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Research trends in mental health problems of children and adolescents during the COVID-19 pandemic: A bibliometric and visualization analysis

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Abstract

COVID-19's impact on children and adolescents' mental health has heightened global focus, leading to analysis with bibliometric and visualization tools of related studies in the Web of Science™ database from 2020 to 2023. In total, there are 5,189 studies authored by 27,102 researchers from 147 countries and significantly involving 6,926 institutions. These studies are covered by 1,246 journals. Depression, anxiety, and stress are currently well-developed and important research areas and will continue to be a priority and hot topic for further exploration and discussion in the academic research field in the future. However, certain topics, such as child maltreatment, need to be reassessed in terms of their importance. Additionally, emerging areas like telemedicine and vaccine hesitancy have emerged. Fundamental aspects such as COVID-19, family, and parenting reflect the far-reaching impact of the pandemic. Given that public health emergencies may affect the mental health of children and adolescents, it is particularly important to establish specialized response mechanisms. In addition, strengthened interdisciplinary and intersectoral cooperation focusing on the mental health of children and adolescents from vulnerable groups is crucial to ensure their healthy development and promote long-term social stability and scientific and technological progress.

Impact statement

Bibliometric and visualization analyses were used to systematically review the research overview and trends of child and adolescent mental health issues in the context of the new epidemic. Through the comprehensive bibliometric statistics, we identified the core authors, institutions and countries in the field, revealing the relationship between disciplinary cooperation and knowledge transfer, which can help promote the coherence of research. By identifying high-impact journals and publications, we can refer to the core results of related fields. Visualization technology is used to depict the keywords relationship network, which clearly presents the research hotspots and cutting-edge directions and provides research guidance for scholars. Thematic evolution analysis reveals emerging hotspots and suggests future research priorities. The thematic maps strategically position different research themes and provide valuable insights into the maturity and importance of each theme, thus guiding researchers to identify directions for continued exploration. This study highlights the global interest in child and adolescent mental health during a pandemic, with a particular focus on the important topics of stress, depression and anxiety. By providing a comprehensive overview of developments in the field, this study helps researchers and policymakers in related fields to develop targeted interventions and policies based on resilience, support and well-being, among others, and ultimately shapes further directions and future trajectories of research on the mental health of children and adolescents in a pandemic world.

1. Introduction

On March 11, 2020, the World Health Organization officially declared the novel coronavirus disease 2019 (COVID-19) a global pandemic (Guan et al., 2020, Liu et al., 2020; World Health Organization, n.d.a, n.d.b). The uncertainty of the outbreak and the public health measures implemented to slow the spread of COVID-19 affected the mental health of the public (D'agostino et al., 2020; Mukhtar, 2020; Usher et al., 2020) (e.g., extensive and prolonged home isolation, maintenance of strict social distancing, mandatory masks (Bundgaard et al., 2021;

Cheng et al., 2023; Galloway et al., 2021; Hu et al., 2021)), especially children and adolescents (Chen et al., 2022; Golberstein et al., 2020). As their brains are still developing, high levels of stress and social isolation may lead to permanent abnormalities in their growth (Gunnar and Quevedo, 2007; Quinlan et al., 2017). Children and adolescents account for 42% of the world's population, 26% of whom are under the age of 15 years (Organization). Exposure to stressors, such as through isolation from family and friends, seeing or becoming aware of a seriously ill member affected by COVID-19 or the death of a loved one (or even its possibility), can lead to anxiety, panic attacks, depression and other mental illnesses (Pierce et al., 2020).

Mental health is an important component of human development, determining the educational attainment outcomes of children and adolescents and their potential to lead full and productive lives. Although mental health problems in children have always existed (Vella et al., 2019), physicians and psychologists warn that the COVID-19 outbreak may exacerbate this trend, as the impact of the health crisis on some children may be traumatic. A previous study has found that children who were quarantined because of the outbreak scored four times higher on post-traumatic stress tests than those who were not in isolation (Sprang and Silman, 2013). Owing to the special nature of growth and development, children and adolescents are not sufficiently mature concerning their psychological development and have poor tolerance for stressful events, such as public health emergencies, which may result in excessive stress reactions (Nelson et al., 2020; Garner and Yogman, 2021; Rider et al., 2021).

The COVID-19 pandemic has contributed significantly to the surge in publications on the novel coronavirus. Bibliometrics provide a quantitative analysis of a large body of literature for the comprehensive understanding of a specific area of research (Li et al., 2021). Bibliometric methods have been used in different areas of medical research (Thompson and Walker, 2015). To our knowledge, although bibliometric studies have been conducted on public mental health during the COVID-19 pandemic (Akintunde et al., 2021; Chen et al., 2021; Maalouf et al., 2021), there is a gap in the literature concerning a focus on children and adolescents. Thus, we conducted a bibliometric analysis based on the Web of Science™ core collection (WoSCC) database to gain an understanding of the trends and hotspots of research related to child and adolescent mental health during the COVID-19 pandemic. Thus, we aimed to provide ideas and directions for subsequent research on child and adolescent mental health in the post-pandemic era.

2. Materials and methods

2.1. Selection of citation data

Mongeon and Paul-Hus reported that most bibliometric studies have a common source of data: Thomson Reuters' Web of Science and Elsevier's Scopus. Considering the powerful information retrieval capabilities, Web of Science is the world's largest, most comprehensive and multidisciplinary research platform for scholarly resources. Owing to its groundbreaking content, high-quality data and long history, WoSCC was selected to access initial data (Mongeon and Paul-Hus, 2016) and was considered the best database for bibliometric analyses (Gazzaz et al., 2020). Hence, a search formula was developed by searching the WoSCC database on February 5, 2023, using a combination of subject terms and free words: TS = (COVID-19 (MeSH Terms) or SARS-CoV-2 (MeSH Terms) or coronavirus (MeSH Terms) or NCOV (All Fields) or pandemics (MeSH Terms)) and TS = (mental health (MeSH Terms) or mental disorders (MeSH Terms) or psychological (All Fields) or stress (All Fields) or anxiety (MeSH Terms) or depression (MeSH Terms) or loneliness (MeSH Terms) or fear (MeSH Terms) or resilience (All Fields)) and TS = (adolescent (MeSH Terms) or child (MeSH Terms) or kid (All Fields) or minors (MeSH Terms) or youths (All Fields) or juveniles (All Fields) or toddlers (All Fields) or young ones (All Fields) or preteens (All Fields) or "school-age kids" (All Fields) or teens (All Fields) or teenagers (All Fields) or youth (All Fields) or "young people" (All Fields) or "teenage years" (All Fields) or adolescence (All Fields) or preadolescents (All Fields)). To comprehensively capture the academic trends and responses related to the mental health of children and adolescents throughout the pandemic, we selected the period from the discovery of the first COVID-19 case on December 1, 2019, to February 5, 2023 (search date) for our study. Notably, this timeframe encompasses the entire phase from the first appearance of the pandemic to the full lifting of lockdown measures in China on December 5, 2022. English was selected as the language type, and the literature type excluded book chapters, data reports and proceedings, newspapers, letters and comments. The query was limited to subject fields (title, abstract or keywords), and the following information was extracted from the retrieved documents: year of publication, title, keywords, abstract, author, country or region, affiliation, document type, journal and number of citations. All literature was independently screened initially by two researchers so that those that did not meet the criteria were excluded. When there are obvious differences between two researchers in literature screening, we first let them have a full discussion on the disputed literature and review it together to understand the basis of each other's viewpoints. This helps to clarify the differences and reach a consensus. If there is still disagreement after consultation, we will ask a third independent reviewer to re-examine the disputed documents and make a decision based on his or her own judgment. The independent third-party judgment helps to deal with the disagreement in a fair and objective manner and ensures the scientific nature of the screening process. A total of 5,189 studies were finally used for the analysis (Figure 1).

2.2. Statistical analysis

Data for this study was sourced directly from the Web of Science database. Our retrieval strategy was meticulously detailed, encompassing the use of subject terms, free words, phrase search, Boolean operators and field identifiers. After setting the search timeframe, we also defined the criteria for study inclusion and exclusion. Specifically, during the literature screening phase and based on our research objectives and methodology, we opted to include all retrieved documents. This decision was primarily driven by two factors: firstly, to ensure the breadth and comprehensiveness of the study, aiming for a complete overview of the literature; and, secondly, to leverage the adaptability of statistical methods, combined with the advanced algorithms of various software tools, designed to handle vast amounts of data and automatically pinpoint and highlight themes or patterns, thereby minimizing the need for manual selection. During the data extraction phase, we exported the full records and citations of all retrieved documents in plain-text format. Given potential formatting inconsistencies in data exported from Web of Science, we manually formatted and cleaned the data to ensure a high level of analysis accuracy. For data quality, publication journals and citation counts of served as our main assessment indicators. All textual data, after frequency analysis, were encoded and digitized. Initial data processing was executed in Excel, where the frequency and percentage distribution of various variables were computed. Moreover, tools like RStudio

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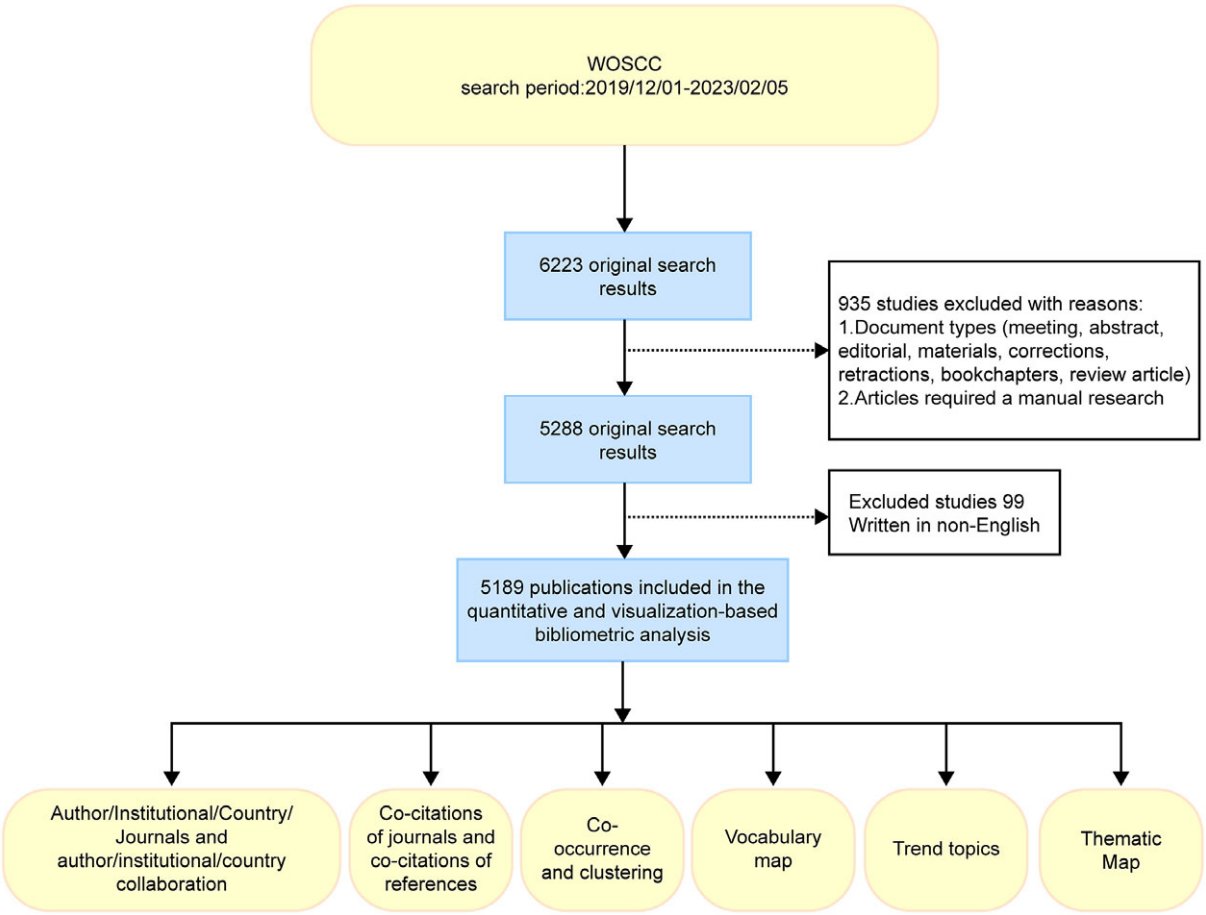

Figure 1. Flowchart of the literature selection process.

(v.3.4.1), VOSviewer (1.6.16), Gephi (0.9.7) and the Graphical Clustering Toolkit (Gcluto 1.0) were utilized for in-depth bibliometric analysis and visualization. A new and innovative bibliometric analysis tool, "Bibliometrix," a package for RStudio programmed in R (Aria and Cuccurullo, 2017), was introduced in this study to analyze data and visualize relevant bibliometric networks (Ekundayo and Okoh, 2018). Gephi is a JVM-based complex network analysis software with view indicative and dynamic analytical features for optimizing visual graphs with excessive data (Jacomy et al., 2014). VOSviewer is a JAVA-based scientometric network analysis software developed by Van Eck and Waltman (2010) in 2009 to create network, coverage and density visualization maps based on network data, focusing on scientific knowledge visualization. Gcluto is a cluster analysis software developed by researchers at the University of Minnesota. Its main feature is that it provides a description of different clusters and has relevant parameters to evaluate the clustering effect, which can help researchers cluster and summarize more scientifically the thematic directions of the research field. Data were imported into the Bibliometrix program in RStudio with the advantageous algorithms of each software. The analysis data extracted from the software included the most productive authors, active institutions and journals, countries with the most contributions and collaborations, literature and journal co-citations, vocabulary map, trend topics and thematic maps. Gephi was used to identify collaborative networks of authors; VOSviewer for keyword co-occurrence analysis (Çatal et al., 2018); and Gcluto for keyword clustering analysis to show structural relationships in knowledge areas and research frontier hotspots.

2.3. Methodology

Bibliometric methodology was used to comprehensively analyze the research trends in mental health problems of children and adolescents during the COVID-19 pandemic. The English literature was carefully selected from the Web of Science database to ensure quality of the study. RStudio, VOSviewer, Gephi, Gcluto and other software were used to analyze the authors' network, keyword co-occurrence analysis and thematic clustering according to their respective advantages. In particular, the introduction of Bibliometrix tool makes quantitative analysis more convenient. These methods are complementary to each other and refine the knowledge structure of literature and research trends from different perspectives. This study aims to observe the development of the discipline objectively and comprehensively through the integration of multiple methods in bibliometrics. Compared with a single method, this integrated strategy is more capable of exploring the multidimensional attributes of the problem. Of course, there are limitations in this study, such as language bias that may affect the generalizability of the results. However, we strictly screened the English literature and adopted various statistical strategies to improve the robustness of the results. This study is not an exhaustive description of every detail, but rather provides a macro-perspective through methodological integration to support

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Table 1. Number of authors and first authors of published studies

No. of studies	No. of authors	Percentage of total authors (%)	No. of first authors	Percentage of total number of authors (%)
1	22,593	83.63	4,464	93.16
2	3,095	11.42	276	5.76
3	829	3.06	39	0.81
4	297	1.10	9	0.19
≥5	288	1.06	4	0.08
Total	27,102	100	4,792	100

scientific judgment of trends in child and adolescent mental health research. In the future, the language could be expanded and more cutting-edge technologies could be employed to enhance the methodology of the discipline.

3. Results

3.1. Authors

3.1.1. Author publications

An author's publication count refers to the cumulative number of studies published over a period, which can reflect the author's research activity and ability to an extent. The bibliometric analysis of the WoSCC database, without considering the duplication of authors' names, identified 27,102 authors; the average degree of author collaboration was 6.6. According to the inference of Lotka's law, the number of authors who write a study over a period constitutes approximately 60% of all authors. Table 1 shows that 86.64% of the authors had published only one study, approximately 25% higher than the percentage stated in Lotka's law, indicating that most scholars conducted only experimental research and had not researched further and that their research lacked continuity.

3.1.2. Core authors' characteristics

Core authors are scientific researchers who make a significant contribution to the development of research in their subject area. They are generally defined using Price's law: the number of studies published by the lowest-producing author is 0.749 times the square root of the total number of studies published by the highest-producing author in a group (5) ($N = 0.749(N_{max}1/2)$). The author with the most publications on children's and adolescents' mental health during COVID-19 was L. Zhang ($N_{max} = 18$). When $N_{max} = 18$, $N \approx 3$; therefore, the number of authors whose publication frequency was greater than or equal to 3 was counted. There were 1,414 authors with 5,457 publications, accounting for 15.94% of the total number of publications, which is still a large gap from the 50% specified in Price's law, indicating that the core group of authors in this field had not yet been formed (Lee and Jeong, 2008). Table 2 shows information on authors with 10 or more publications, and the top three authors are L. Zhang (n = 18; h-index = 6; total citations = 138), J. Lee (n = 17; h-index = 6; total citations = 125) and Y. Wang (n = 16; h-index = 6; total citations = 475). The h-index is an accurate reflection of academic contributions and achievements and has been used in many bibliometric analyses (Miao et al., 2018). The citations of researchers can be used as an indicator of influence (Su et al., 2018). In our study, as the study spanned just over two years, the top 10 authors concerning number of publications were not considerably far apart, and the authors with a high h-index and high citation frequency were C. Mazzeschi, which had a greater influence on other scholars.

3.1.3. Author collaboration network

When a study is co-authored by two or more authors, it shows a scientific collaboration between these authors. When multiple authors collaborate, the scientific collaboration relationship presents a net-like structure. Author collaboration networks describe the total number of co-authored studies in a selected research area. Considering the social network graph in Gephi, an author collaboration network graph with 76 nodes, 135 edges and a graph density of 0.047 was obtained (Figure 2). Each edge represents the collaboration relationship between two authors (two points); the more the cooperation, the thicker the connecting line. The average clustering coefficient of this graph is 0.715, and the modularity index is 0.793, which indicates that the collaboration network of authors appeared to demonstrate a certain degree of small-world characteristics (a large average clustering coefficient and a short average path length), and several significant collaboration networks have emerged.

3.2. Institutions

3.2.1. Institutions' publication

The publishing institution, also known as the systematic distribution of authors, reflects whether the institution is part of the main research force on a subject matter. Regarding issuing institutions, 6,926 institutions were involved in research on child and adolescent mental health during COVID-19. Among the institutions with a publication volume greater than or equal to 40, all but Murdoch Children's Research Institute were universities. Similar to other research areas, universities were an essential research force (Wang et al., 2019). The top three research institutions were the University of Toronto (n = 116; h-index = 17; total citations = 2098), the University College London (n = 109; h-index = 22; total citations = 3,195) and the University of Melbourne (n = 93; h-index = 17; total citations = 1,155). There were 288 (4.16%) institutions with 10 or more cumulative publications. A total of 4,876 (70.40%) research institutions had a volume of one study, indicating a lack of continuity of research in this field (Figure 3).

3.2.2. Institutional collaboration network

Figure 4 shows the four major research clusters represented by four different colors. Node size corresponds to the total publication volume of each institution, and the links reflect collaborative relationships. Cluster 1, indicated by red, is the largest cluster in this network and contains 26 nodes. The University of Toronto not only had the highest outputs but also had the highest betweenness, closeness and page rank, 122.20, 0.0189, and 0.052, respectively, making it the most important node in the network. Clusters 2 and 3 are indicated by blue and green with 17 and 6 nodes, respectively, with the most important nodes being the University of Washington (BC = 26.69, CC = 0.0167, PR = 0.026) and the University of Melbourne (BC = 33.60, CC = 0.0169, PR = 0.028), which had the highest betweenness, closeness and page rank in their respective clusters.

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Table 2. Information of authors with 10 or more publications

Author	NP	h_index	g_index	p_index	z_index	TC	PY_start
Zhang, L	18	6	11	10.19	6.89	138	2020
Lee, J	17	6	10	9.72	7.72	125	2020
Wang, Y	16	6	16	24.16	10.63	475	2020
Zhou, X	13	4	10	9.76	6.12	110	2020
Wang, J	11	3	6	4.99	3.49	37	2020
Mazzeschi, C	11	7	11	32.06	21.12	602	2020
Sciberras, E	11	6	11	22.12	16.92	345	2020
Baker, FC	10	5	8	7.81	5.90	69	2021
Lin, CY	10	7	10	21.90	18.77	324	2021
Zhang, Y	10	2	3	2.70	1.78	14	2021
Hutchinson, D	10	5	10	13.79	10.08	162	2020
Li, Y	10	4	10	14.13	7.28	168	2020
Zhang, J	10	5	9	9.66	6.78	95	2020
Chen, J	10	4	10	14.19	8.26	169	2020
Liu, CH	10	4	9	9.32	6.76	90	2020

Abbreviation: TC, total citations.

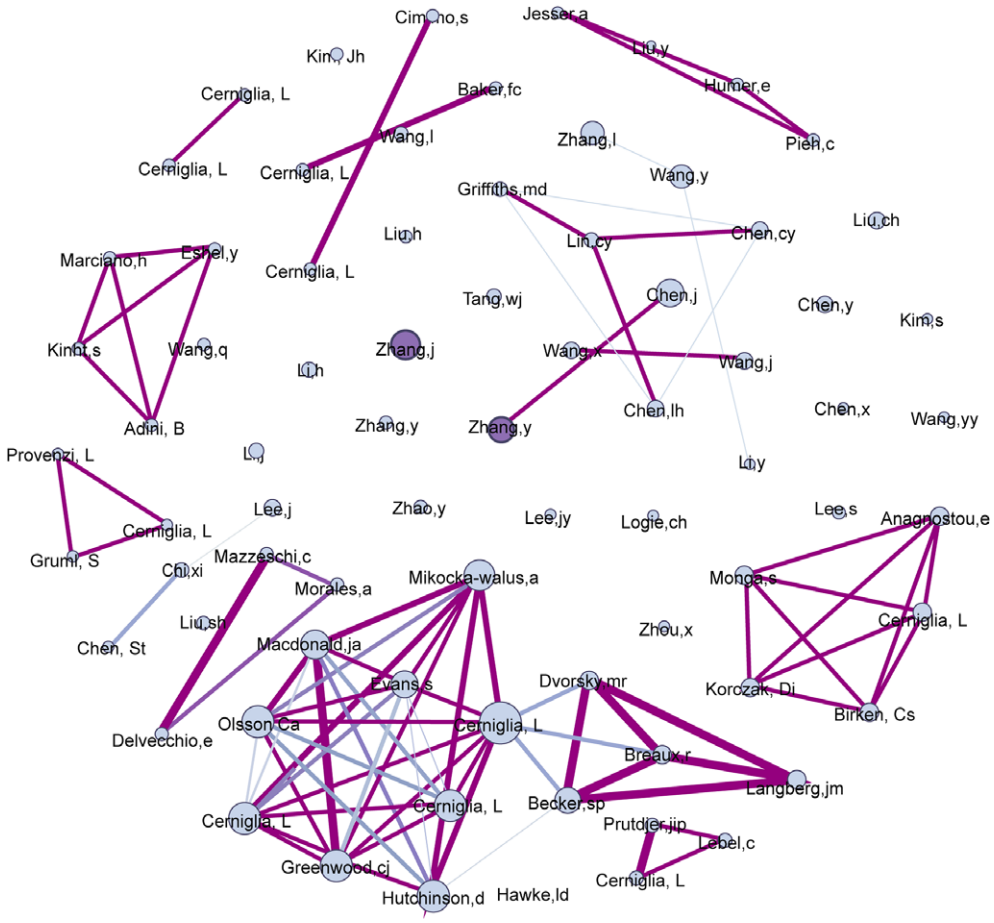

Figure 2. Author collaboration network map.

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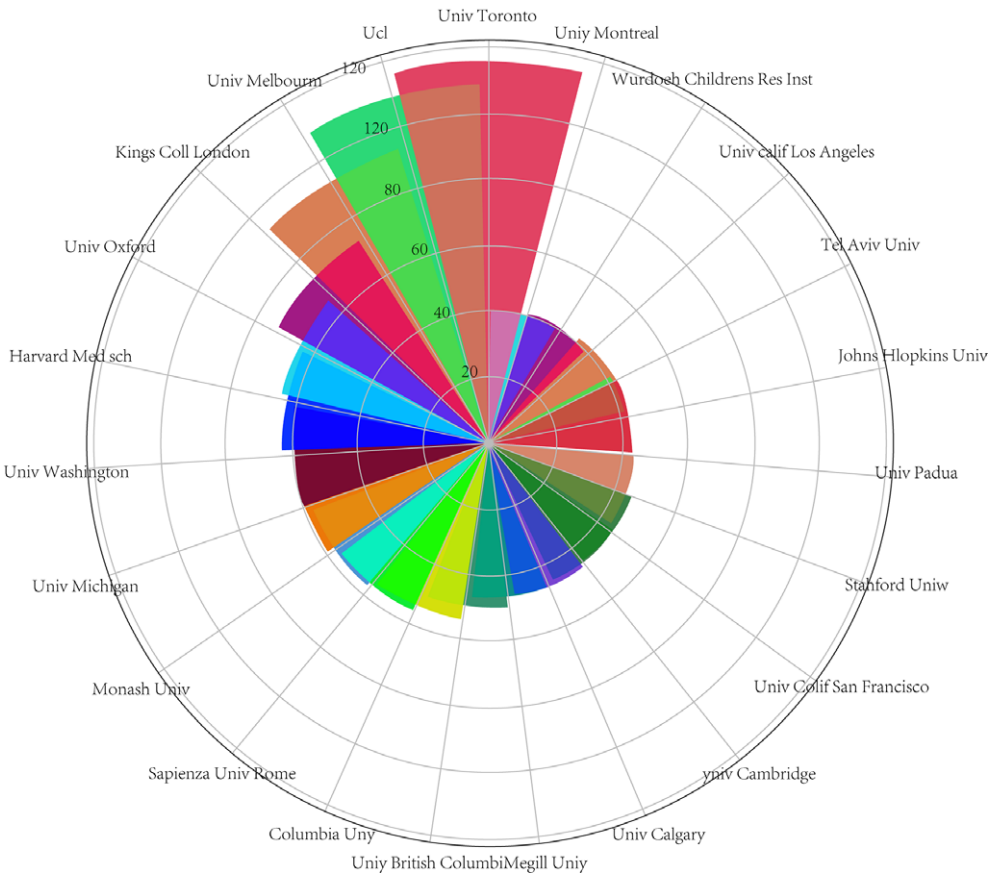

Figure 3. Ranking of research institutions with 40 or more publications.

3.3. Country

3.3.1. Country production

The author's country of origin is a commonly used variable in scientific evaluation, which can reflect the scientific output, academic climate and the degree of importance of a subject area in that country. A sum of 147 countries contributed to the publication output. As shown in Figure 5, the US' output was overwhelmingly dominant, with 1,656 publications, or 21.34%. The second highest ranking country was the UK with 589 publications, followed by China (n = 560), Italy (n = 452) and Canada (n = 407). The top 10 countries accounted for a large share of 62% of publications, with 75 countries with fewer than 10 publications.

3.3.2. Country collaboration networks

Figure 6 depicts the trend of research collaboration on the world map. The more connected lines and the denser the network, the closer the collaboration between countries. Overall, research activities related to child and adolescent mental health during COVID-19 existed in most countries. The largest contributor was the US, with 1,257 collaborations across 117 different countries worldwide, with the highest number of collaborations with the UK (n = 111), Canada (n = 103) and China (n = 97). Next was the UK, having 924 collaborations with 108 countries, the highest being with Australia (n = 69). Long distances did not prevent cooperation between countries.

3.4. Source

3.4.1. Core journal characteristics

Bradford's law is a model first described by Bradford (1934) that estimates the exponentially decreasing returns of searching for references in scientific journals. When scientific literature grows exponentially, Bradford's law helps us quickly identify and access the core journals in a specific field in the shortest possible time (Venable et al., 2016). A total of 1,246 journals published studies on related topics, with an average journal load of 4.16. According to Bradford's law, journals can be divided into core zones. Two zones containing the same number of studies can both be categorized as the core zone, each accounting for one-third of the total number of studies published in the discipline in all journals. At this point, the relationship between the number of journals in the core and successive zones is $1{:}n{:}n^2$ (Chongde and Zhe, 1998) (n is the Bradford coefficient). Table 3 shows that the average publication density of core zone journals was 78.64, which was considerably higher than that of related and discrete zone journals. Overall, 1,730 studies were published in core zone journals, accounting for 33.34% of the total number of studies published in this field. This indicated that research on COVID-19 and child and adolescent mental health was more stable in the WoSCC source journals.

Regarding the number of studies published in the journals and their influence, the journals with the highest numbers were *International Journal of Environmental Research and Public Health* (402; 7.75%), *Frontiers in Psychology* (212; 3.86%) and *Frontiers in Psychiatry* (168; 3.24%) (Table 4).

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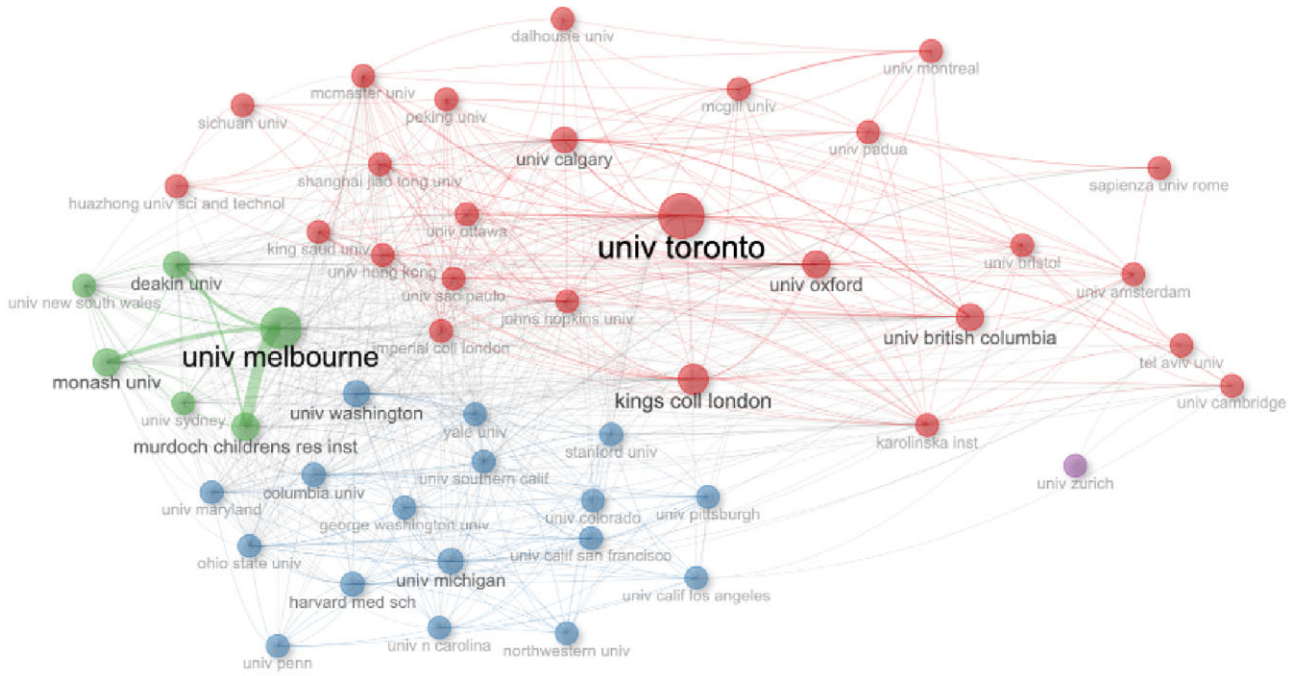

Figure 4. Institutional collaboration network map. BC, betweenness; CC, closeness; PR, page rank.

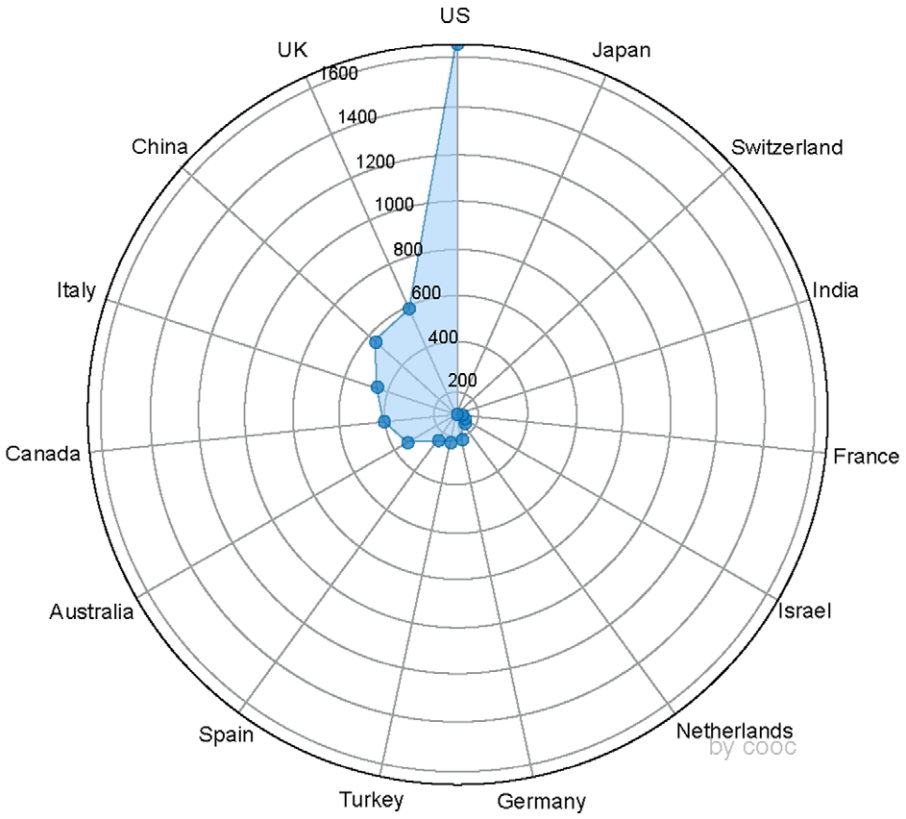

Figure 5. Countries with 100 or more publications.

3.4.2. *Journal co-citations*

Co-citation was introduced by intelligence scientist Henry Small and refers to two publications that are cited simultaneously in the reference of a third publication (Small, 1973). Figure 7 shows the co-citation network of journals on COVID-19 regarding child and adolescent mental health study. The network contained two different clusters. The red cluster was dominated by *Frontiers in Psychology* (BC = 49.29; CC = 0.0135; PR =0.034), which had a

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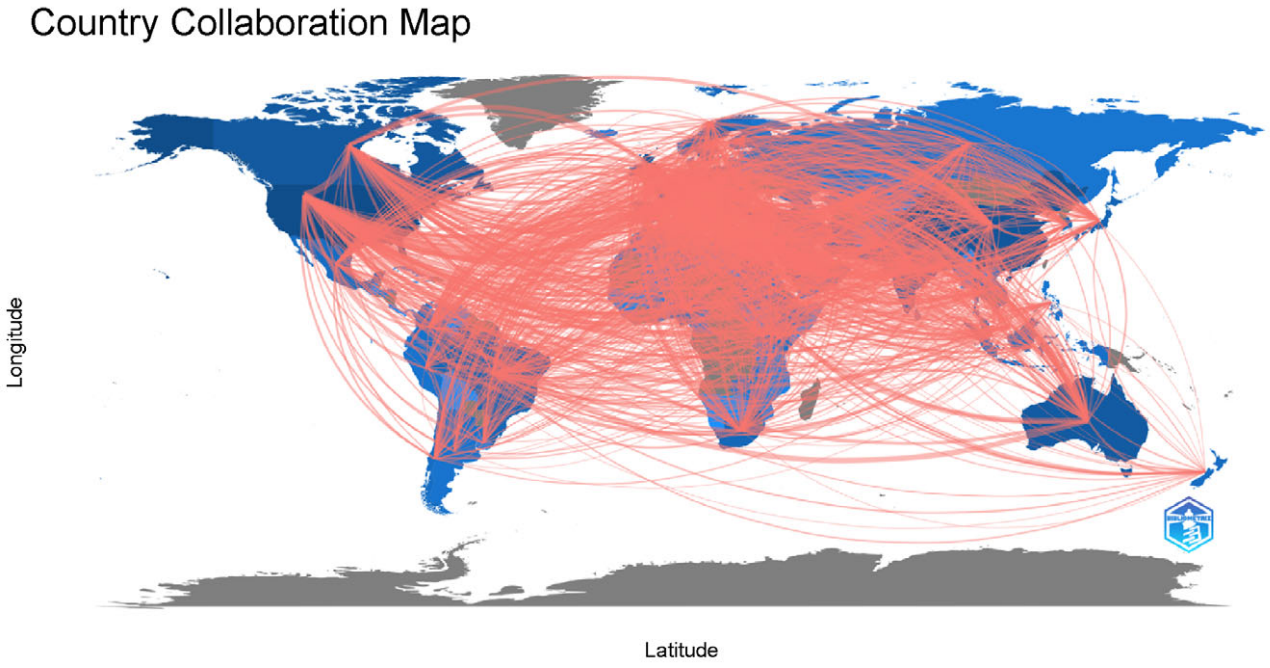

Figure 6. National cooperation map of publications worldwide.

Table 3. Core journals distribution

	No. of studies in journals	Total no. of journals	Percentage of total no. of journals (%)	No. of studies	Percentage of the total no. of studies (%)	Average total text density (studies/species)
Core zone	≥30	22	1.77	1,730	33.34	78.64
Related zone	5–29	183	14.69	1,793	34.55	9.80
Discrete zone	<5	1,041	83.55	1,666	32.11	1.60
Total		1,246	100.00	5,189	100.00	4.16

significant position in the journal co-citation network; the blue cluster was dominated by the *International Journal of Environmental Research and Public Health* (BC = 51.66; CC = 0.0139; PR =0.043).

3.5. Co-citation of literature

Co-citation of literature refers to the co-occurrence of multiple documents in the bibliography of a given cited document. By analyzing the key nodes in the co-citation network, we can analyze the classic literature of research fields and thus understand its knowledge structure and foundation. The higher the frequency of co-citations, the more closely related the academic research directions are, and the more likely they are to form a knowledge structure group in the field. Many bibliometric studies use literature co-citation analysis to study the knowledge structure groups that constitute the target literature (Pilkington and Meredith, 2009; Fahimnia et al., 2019). The most co-cited study was "The psychological impact of quarantine and how to reduce it: rapid review of the evidence" by SK Brooks, published in *The Lancet*, with 564 citations (Figure 8).

3.6. Co-occurrence network of author keywords

The co-occurrence of keywords refers to the simultaneous occurrence of different keywords; a higher frequency of co-occurrence indicates a higher degree of association of different keywords. By analyzing the co-occurrence of keywords, the internal structure of the research field and its relationships can be described, revealing the main dynamics of current research and, to a certain extent, the future development direction of the field. The co-occurrence of author keywords is presented in Figure 9. The analysis divided the author-supplied keywords into seven clusters, distinguished by their colors. The keywords that belonged to the same topic are gathered in one cluster identified with a different color scheme. The thickness of the lines depicts the strength of association between the keywords. The size of the circles depicts the number of occurrences of the keywords.

Seven clusters were formed, which were weighted based on the occurrences. Cluster 1 (23 items) is indicated in red, Cluster 2 (22 items) in green, Cluster 3 (21 items) in blue, Cluster 4 (21 items) in yellow, Cluster 5 (17 items) in purple, Cluster 6 (9 items) in light blue, Cluster 7 (4 items) in orange.

3.7. Country–keyword bimodal matrix bubble diagrams

The bimodal matrix bubble map of countries and high-frequency keywords visualizes the differences in research activity and research focus of different countries on different keywords. The size of the bubbles in Figure 10 indicates the frequency of research on the corresponding keywords, and the warmth of the color

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Table 4. Top 10 journals with the highest number of published studies

Source	NP	h_index	g_index	p_index	z_index	TC
International Journal of Environmental Research and Public Health	402	28	47	30.40	16.10	3,361
Frontiers in Psychology	212	24	50	33.91	15.97	2,875
Frontiers in Psychiatry	168	23	35	24.69	14.59	1,590
Frontiers in Public Health	96	10	19	12.96	7.03	457
PLOS ONE	85	20	35	28.41	17.09	1,396
BMJ Open	83	13	26	19.66	11.34	794
BMC Public Health	64	10	17	12.65	8.02	360
Children-Basel	60	9	15	10.78	5.58	274
Current Psychology	56	8	13	9.78	5.91	229
Journal of Affective Disorders	54	16	48	46.98	26.08	2,366

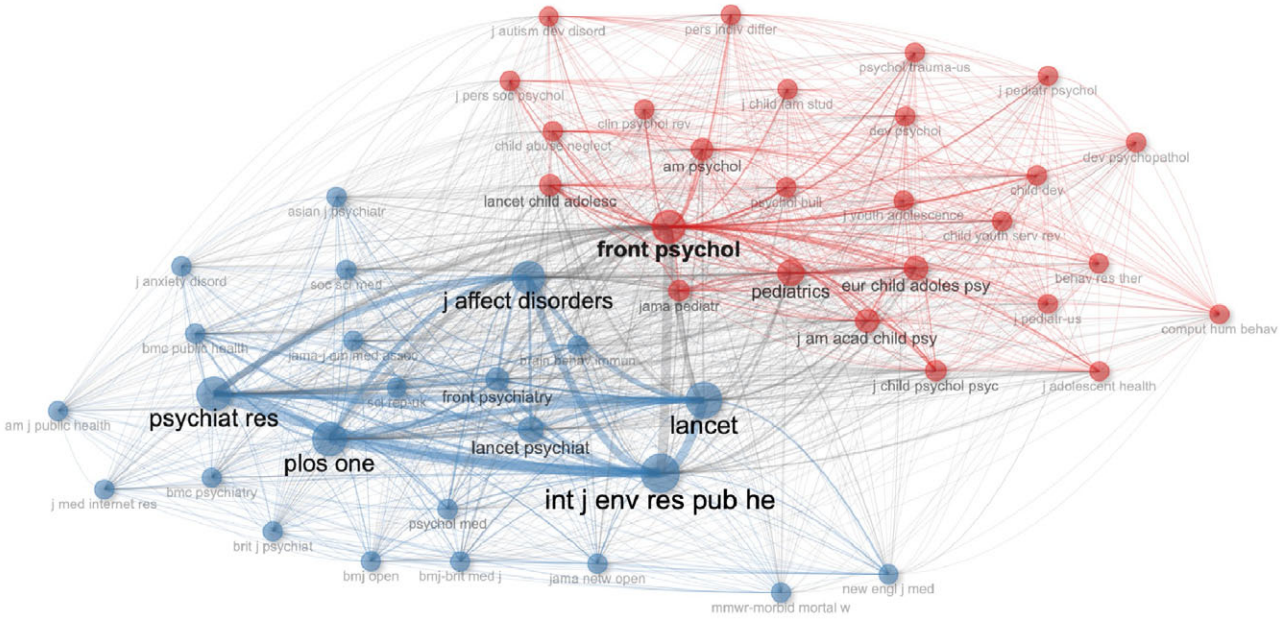

Figure 7. Journal co-citation network map. BC, betweenness; CC, closeness; PR, page rank.

reflects the research activity, with larger bubbles indicating a higher number of studies, and colors closer to warmer colors indicating more active research. The results show that all countries show high research frequency in the field of mental health, especially focusing on "Mental Health," "Anxiety," "Depression" and "Stress." The US is far ahead in the frequency of research activities on almost all keywords, and there are significant differences in the research attention on keywords among different countries. For example, China has a relatively high frequency of research activity on keywords such as "Adolescents," "Children" and "Mental Health"; the UK has a high frequency of research activity on "Mental Health" and "Education"; Germany pays more attention to "Quality of Life" and "Well-Being," while India has relatively high research activity on "Education" and "Public Health." There is a clear difference in research activities on different keywords across countries, reflecting their characteristics and strengths in the field of scientific research.

3.8. Author keyword clustering analysis

Bidirectional clustering analysis was conducted on the authors' keywords and five clusters were identified. Finally, the visualization matrix (Figure 10) and the visualization mountain map (Figure 11) were created. Combining the characteristics of the two figures, it could be concluded that cluster 0 and cluster 1 have the smallest volume, and that the number of studies is the same with the fewest. The peak of cluster 0 is light green, and the theme content is comparative consistency, mainly including children and adolescents, children development, psychological distress and autism. Cluster1 has a dark green peak top, indicating that the research content of this cluster is comparative discrete and mainly related to mental health, stress, depression, fear and life satisfaction. Cluster 3 and cluster 4 have the medium volume and contain the same number of topics. The peak color of cluster 3 is light green, which means that the content of the themes is relatively consistent, mainly

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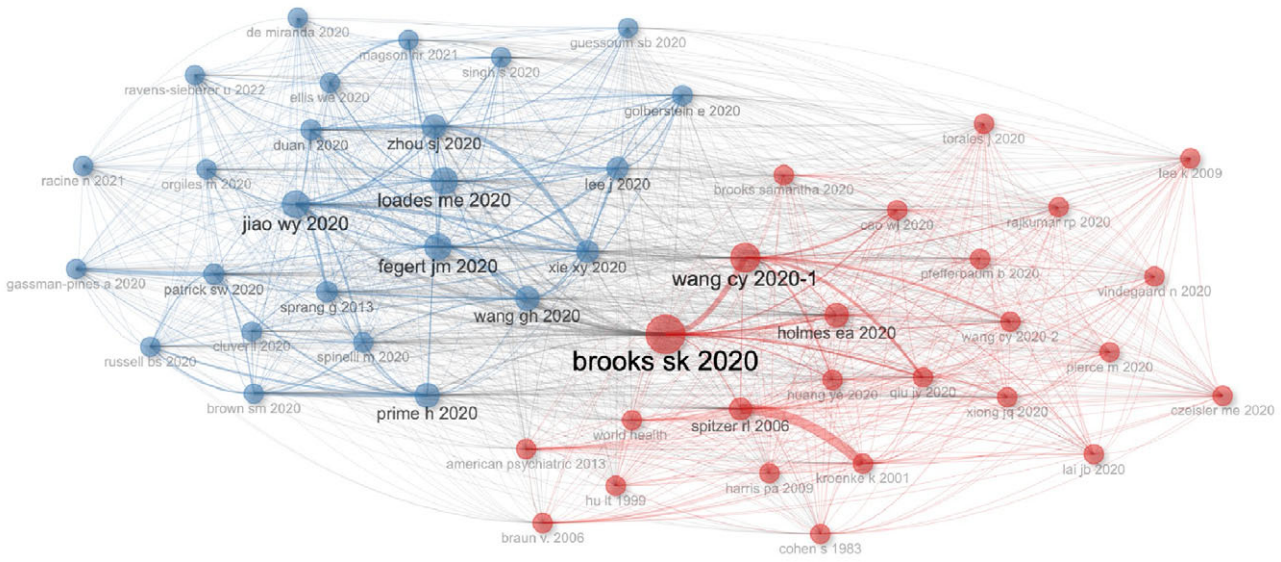

Figure 8. Co-citation network of literature.

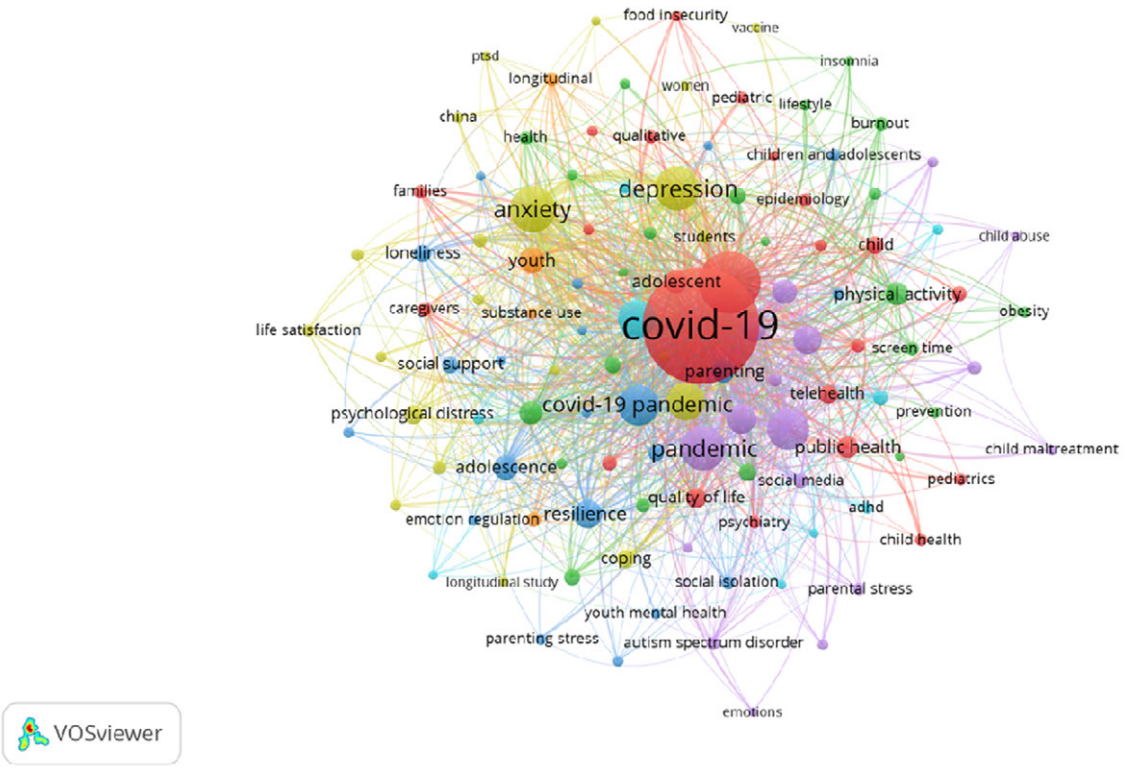

Figure 9. Co-occurrence network of author keywords.

containing physical activity, quality of life, family, education, lockdown, screen time and sleep. Cluster 4 peak color is yellow, indicating that there are more studies in this cluster, with the research content highly concentrated on students, anxiety, burnout, coping and social support. Cluster 2 has the largest volume and the top color is red, which means that the number of studies in this cluster is the largest, and research content is highly consistent, mainly including school, children, telehealth, telemedicine, social isolation, social media, suicide, loneliness, resilience and well-being.

3.9. Trend topics

Figure 12 illustrates the top five author keywords and the trend topics for each year between 2020 and 2022. In 2020, the trend topics included digital, telepsychology, psychological support, psychological effects and peer support. In 2021, children, depression, stress, COVID-19 and pandemic were critical themes for research. Adolescents, anxiety, mental health and resilience emerged as key themes in 2022.

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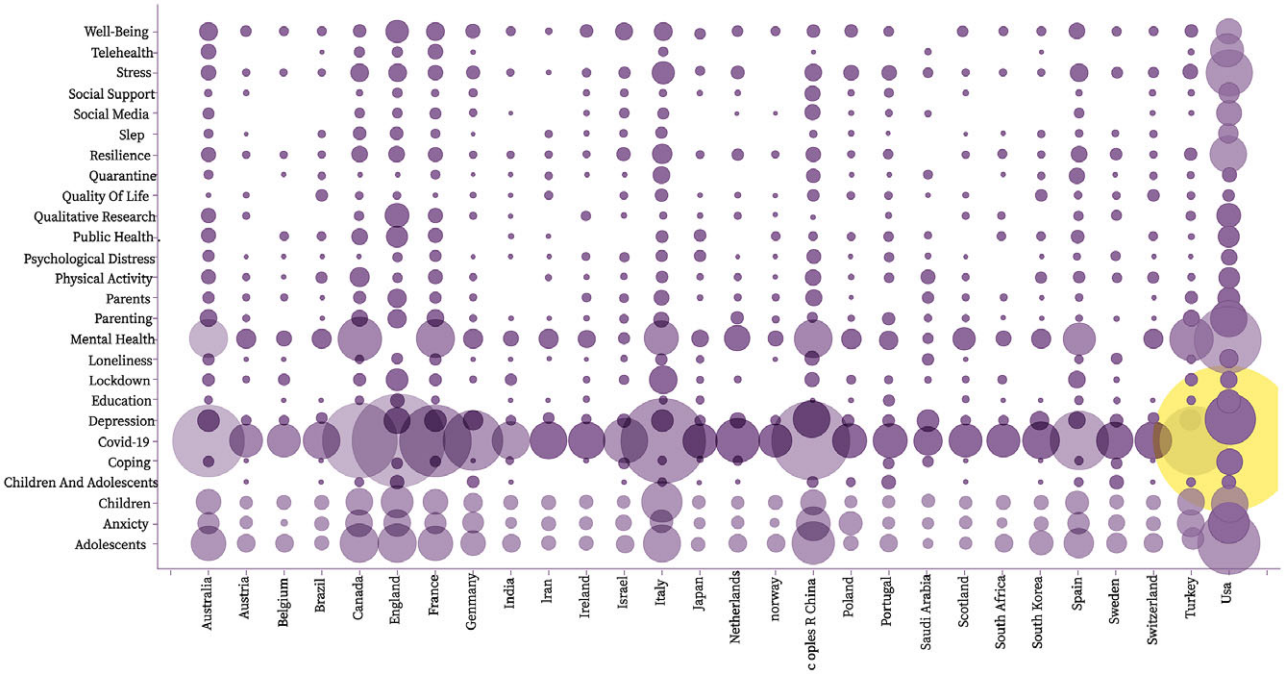

Figure 10. Country–keyword bimodal matrix bubble diagrams.

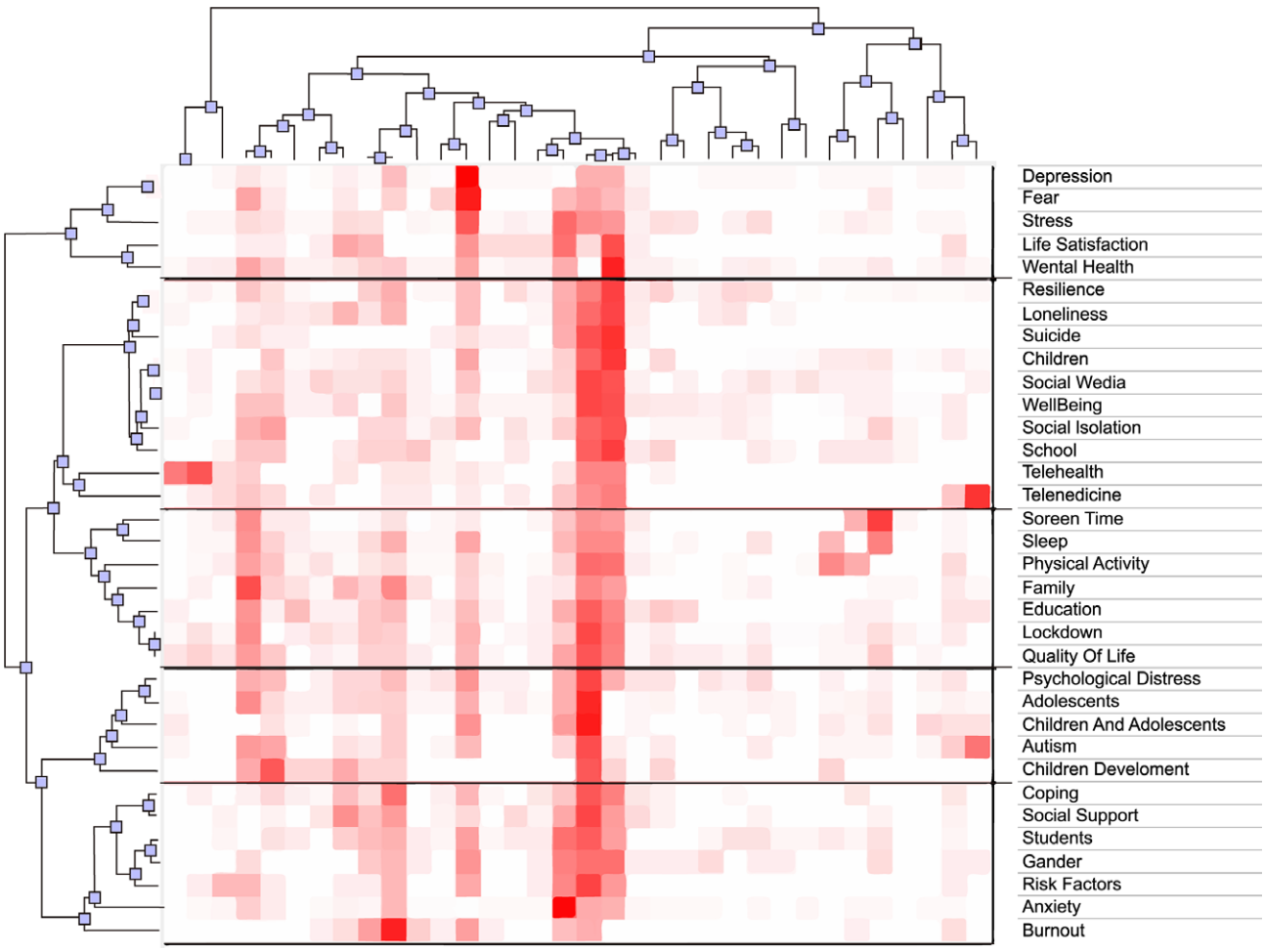

Figure 11. Bidirectional clustering matrix of high-frequency author keywords.

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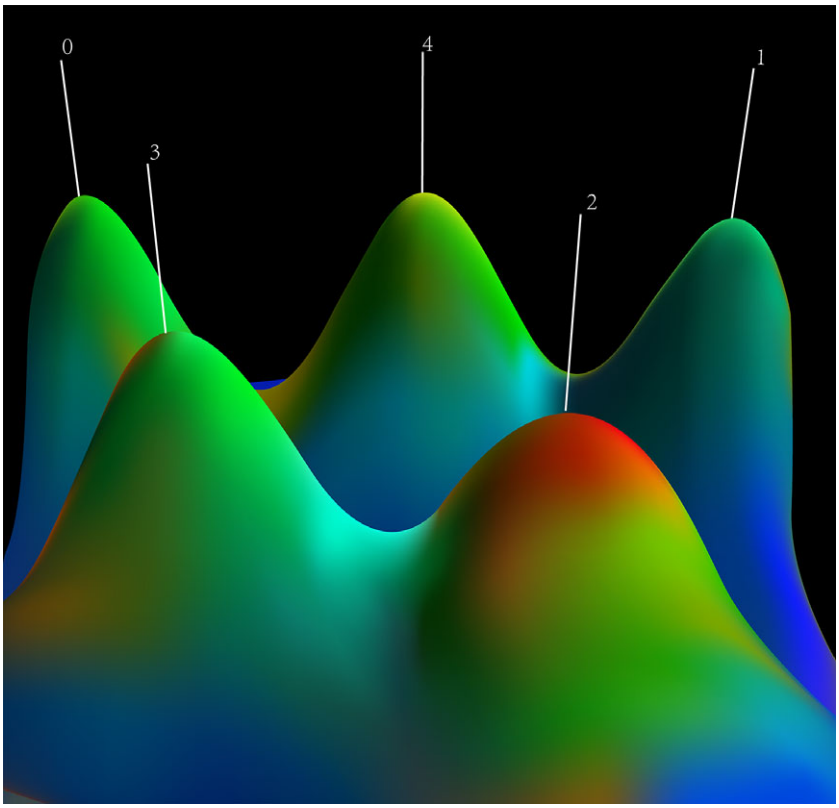

Figure 12. High-frequency author keyword clustering mountain map.

3.10. Thematic evolution

The literature was divided into different time-windows according to one-year intervals, and the annual distribution of the number of literatures was 458 in 2020, 1,891 in 2021, and 2,724 in 2022, because the search date was only until February 5, 2023, so there were only 116 in 2023. By calculating the hotness and frequency of occurrence of each theme in four stages, so as to determine the hot and potential topics in each time-window, the theme similarity of adjacent subperiods was calculated using the jaccard similarity algorithm to construct the thematic evolution trend of child and adolescent mental health during COVID-19. In Figure 13, the blocks of elements on the time axis represent individual themes, and the various colored connecting lines indicate the evolutionary relationships of each theme, including dynamic evolutionary processes such as newborn, extinction, transfer and stability.

The element block represents the research topic, and the element block size represents the weight (frequency) of the contained keywords, that is, the importance of the topic. The connecting lines represent the changes in the topics to which the keywords are subordinated, from left to right representing the years 2020–2023.

3.11. Thematic map

Figure 14 shows the thematic map of child and adolescent mental health research during COVID-19, where the horizontal coordinates indicate centrality and vertical coordinates indicate density, according to which four quadrants are drawn for analyzing the development and mutual influence of research themes. Quadrant I refers to important and mature research themes, indicating that current academic research hotspots include topics such as adolescents, anxiety, depression, stress, physical activity, screen time and exercise, among others. Quadrant II is a well-developed but unimportant research topic in the current field, suggesting that child maltreatment and autism spectrum disorder are not part of the core thematic direction of current research topics. The themes in Quadrant III indicate research directions that have just emerged or will disappear. Finally, the themes in Quadrant IV belong to the knowledge base of the research field.

The size of the circles in the four quadrants of the thematic map covering a number of topic terms usually indicates the importance or frequency of that topic term in the study. A larger circle means that the topic is more prominent or occurs more often in the study.

4. Discussion

The sudden outbreak of COVID-19 left the world shocked and unprepared. In the intervening three years, several studies related to the mental health of children and adolescents emerged for publication. First, scholars from across the world have been paying attention to this special group. Second, after three years of settling, with social life, study and work resuming, the mental health of children and adolescents cannot be ignored. Psychosocial effects follow pathogens (Jones, 2020; Wang et al., 2020) and that the associated effects may not diminish over time (Siu, 2008; Sim et al., 2010). By utilizing bibliometrics – a scientific way of collating and statistically compiling literature –we can quickly grasp the research hotspots, trends and so on. A subject search on WoSCC yielded over 400 publications related to COVID-19; however, bibliometrics related to child and adolescent mental health were not retrieved.

Our analysis of authorship characteristics and patterns of collaboration shows that the distribution of scholarly output varied widely. Although a high proportion of authors had published only

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Figure 13. Time view of high-frequency author keywords.

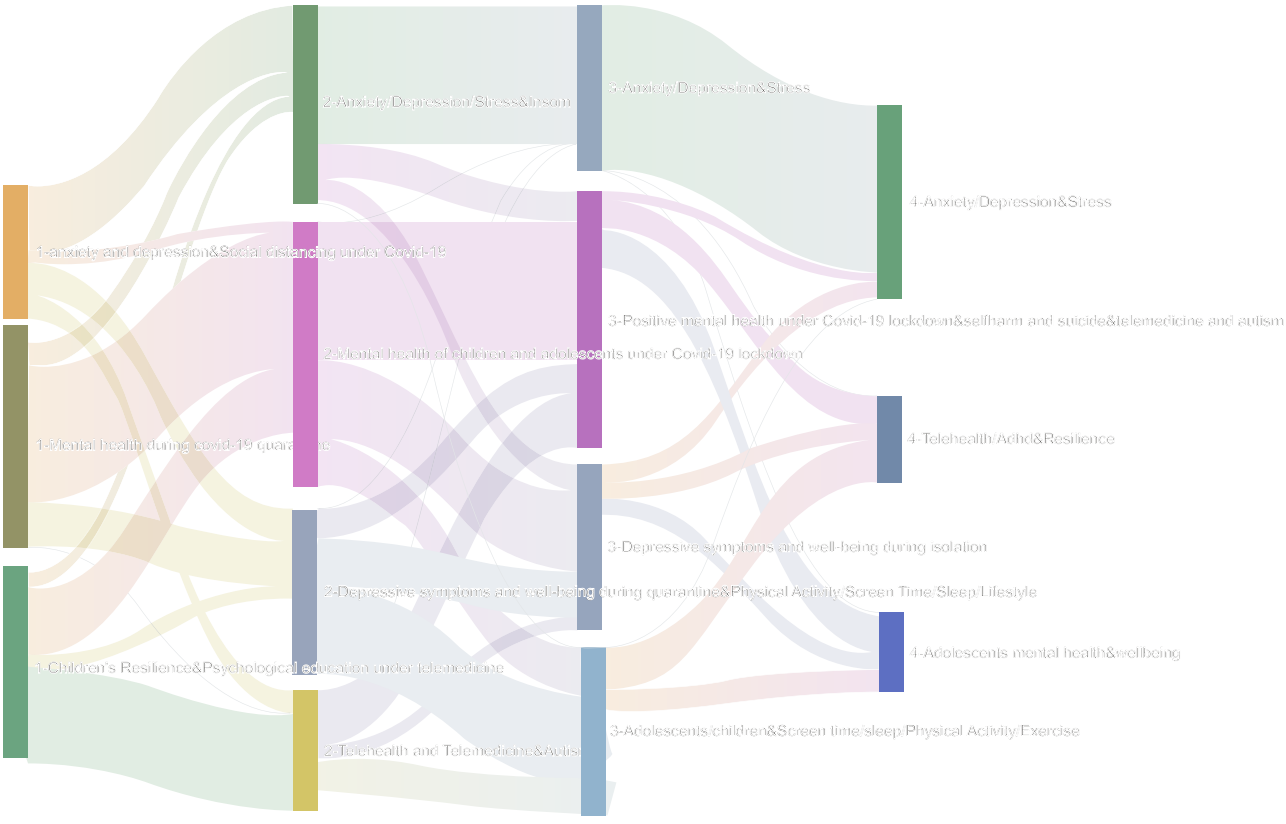

Figure 14. Thematic evolution maps.

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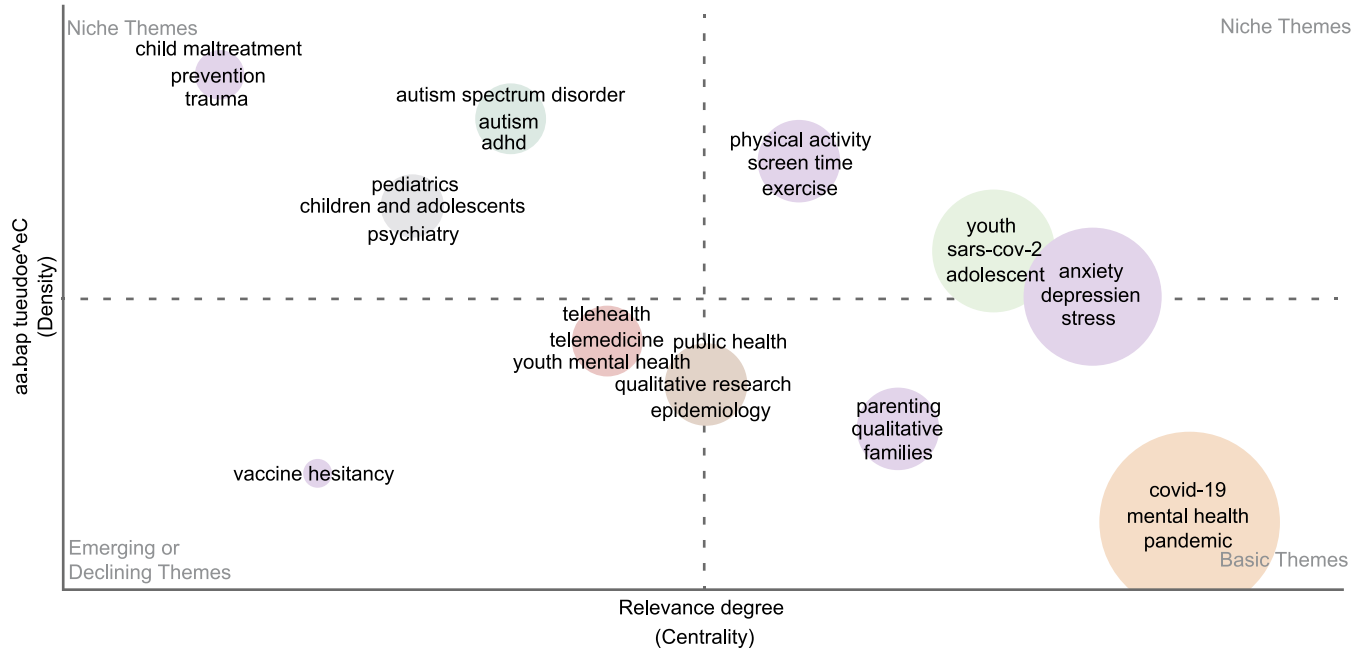

Figure 15. Strategic thematic maps.

one paper, the breadth of participation in the study emphasized the high level of global interest in this critical area. However, the lack of a clear core group of authors suggests the need for further collaboration to advance the field. This also provides an opportunity to promote broader, more coordinated research, for example, through collaborative programs that bring together multiple institutions and experts, especially those with recognized contributions who can play a key role in convening efforts for multicenter, interdisciplinary collaborations. This will both integrate existing research efforts and create synergies that will help advance the systematization of the knowledge base in this area.

An analysis of institutional participation highlights the central role of universities in advancing child and adolescent mental health research during the pandemic. The Universities of Toronto, London and Melbourne led the way in terms of the number of publications. However, 70.40% of the research institutions had only one study output, and the prevalence of single institutions points to the need for a broader range of institutions to maintain research continuity. Strengthening knowledge exchange and collaboration among top universities, especially with those that are leaders in the field, can expand the scope and impact of research. This would not only consolidate existing strengths but would also create synergies to advance knowledge in the field.

The top 40 institutions, excluding the Tel Aviv University, the Hong Kong Polytechnic University, the Chinese University of Hong Kong, the University of Hong Kong and the Shanghai Jiao Tong University, were mostly from European and American countries, with a focus on Canada, the US, the UK and Australia. The US had a leading position in the output of this field, followed by the UK, China, Italy and Canada. The extensive collaborative networks between these countries underscore the international character of the research. Cross-border collaborations such as those in the US and the UK have contributed to a more holistic understanding of the mental health challenges of children and adolescents in the context of the pandemic. Therefore, continuing to nurture these cross-border collaborations promotes knowledge sharing and mutual support to address the complex and diverse psychological needs of children and adolescents globally.

The frequency of research on the keyword "COVID-19" has increased dramatically around the world. Several countries, notably the US, China, the UK, Italy and Canada, have increased their research efforts on this issue. Mental health is a global concern, with several countries focusing on child and adolescent mental health, reflecting a common global concern for the next generation's mental health, especially in the face of challenges such as COVID-19. The US has notable research activities on the vast majority of keywords, which demonstrates the wide coverage of US scientific research and the diverse areas of concern, covering not only health issues but also education, social support, family and many other aspects. China has a relatively high research frequency on keywords such as "Adolescents," "Children" and "Mental Health," which shows China's concern for children and adolescents in the area of mental health. The high frequency of research on "Mental Health" and "Education" may imply that the UK has a focus on education policy and practice alongside important research contributions in the field of mental health. Italy has a high frequency of research on keywords such as "Depression," "Anxiety" and "Stress", which shows that Italy has more prominent research activity in the field of mental health, especially related to emotions and stress. Canada has a high frequency of studies on "Mental Health" and "Social Support," which may imply that Canada is concerned with mental health issues and has conducted research in the area of social support and interpersonal relationships. Australia has a higher frequency of studies on "Adolescents" and "Mental Health," which is similar to that of China, showing the characteristics of Australia's focus on the mental health aspects of adolescents. Research in the field of child and adolescent mental health has attracted a lot of attention in the context of COVID-19, and the differences in the research focus of different countries have also highlighted the importance of global research cooperation, which

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can be achieved through sharing experiences and cooperation among countries. Countries can work together to address global challenges by sharing experiences and collaborating on research. In addition, these findings provide an important reference for national research institutions and policymakers on research investment, resource allocation and research direction planning to better meet the needs of society and promote scientific and technological innovation and social progress.

High average publication density of 78.64 in core area journals signifies that research on child and adolescent mental health during the COVID-19 period stabilized in WoSCC source journals, and research keys can be quickly identified by accessing core journals in specific areas. The studies were mainly published in journals such as the *International Journal of Environmental Research and Public Health*, *Frontiers in Psychology* and *Frontiers in Psychiatry*, among others.

An analysis of the co-occurrence network of author keywords showed that studies on child and adolescent mental health related to family accounted for most of the research, compared to those related to schools and teachers. This may be owing to the closure of schools during the pandemic. The United Nations Educational, Scientific and Cultural Organization estimates that 138 countries worldwide closed schools for the pandemic, affecting the education of 80% of children worldwide (Van Lancker and Parolin, 2020). The COVID-19 outbreak and the resulting mass isolation, lockdowns and shift in social behavior patterns disrupted the daily life, physical activity, social life and educational progress of children and adolescents. It impacted their physical and mental health, leading to anxiety, depression, post-traumatic stress disorder, sleep problems and non-suicidal self-injury (Brooks et al., 2020; Bosch et al., 2022).

Keyword co-occurrence analysis, author keyword clustering and examination of trending themes over time provide valuable insights into the evolving research priorities of the field. The results of the cluster analysis showed that the research hotspots were mainly focused on stress, depression and anxiety, among others. At the same time, a review of the themes in child and adolescent mental health and their interactions during the period 2020–23 revealed that anxiety and depression were present throughout the research cycle. In the early stage of this field (i.e., child and adolescent mental health during COVID-19), digital, telepsychology, psychological support, psychological effects and peer support became important hotspots at that time (e.g., mid-2020). As events changed and evolved, research related to depression and stress became a hot topic, while concurrently there was a gradual expansion of research with children to include adolescent populations and to include studies on topics such as anxiety and resilience. The emergence of keywords such as "digital," "telepsychology," "mental health," "stress," "anxiety," "depression" and "resilience" reflects researchers' dynamic attention to the unique impact of the pandemic on the mental health of children and adolescents. This trend indicates a growing emphasis on understanding the impact of digital interventions, coping mechanisms and mental health support strategies on children and adolescents in the context of a pandemic. Continued monitoring of these trends is critical to adjusting research priorities to meet the changing needs of this population.

Thematic evolution provides a map of how the field of child and adolescent mental health research has developed over the years during the pandemic. These findings demonstrate the evolutionary trajectory of research themes through periods of emergence, stabilization and alteration, reflecting the dynamic nature of scientific inquiry. There were consistent themes in the strategic theme map (Quadrant I), such as "adolescent," "anxiety," "depression," "stress," "physical activity," "screen time" and "exercise," indicating the centrality and maturity of these themes to the field. Researchers can continue to focus on these core themes to contribute to building on existing knowledge to inform interventions and policies. Quadrant II themes such as "child maltreatment" and "autism spectrum disorder," while well developed, do not appear to be at the center of current research, suggesting a need to revisit their importance and relevance in the context of the pandemic. In the future, it may be possible to integrate these themes into broader research that explores the intersection between child maltreatment, the autism spectrum and the mental health implications of the pandemic, thus providing a more comprehensive understanding of these issues. Themes in Quadrant III represent emerging or disappearing research directions that may reflect a shift in the center of gravity of research and deserve close attention. Themes such as "telemedicine," "telehealth," and "vaccine hesitancy" in this quadrant emphasize the importance of mental health services. Quadrant emphasizes the changing nature of mental health services and the importance of evaluating the effectiveness of new intervention models. Finally, the positioning of themes in Quadrant IV of the thematic map signaled foundational aspects of the research field. These themes include "COVID-19," "mental health," "families" and "parenting," representing the core pillars of child and adolescent mental health research during the pandemic. As researchers delve deeper into these fundamental aspects, it is necessary to consider the broader context of children's lives, including their educational experiences, social interactions and overall well-being. This fundamental knowledge is critical to developing a comprehensive approach to addressing mental health issues and increasing the resilience of children and adolescents facing the challenges of the COVID-19 pandemic.

In the face of completely different contexts and environments during COVID-19, such as social pressures, social isolation and learning environments, these factors may have an impact on child and adolescent mental health, but in the face of these differences, anxiety and depression have been dominant themes in the field of child and adolescent mental health research. The relative stability of the research focus may reflect the continuity and robustness of child and adolescent mental health research themes and concerns. This suggests that researchers and policymakers in related fields have maintained a focus on child and adolescent mental health amidst the challenges and changes brought about by the epidemic, which has important implications for the development and implementation of related policies and practices. In the face of the potential impact of public health emergencies, such as COVID-19, on the mental health of children and adolescents, we strongly advocate the development of specialized contingency plans to ensure timely intervention and support for this vulnerable group. Firstly, by raising public awareness, we aim to reduce social indifference to child and adolescent mental health issues and create a basis for effective intervention. Second, we call for close collaboration among experts across sectors and fields to study child and adolescent mental health issues to formulate systematic and effective policies. Finally, special attention should be paid to children and adolescents with pre-existing mental health problems and those on the margins of society to ensure that they receive adequate psychological care. Only through the concerted efforts of all sectors can we build a society that attaches great importance to the mental health of children and adolescents and responds to it effectively. Child and adolescent mental health is a long-term and critical area that is related not only to the healthy development of children and adolescents but also to the long-term stability of society.

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5. Limitations

This study had the following limitations. First of all, bibliometrics as a research method has some inherent defects of its own. Specifically, it is difficult for us to assess the quality of each document in detail, and the use of secondary literature analysis also makes it impossible for us to validate the original data, and the results of statistical indicators of bibliometrics are only accumulated by the method and do not fully reflect the actual situation. For example, the number of citations is a common statistical indicator in bibliometrics; however, it can only reflect the relative influence of the literature and not its actual value. Moreover, the results of statistical indicators in bibliometrics are influenced by the measurement methods. For example, the use of different measurement methods can lead to different results of statistical indicators. This means that the results of statistical indicators of bibliometrics are not completely accurate and there are certain biases. Therefore, caution is needed when relying on the statistical results of bibliometrics to make inferences. Our findings and conclusions need to be interpreted cautiously and cannot be directly equated with bibliometric statistical values. In the future, we will adopt meta-analysis and other methods to validate the raw data as well as optimize the process of literature screening and assessment to make up for the shortcomings of bibliometrics and improve the quality and reliability of our study. At the same time, we have not been able to both make a clear distinction between children and adolescents, given that the data sources in the literature are mainly secondary and some studies do not distinguish between the two groups, as well as explore in depth the differential impact of the pandemic on different subgroups of children and adolescents. In addition, as a literature analysis, this study did not take into account cultural or contextual factors that may have influenced the mental health of children and adolescents during the COVID-19 pandemic, which may limit the generalizability of the findings. Despite this limitation, our findings may provide valuable information to policymakers at the macro level to understand the full scope of research in this area. Of course, we also recognize that due to the differences in psychological development between children and adolescents, it is necessary in the future to conduct research that differentiates between these two populations and to conduct more detailed studies that take into account cultural and contextual factors in order to develop policies and practices that are more responsive to the needs of different cultures at different ages and stages. Second, we retrieved data only from the Web of Science. The limitation of selecting a single database for bibliometric analysis can affect the comprehensiveness of the bibliographic search results and the generalization of the results. This is because different databases may include different literature, and selecting a single database for the search may lead to the omission of some relevant literature and affect the comprehensiveness of the search results. Additionally, the literature in a single database may reflect some kind of bias, such as the high number of publications of certain literature, which may lead to less generalized results of statistical analysis. In addition, because positive results are more likely to be published, the bibliometric analysis may suffer from publication bias and overestimation of certain statistical parameters, and also, this study only included English literature, which may suffer from language bias and did not include relevant studies in other languages, which attenuated the generalizability of the results. In this study, we selected the timeframe from December 2019 to February 5, 2023, which encompasses the entire phase from the initial outbreak of the COVID-19 pandemic to the complete reopening of China's borders. We believe this timeframe adequately reflects the primary progression of the COVID-19 pandemic. Based on the records exported from the database, we included a total of 5,189 publications. To ensure the comprehensiveness and diversity of the research, we chose not to further filter the literature. However, this approach brings a significant limitation: including all retrieved articles might introduce noise from non-essential studies. Yet, this comprehensive method also allowed us to capture a broader range of research trends. The analytical tools we employed ensured accurate identification and emphasis of vital themes and patterns, offering valuable insights into the research trends regarding the mental health of children and adolescents under COVID-19 and laying a solid foundation for future studies. Meanwhile, we also encourage other researchers to adopt stricter literature screening criteria in more specific or segmented research fields to enhance the accuracy of research analysis. Due to the existence of various possible biases mentioned above, the results of this study need to be interpreted with caution, and subsequent studies need to take measures to minimize the effects of various types of bias.

6. Conclusion

The COVID-19 pandemic has captured the mental health discussion worldwide (Yalcin et al., 2022). Facing overwhelming information and rapid turnover, bibliometrics as a scientific way of bibliographic and statistical organization has gradually become the core concern of researchers worldwide. This study draws on Lotka's, Price's and Bradford's laws (which are most commonly used in bibliometrics) to determine the core author and core journal characteristics. It also combines the advantageous algorithms of each software and adopts a novel bibliometric statistical tool from author, affiliation, country, journal, literature, keywords and so on to describe their external characteristics and internal associations in detail to pay more attention to the trend of research on the mental health of vulnerable groups during the pandemic. The findings of this study can provide insights and guidance for policymakers, practitioners and researchers. For policymakers, we recommend investing more resources and encouraging interdisciplinary collaboration to build a stable and high-level core team of authors, which will in turn enhance the continuity and depth of research. This will help better plan policies and resource allocation to ensure efficient and long-term research outcomes. For practitioners, we encourage active participation in international collaborations to enhance impact through publication of research results in high-quality journals and to facilitate sharing of domestic and international experiences to enhance practice. For researchers, we recommend continuing to focus on core themes, especially research in the areas of depression, anxiety and stress while closely tracking emerging issues such as telehealth and social isolation. This will help build a more systematic research base while addressing the changing challenges in the field and promoting the continuous development of the research field to better respond to the challenges and needs faced by children and adolescents in this special period.

List of abbreviations

COVID-19	coronavirus disease 2019
TS	Topic searches title, abstract, author keywords and Keywords Plus
WoSCC	Web of Science™ core collection

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Data availability statement. The datasets generated or analyzed for this study can be found in the WoSCC website (https://www.webofscience.com).

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Author contribution. Mengxue Fu: Conceptualization and roles/writing – original draft; Mengxue Fu and Qin Lin: Data curation and formal analysis; Jijun Wu: Supervision and validation; Mengxue Fu and Pan Li: Funding acquisition and project administration; Lingyao Meng and Linfeng Liu: Methodology and writing – review and editing.

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Competing interest. The authors declare none.

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