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RAPID COMMUNICATION

Effects of COVID-19 pandemic on human fertility: A scientometric and visualized evaluation

COVID-19, also known as coronavirus disease 2019, is a novel coronavirus disease with high infectivity, strong heterogeneity, and long incubation period (generally 3—14 days). Its main symptoms and signs include fever, dry cough, nasal congestion, fatigue, disorientation, lymphopenia, and dyspnea.[1] The short-term and long-term impacts of COVID-19 on human health, particularly its effects on human reproduction and offspring development, continue to receive significant concerns, as they may lead to potential sequelae for several decades or even centuries.

Although some results have been obtained on the effects of the COVID-19 pandemic on reproduction and development, there is significant controversy about the uncertain conclusions due to the difficulties of data collection and controlled studies on the research of human reproductive system. Several papers reviewed and retrospected the research results in this area, but systematic and visual analyses using scientometric methods have not yet been available.

In this study, a total of 14,613 literature and data records related to the COVID-19 epidemic affecting human fertility were collected from the Web of Science core collection, and then the data were analyzed and visualized in terms of the research framework, hotspots, and frontier research areas with the visualization software *CiteSpace* (detailed as Data Sources and Methods in supplementary file). In addition, the limitations and controversies of current research are analyzed and discussed.

The study utilized keyword co-occurrence clustering analysis to summarize the closely related keywords and obtain core themes. The analysis revealed that there were eight subclusters of co-occurring keywords in this field, including #0 vertical transmission, #1 sars-cov-2, #2 telemedicine, #3 anxiety, #4 domestic violence, #5 vaccine hesitancy, #6 sexual health, and #7 preterm birth (Fig. 1A).

The study also utilized literature co-citation clustering analysis to anchor the research frontiers in this field. As shown in Figure 1B, the analysis revealed #0 vertical transmission, #1 semen, #2 anxiety, #3 placenta, #4 vaccination, #5 children, #6 sexual behavior, #7 pregnancy, #8 breastfeeding, #9 preterm birth, #10 remdesivir, #11 vaccine hesitancy, #12 abortion, #13 preeclampsia, and #14 menstrual cycle as the top 15 clusters. Finally, the study utilized an alluvial flow diagram to reveal the patterns' evolution for research concepts in the scientific field over time. The results showed that among numerous keywords, "psychology", "mechanism research", "short- and long-term symptom", and "management" presented the longest research flow, with a focus on symptoms and management in early time, the proportion of attention paid to mental health and mechanism research had been increasing year by year (Fig. 1C). The representative words of psychology were mental health, antenatal depression, domestic violence, postnatal depression, hospital anxiety, racial disparities, and online media. The representative words of other directions are shown in Figure 1C.

Despite current research on the impact of COVID-19 on human reproductive and newborn development, the study highlights several debates and limitations based on the visualization maps and literature review. (i) Current research has preliminarily proven the safety and effectiveness of COVID-19 vaccines in preventing infection and its after-effects. (ii) Although most studies have no evidence of vertical transmission of the SARS-CoV-2, a few reports suggest that the virus is detected in newborns, and there is almost no detection of mother-offspring bonds (*e.g.*, placenta, umbilical cord, and amniotic membrane), therefore the possibility of vertical transmission remains to be investigated.[2] (iii) There is no clear conclusion as to whether there is SARS-CoV-2 virus in male semen. A few cases of virus detected in semen are considered polluted by surrounding tissues and cells or the external

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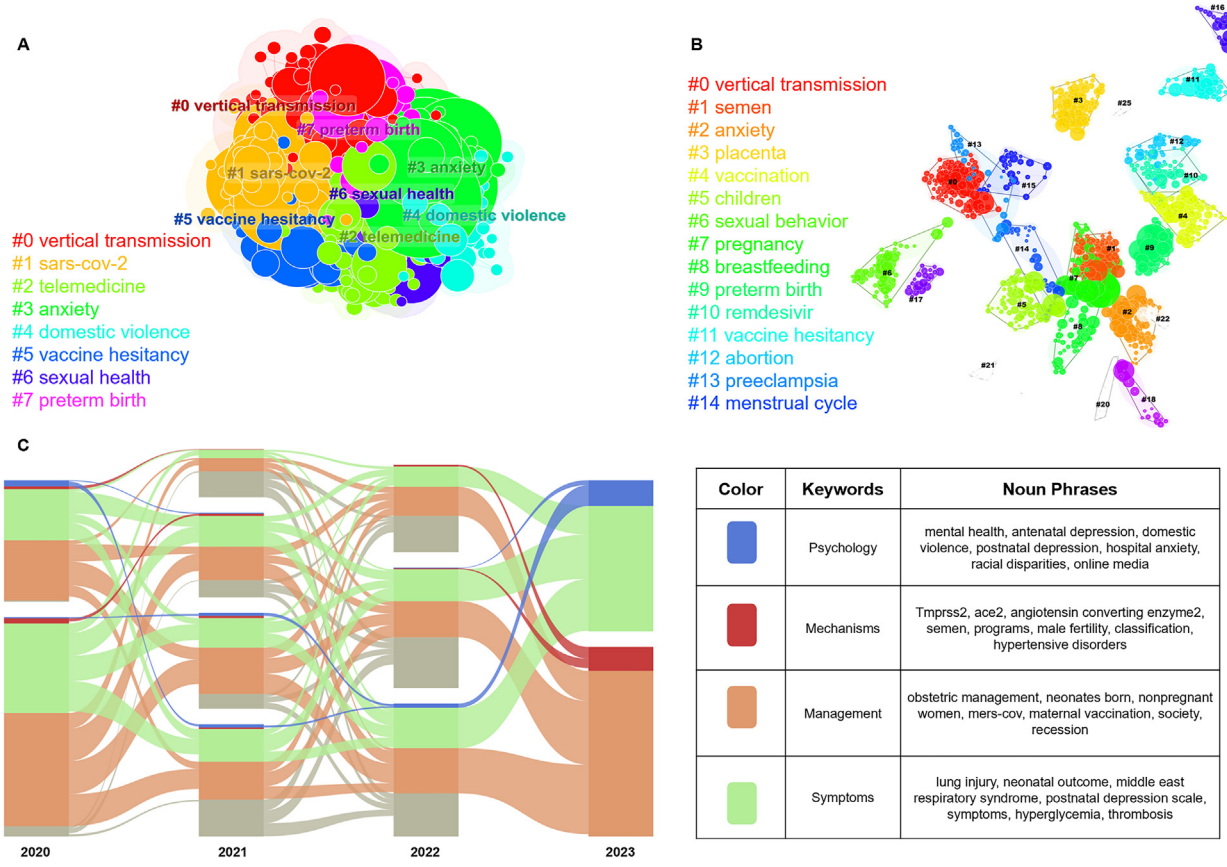

Color	Keywords	Noun Phrases
	Psychology	mental health, antenatal depression, domestic violence, postnatal depression, hospital anxiety, racial disparities, online media
	Mechanisms	Tmprss2, ace2, angiotensin converting enzyme2, semen, programs, male fertility, classification, hypertensive disorders
	Management	obstetric management, neonates born, nonpregnant women, mers-cov, maternal vaccination, society, recession
	Symptoms	lung injury, neonatal outcome, middle east respiratory syndrome, postnatal depression scale, symptoms, hyperglycemia, thrombosis

Figure 1 Scientometric and visualized evaluation of the effects of the COVID-19 pandemic on human fertility. **(A)** Keyword co-occurrence clustering and **(B)** co-citation clustering analysis (Modularity $Q = 0.8091$). Modularity Q is an evaluation index of network modularization. If the value is above 0.5, the clustering result could be considered reasonable. **(C)** Alluvial flow of keywords. Each year top 100 noun phrases formed a Pathfinder network.

environment, so more rigorous sampling and detection are necessary.[3] (iv) Whether vitamin D deficiency is related to the clinical symptoms of pregnant women after viral infection is also controversial, and needs more clinical data to conclude. Appropriate prenatal vitamin D supplementation is mostly recommended.[4] (v) The benefits of breastfeeding far outweigh the very low risk of COVID-19 infections in infants, so direct breastfeeding with appropriate hygiene precautions is strongly recommended.[5] (vi) The understanding of the specific pathogenesis and mechanism of the virus on the reproductive system after SARS-CoV-2 infection is still lacking, and the expression of ACE2 receptor alone cannot determine the invasion of the virus, hence more prospective and long-term research is needed to deepen our understanding of the impact of COVID-19 on human reproductive ability and to improve our comprehensive understanding of feasible strategies for mitigating or eliminating potential sequelae. (vii) Attention should be paid to the current social issues related to COVID-19, especially the psychological problems related to reproduction, including the risks of sexual relationships, sexual behavior, and anxiety and depression in pregnant women under the influence of COVID-19, as well as the economic development, medical facilities, epidemic prevention measures, and resource allocation in different regions while raising public awareness of the necessity of basic and clinical research, evaluation, and follow-up. (viii) Continuous attention and research should be given to the impact of mutant strains of the virus on fertility and fetal development, and professional online medical consultation and counseling, and even the development of public psychological counseling platforms, should be actively carried out, while sharing the latest clinical data of patients domestically and internationally, which will help to some extent in disease prevention and control, drug development, evolution analysis of mutant strains, and even help researchers to predict possible trends of virus mutation.

In this study, as comprehensive keywords as possible were provided to collect a wide range of literature data related to COVID-19 and human fertility. Utilizing the scientometric method *CiteSpace*, this field's landscape and core themes were objectively and systematically visualized to reflect the research hotspots and trends over time. Additionally, summarizing the conclusions and hotly debated topics from the latest literature offered a clearer

macroscopic perspective of the topic. The findings emphasize the importance of continued research into the virus's long-term effects, to guide future research efforts and public health strategies to mitigate potential sequelae and address psychological, medical, and social issues related to COVID-19's impact on human reproduction and offspring development. However, it should be noted that a small number of relevant literature may still be missing, or some non-closely related publications could be included in the input data. Given the substantial volume of literature data used, any potential impact on the results is considered minor.

Author contributions

G.X. Wang and X.C. Rao conceived the study idea; X.X. Wang and L.L. Tan collected and analyzed data; Z.Q. Hu, L. Wen, W.X. Qin, B.Y. Li, K.Q. He, T.Y. Yin, J.H. Qiu, and Y.M. Wang participated in data analysis and discussion; X.X. Wang, Z.Q. Hu, Y.F. Rao, and L.L. Tan wrote the manuscript draft. G.X. Wang, X.C. Rao, and Y.K. Chen revised and polished the manuscript; all authors contributed to literature reading & analysis and the writing of the manuscript.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gendis.2023.101127.

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