflects the dominant global scientific discourse rather than an exhaustive census of all clinical insights available in the broader medical literature.

Second, the restriction to English-language publications was a technical necessity for the Natural Language Processing (NLP) algorithms used in our science mapping. However, this creates a linguistic bias that may inadvertently marginalise significant traditional medicine research from Asian territories or community-based social research from non-English-speaking LMICs. Third, the exclusion of grey literature and conference proceedings intended to prioritise peer-reviewed integrity means that emerging or informal clinical observations are underrepresented in the mapped intellectual structure.

In addition, the 2025 data represent only the first quarter of the year. The apparent plateau in publication volume observed in Figure 1 should be interpreted as a data artefact of the search window rather than a definitive shift in scientific interest. Consequently, our findings should be viewed as a high-resolution mapping of the dominant global scientific discourse rather than an exhaustive census of all long COVID knowledge.

Furthermore, the primary research gaps identified in this study, specifically the limited volume of interventional and paediatric research, are derived from keyword-based thematic mapping. While this methodology effectively identifies the "thematic visibility" and structural priorities of the field, it may not account for relevant studies that did not explicitly include these specific descriptors in their titles, abstracts, or indexed metadata. Consequently, these gaps should be interpreted as an indication of current research trends rather than an absolute clinical census.

Finally, it is important to note that the quantitative gap analysis regarding interventional and paediatric research is derived from keyword frequency. This metric represents "thematic visibility"—the extent to which these topics are highlighted as primary research focuses within the indexed metadata—rather than an exhaustive census of all clinical activities. While our manual validation (Section 3.5) indicates that keywords are a reliable proxy, some relevant studies may not include specific interventional or paediatric terms in their titles, abstracts, or author keywords. Consequently, the identified gaps should be interpreted as structural imbalances in the dominant scientific discourse rather than a definitive count of every existing study in these niches.

5. Conclusions

The evolution of Long COVID research (2020–2025) reflects an unprecedented mobilisation, transitioning from descriptive epidemiology toward deep mechanistic and rehabilitative science. The identification of four maturing thematic pillars demonstrates that the field has moved beyond emergency observation into scientific consolidation. However, this data expansion reveals a critical research paradox: while morbidity is now well-mapped, therapeutic validation remains incomplete. A significant "interventional lag" persists, with clinical trials representing less than 2% of the total corpus. Structural imbalances also remain; paediatric-related research accounts for only 4.2% of the literature, and a stark geographic disparity exists, with high-income countries producing 78% of global output while low-income countries contribute less than 1%. This study provides a strategic roadmap for the next phase of the pandemic response. To transition from "mapping the problem" to "validating the cure," future research must prioritise interventional trials and the evaluation of integrated service models. By addressing these quantified imbalances

and fostering inclusive international partnerships that transcend geographic hegemony, the scientific community can ensure that this intellectual investment translates into equitable, evidence-based recovery for the millions still affected by this debilitating condition.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/metrics3040021/s1, Supplementary File S1: Verbatim Scopus Search Query; Figure S1: The PRISMA 2020 statement, with the full workflow documented in a data curation flow diagram for the bibliometric analysis of long COVID research documents; Supplementary File S2: Manual Thesaurus for Keyword and Author Disambiguation; Figure S2: Most relevant authors in long COVID research; Figure S3: Author Co-authorship Network. The visualisation highlights collaborative research dynamics in long COVID studies from 2020 to 2025; Figure S4: Journal co-citation and occurrence network in long COVID research (2020–2025). The size of each node represents the total number of articles published, while the links indicate the strength of co-citation between journals. Colour-coded clusters represent distinct disciplinary communities (e.g., Blue for multidisciplinary/general medicine, Green for immunology, and Red for public health/environmental science).

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Abbreviations

COVID-19	Coronavirus Disease 2019
PASC	Post-Acute Sequelae of SARS-CoV-2 Infection
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
NASEM	National Academies of Sciences
Engineering	and Medicine
RIBA	Reporting Items for Bibliometric Analysis
GLOBAL	Guidelines for Bibliometric Analysis
CSV	Comma-Separated Values
BibTeX	Bibliographic TeX
DE	Author Keywords
ID	Keywords Plus
NIH	National Institutes of Health
LMICs	Low- and Middle-Income Countries

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