

Exploring the advantages, challenges and strategies of online medical education during the COVID-19 pandemic: A Structured Narrative Review

Yang Zhang¹, Guoliang Pang², Men Liang³, Shuyu Zhan⁴, Xiaoming Li⁵

Abstract

In late 2019, the coronavirus disease-2019 pandemic emerged in Wuhan, China, and rapidly spread across the globe. Many medical schools and institutions implemented online medical education to mitigate the spread of the virus. The current narrative review was planned to provide to explore how the pandemic affected the medical education sector and the transition to online teaching. The review synthesised empirical research on online medical education since the pandemic through thematic content analysis, comprehensively analysing 33 high-quality published studies involving students and teachers from medical colleges in various countries, their attitudes and satisfaction towards online medical education, and the pros and cons of such a mode of education. Moreover, it's the effects of online education on students' learning, personal lives and career development were explored. Finally, the review aimed at offering practical solutions to address the challenges facing online medical education. The review would likely attract further attention to online medical education, promoting awareness and supporting its future development and progress. Future research could focus on developing an efficient blended teaching model that combines online and in-person teaching, establishing a reasonable proportion of integrated teaching time.

Key Words: COVID-19, Online education, Medical education, Online medical education, Structured narrative review.

DOI: <https://doi.org/10.47391/JPMA.30302>

Introduction

In late 2019, a severe outbreak of pneumonia occurred in Wuhan, the most stringent in China in almost a century,

.....
¹⁻³Department of Psychiatry, School of Mental Health and Psychological Science, Anhui Medical University, Hefei, China. ⁴School of Psychology, Australian National University, Sydney, Australia. ⁵ Department of Medical Psychology, School of Mental Health and Psychological Science, Anhui Medical University, Hefei, China.

Correspondence: Xiaoming Li. **Email:** lixiaoming@ahmu.edu.cn

ORCID ID: 0000-0002-5228-1372

Submission complete: 11-09-2025 **First Revision received:** 10-02-2026

Acceptance: 10-06-2026

Last Revision received: 09-06-2026

and its cause remained unclear.¹ Later, it was discovered that the illness was caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).² Epidemiological measures, such as isolation, contact tracing, social distancing, continuous testing and educational initiatives, effectively prevented sustained transmission of the virus.³ Due to the rapid spread of the virus, however, medical schools and institutions in many countries turned to online medical education to ensure the safety of medical students and staff, as well as the continuation of academic process.⁴

Before the pandemic, poor technical skills, inadequate infrastructure, time constraints, negative attitudes of participants, and lack of institutional strategic support were the main shortcomings of online medical education.⁵ But online learning gained popularity for its proven ability to increase the efficiency and effectiveness of educational interventions.⁶ Even though it had a significant impact in terms of reducing the contagion and maintaining teaching continuity, online medical education faced, and still faces, challenges, such as equipment, network connectivity, teaching methodology and mental health issues, which affect its overall effectiveness.⁷⁻⁹ The most significant challenge was the need for clinical rotation and practical experience, which is difficult to achieve in online teaching.¹⁰ Additionally, medical students had higher rates of depression and anxiety than the general student population, and psychological issues among medical students during the pandemic should not be overlooked.¹¹⁻¹³

Although numerous studies have extensively examined aspects such as audience satisfaction, teaching quality, strengths and weaknesses, and the impact of online medical education, significant gaps remain in a comprehensive understanding of this mode of learning.¹⁴ Moreover, the rapid transition to online learning during the coronavirus disease-2019 (COVID-19) pandemic has raised questions about the psychological impact of this mode of education on medical students. The extent to which online education can meet the emotional and social needs of the students, which are traditionally supported in a campus setting, is still unclear.¹⁵ Furthermore, while some studies have focussed on the

technical challenges of online medical education, such as connectivity issues and access to digital resources, the empirical evidence shows that these challenges are disproportionately concentrated in low-income and developing regions, and the resulting learning inequality has become a prominent problem that cannot be ignored, which is worthy of in-depth analysis and targeted solution.¹⁶ The current narrative review was planned to fill these gaps in literature by synthesising current achievements and shortcomings, analysing perspectives from both students and instructors, and proposing feasible recommendations to address the challenges faced by online medical education. Such efforts are crucial for contributing to the establishment of a more efficient and equitable online medical education system, which is essential for training the next generation of healthcare professionals.¹⁷

Online medical education plays a vital role in meeting the increasing global demand for healthcare services. With a rising global population and an ageing demographic, the demand for medical professionals is at an all-time high. Efficient and accessible online education systems can significantly enhance the qualifications and skills of healthcare professionals, ensuring a higher quality of care for patients.⁴

Moreover, the integration of online learning in medical education is pivotal for adapting rapidly to technological innovations. Online medical education offers a scalable and cost-effective solution to train a larger number of practitioners compared to traditional methods. This approach can substantially reduce the costs associated with education and training, making medical education more accessible and helping to fill gaps in healthcare systems, especially in underserved areas.¹⁷

Materials and Methods

The narrative review adopted a thematic content analysis approach to synthesise the existing empirical evidence on online medical education during the COVID-19 pandemic, focussing on core research related to the implementation effect, stakeholder attitudes, and the challenges identified, with the aim of systematically combing the multi-dimensional impact and optimisation path of online teaching mode.

A targeted search of full-text articles on online medical education was conducted across core academic databases, including PubMed, Elsevier, Web of Science and Wiley, with the search time ranging from 2019 to the present. The search key words were "online education", "COVID-19" and "medical education". The search was conducted regardless of medical discipline, study design,

country of origin and research methodology, such as quantitative analysis, qualitative analysis and mixed-methods research.

The studies were screened on the basis of focus on the research and practice of online medical education for medical students, teachers and resident trainees during the COVID-19 pandemic; and original empirical data and specific research results on online medical education effectiveness, attitudes and challenges. Editorials, opinion pieces, conference abstracts and review articles without original data were excluded.

Core information of the selected studies was noted, including first author, year of publication, country, study design, sample size, research discipline, and key research results. The data was subjected to thematic content analysis.

To ensure the validity and reliability of the synthesis, the included studies were appraised against medical education research criteria.¹⁴ A few studies with simpler designs did not alter the overall synthesis, as their conclusions aligned with the broader evidence. Key potential biases included causal inference limits in cross-sectional designs, subjectivity in self-reported data, and sampling limitations. These were addressed through cross-validation with complementary high-quality studies, and possible implications were noted.

Results

Overview of the 33 included studies: The literature search led to the selection of 33 studies^{16,18-49}, which demonstrated strong multi-country, multi-disciplinary coverage and diverse designs, with findings grounded in objective metrics and standardised subjective assessments, supported by clear, replicable methods. Collectively, these studies involved over 1.02 million participants (including medical students, resident trainees and teaching faculty) across 18 countries on 5 continents, with a balanced representation of developed and developing economies. Overall methodological quality was high, with rigorous statistical analysis in quantitative work, validated coding in qualitative studies, and triangulation in mixed-methods research (Table). Geographically, 17 studies were conducted in Asia (including two large-scale national surveys from China),⁸ in Europe, 5 in North America and 3 in the Middle East and Africa; disciplinarily, they covered 11 core medical fields ranging from clinical medicine and dentistry to basic medical sciences and nursing. The thematic analysis of the studies led to the formation of three core themes: the influence of online medical learning on educational achievements; the advantages and disadvantages of

Table: Key characteristics of the representative empirical studies analysed (n=33).

Author	Country	Disciplines	Research method	No. of participants	Software	Summary
Li-b et al ¹⁶	China	international medicine and nursing	quantitative	436	NR	The factor influence the satisfaction of online education; Barriers and facilitators to online medical and nursing education.
Alghamdi et al ¹⁸	Saudi Arabia	pharmacy	quantitative	241	Rafid	The evaluation of technology access and online skill; the compare between the effect of online and offline teaching; how about the motivation for students.
Alamer et al ¹⁹	Saudi Arabia	radiology	quantitative	145	Blackboard Collaboration, zoom	Assess the effectiveness of teaching radiology; exploring students' perceived satisfaction and concerns. Students'; attendance, grades, and frequency of technical difficulties.
Ali et al ²⁰	Saudi Arabia	pharmacy	qualitative	NR	NR	Pharmacy students' perspective on its impact on their learning.
Armon et al ²¹	Israel	Gynecology	quantitative	27	Zoom, Kahoot	Identify effective pedagogical modalities as well as obstacles to online learning.
Banovac et al ²²	Croatia	anatomy	quantitative	181	NR	Compare the efficacy between different components of online and contact anatomy classes as perceived by medical students.
Chandrasinghe et al ²³	Sri Lanka	surgery	quantitative	1047	Zoom	Investigate the effect of a new study methods learning outcomes and interest.
Conway et al ²⁴	American	medicine	quantitative	122	Zoom	Comparing the grades of two group (group A experience offline education in 2023; group B experience online education in 2020) by exam and fill the questionnaire about satisfaction.
Cygan et al ²⁵	American	nursing	quantitative	142	AACN	The pandemic-enforced transition from face-to-face to remote learning impacts student.
Generali et al ²⁶	Italy	dentistry	quantitative	399	NR	Impact of COVID-19 toward academic career, risk of injection and the substitution of online education for traditional education of students in dentist subject.
Gopalan et al ²⁷	American	physiology	quantitative	33	Zoom (Virtual flipped teaching)	Evaluate the effect of FT in satisfaction, grades, adjusting and discussion in course.
Haftador et al ²⁸	Iran	nursing	quantitative	84	synchronous online class, combination of flipped and jigsaw methods	Compare the effect of two teaching strategy (synchronous online class/combination of flipped and jigsaw methods) in nurse subject.
Hattar et al ²⁹	Jordan	Dentistry	quantitative	310	NR	Investigate online education experience, and the level of self-perceived preparedness for a range of cognitive, communication and professional skills.
Herr et al ³⁰	korea	Dentistry	quantitative	220	NR	Investigate the satisfaction and effect of online education toward the students learning dentistry.
Idris et al ³¹	Brunei Darussalam	health science	quantitative	335	Canvas, Microsoft Teams, Google Meet, Skype, Zoom	Investigate the learning experience for students and mental health and the teaching experience, mental health for teachers.
Jiang et al ³²	China	pharmacy	quantitative	42	rain class, tencent meeting	Compare the satisfaction and grades of two class, 2017 (experience traditional education) and 2018 (mixed education).

Continued on next page...

Continued from previous page...

Author	Country	Disciplines	Research method	No. of participants	Software	Summary
Kang et al ³³	Korea	medicine	mixed	425	Blackboard	Investigate the general experience, learning strategies, important features, and overall satisfaction of medical students.
Khalid et al ³⁴	Saudi Arabia	medicine	mixed	180	PPT	the research addresses: medical students study using online resources.
Kim et al ³⁵	Korea	medicine	quantitative	110	ZOOM	Evaluate the assessment to and satisfaction with student clerkship.
Li-a et al ³⁶	China	medicine	quantitative	118030	NR	Survey medical students' perspectives on online learning experience and challenge.
Liu et al ³⁷	China	medicine and Health Sciences	mixed	12830	rain class	Evaluate the nature, quality, and outcomes of online learning using mixed methods and the participant including students, teachers and leaders.
Loda et al ³⁸	Germany	medicine	quantitative	372	NR	The research addresses: investigate the mental health of medical students.
Manna et al ³⁹	India	medicine and Allied Health	quantitative	1042	Google platform, Edmodo, Zoom application	Evaluate the current online education practice, its effectiveness.
Manou et al ⁴⁰	Greece	Pathology	quantitative	257	Skype for Business, YouTube	Explore participation and interactivity in a synchronous e-learning non-mandatory participation course.
Mohamed et al ⁴¹	Egypt (92 different countries)	Veterinary	quantitative	1392	YouTube videos, university platforms, educational websites, educational applications, Zoom(highest), WhatsApp, Google classroom, social networks, Microsoft Teams, Edmodo, Skype, Google Meet	Study the academic performance of veterinary medical students and researchers who experience online education.
Morgado et al ⁴²	Portugal	Dentistry	quantitative	118	NR	Determined the perception toward online education among faculty.
Nathaniel et al ⁴³	America	Neuroscience	quantitative	204	Panopto	Compare students' performance in summative and formative examinations between adaptive blended learning activities and face to face learning.
Shrivastava et al ⁴⁴	India	Dentistry	quantitative	533	Microsoft Teams	Study academic outcome of online dental education and psychological and physical well-being of the students.
Suhaib et al ⁴⁵	Arab	health sciences	quantitative	1210	Zoom, eLearning,	COVID-19 affect attitudes about online education for undergraduate health sciences students.

Continued on next page...

Continued from previous page...

Author	Country	Disciplines	Research method	No. of participants	Software	Summary
					School Portal, Moodle, Microsoft Teams, Email, Google Classroom, Online forum, WhatsApp, and Facebook.	
Tao et al ⁴⁶	China	nursing	quantitative	90	MOOC, SuperStar Universal Learning	Compare their abilities in the process of new knowledge acquisition between traditional group, blended group and online group.
Thom et al ⁴⁷	America	anatomy	mixed	552	NR	Evaluate the effectiveness and student perceptions of an online near-peer anatomy curriculum.
Vishwanathan et al ⁴⁸	India	medicine	quantitative	465	Zoom, Google Meet	the impact of online teaching using video conferencing platforms on the education environment, satisfaction, and perception of the medical undergraduate students to online teaching.
Wang et al ⁴⁹	China	Dentistry	quantitative	874027	Superstar Learning, Rain Classroom, Tencent Classroom, Pmhmoooc, DingTalk, Zoom Meeting, Tencent Meeting	Survey satisfaction, necessity and efficacy of online education for dental education.

online medical education in practical application; and targeted approaches to overcoming the core challenges of online medical education.

Attitudes of students: Medical students generally express satisfaction with the online medical education courses.⁵⁰ Online education reduces the risk of infection, compensates for shortcomings of traditional learning strategies, and enables teaching activities to continue during home isolation.⁵¹ The transition to online medical education has also resulted in changes in examination methods. Studies on medical students' academic performance have shown that test scores do not decrease in online education and may even be higher than those in traditional teaching methods.⁵² Students praise online testing for its efficiency, accuracy and objective reflection of their abilities.⁵³

Nonetheless, some medical students have poor cognition and performance on digital learning.⁵⁴ Some students, including residents, feel that online classes have notable deficiencies in medical majors' laboratory courses and clinical skills training, requiring assistance in achieving the intended learning outcomes.^{7,8}

Students' positive views of online medical education centre on practical convenience and infection risk avoidance, with negative feedback focused on lost clinical practice — stemming from their core skill-acquisition stage, where limited hands-on experience impacts professional development and career anxiety. Teachers' attitude differences, by contrast, tie to technical literacy and teaching adaptability; their concerns focus on insufficient teaching feedback and heavier workloads, reflecting the distinct core demands of the two groups in online teaching.

Attitudes of teachers: A survey indicated that most teachers offered positive feedback on online teaching, emphasising its effectiveness in medical education. Moreover, they found that online instruction can enhance the development of computer skills and teaching innovation.⁵⁵ Some faculty members also believe online teaching is crucial to students' learning since it allows for more personal opportunities and resources.⁵⁶

Nevertheless, significant discrepancies exist among teachers concerning the effectiveness and feasibility of online education in medical education. Some teachers

need online training and data reporting, or need to be technology-savvy.⁵⁷ It is worth mentioning that online education is also a physical and psychological challenge for teachers, and some teachers reported that they had musculoskeletal and psychosocial status problems during online teaching.⁵⁸⁻⁵⁹ Additionally, there needs to be a perfect online teaching supervision and evaluation system that may not deprive them of timely feedback on teaching quality.⁶⁰ More importantly, some teachers believe online education is more suitable for non-practical courses as it lacks hands-on practice opportunities.⁶¹

The inter-teacher differences in attitude towards online medical education are significantly correlated with institutional support and pre-training: teachers from institutions with complete online teaching training and technical support systems show higher acceptance, while those without relevant support report more obvious physical and psychological pressure and teaching frustration.^{16,59} This difference further indicates that the implementation effect of online medical education is not only determined by technical means, but also by the completeness of institutional supporting measures.

Merits of online medical education: During epidemics, online education effectively reduces the risk of infectious disease transmission through person-to-person contact.⁵¹ Online education offers a more extensive reach and flexible scheduling, which promotes independent learning among students, replacing traditional teacher-centred teaching models.⁶² Online teaching platforms' accessibility facilitates the provision of high-quality medical education resources to students regardless of location or language. Additionally, lectures can be recorded for future reference.⁶³

Online learning is well-suited for courses and ward studies involving telemedicine technology.⁶⁴ Through telemedicine, students can participate in decision-making, patient and family counselling, and implementation planning, resulting in higher engagement and significant patient benefits.¹³

Online remote virtual examinations provide significant financial and time advantages to trainees, evaluators and organisations conducting licensing examinations and training interviews.⁵⁵ When face-to-face structured oral reviews are unavailable, online aggregated Structured Oral Examination (SOE) can be a viable alternative.⁶⁵

Demerits of online medical education: Long-term online learning can cause physical ailments, like pain in the neck, back and shoulder.^{51,66} Some medical interns participating in clinical rotations reported that online

education disrupted their plans due to the epidemic's impact, and they experienced high stress and anxiety levels due to pressure from employment and entrance exams.^{8,67}

In online teaching, network interruptions can hinder the regular progress of education, leading to low-quality interaction between teachers and students.^{10,57} Teachers also need help receiving timely student feedback on their learning progress.^{68,69}

Furthermore, online testing software and remote invigilation present practical issues, including candidate authentication, cheating prevention, network security, and information technology (IT) failures.⁷⁰ The evaluation of online learning mainly focusses on outcomes or learning objectives, lacking standardised evaluation tools for content verification.⁷¹

Lastly, online medical education needs more practical teaching, especially clinical rotations. Online practical surgical teaching often fails to meet expected educational objectives due to inadequate equipment, time, and professional supervision and guidance.⁸

Strategies to address equipment issues: The digital divide led by socioeconomic disparities is a key barrier to online medical education, and it is far more severe in developing and low-income regions. Medical students there often lack stable internet and dedicated devices, with device-sharing being common, hampering live class attendance and online practical training. Such issues are rare in developed countries where institutions promptly offer network and equipment subsidies. This gap leads to immediate learning inequities for disadvantaged students, and worsens long-term professional development disparities, as limited access to quality online medical resources further widens regional gaps in medical talent training. The digital divide poses a significant challenge for students to access online education.⁷²

To overcome this challenge, schools can offer low-cost or free wireless internet access to support online learning.⁷³ Choosing widely-used software suitable for live broadcasting or recording, like Zoom, Massive Open Online Courses (MOOCs), and Tencent Conferences, is essential to preventing network outages or software glitches from disrupting the educational experience.⁷⁴ To optimise virtual courses, educators can adopt strategies such as shortening meeting lengths to promote active participation, increasing group interaction, utilising virtual simulation, optimising chat functions on digital platforms, and incorporating videos to enhance attention.⁷⁵

Strategies to address teaching issues: It is essential to provide standardised training and discussion for teachers, covering topics such as software use, network troubleshooting, online teaching methods, and primary education standards.^{76,77} Appropriate teaching methods can significantly enhance the learning experience for both students and teachers, leading to increased motivation, engagement and overall success in education.^{78,79} Adopting open-book examination (OBE) can reduce students' anxiety and improve clinical analytical thinking in online education.⁸⁰ Maintaining a stable internet connection is also crucial for students to obtain satisfactory results in exams.⁸¹

Virtual teaching methods can help minimise the loss of clinical rotations and practical experience due to the pandemic's impact.⁸² Additional teaching methods, such as three-dimensional (3D) teaching models, online simulation diagnosis software, image Electrocardiogramme (ECG) simulation software, and surgical video playback, can enhance surgical medical students' operational skills and clinical diagnostic thinking levels.^{83,84}

Strategies for addressing physical and psychological challenges: To mitigate the risk of musculoskeletal issues arising from poor ergonomics in office settings, comprehensive training in office ergonomics should be mandatory for both students and faculty.⁵⁸ Additionally, universities should assist undergraduates and graduate students in acquiring ergonomically designed computing equipment and furniture.⁶⁶

Even prior to the pandemic, medical students exhibited elevated rates of depression and anxiety compared to their non-medical counterparts. Given their prospective roles as healthcare providers, these students were particularly susceptible to the stressors induced by the pandemic.¹¹ Academic institutions must, therefore, prioritise the mental health by offering robust resources for the prevention and management of psychological disorders. This should include online mental health courses and counselling services, with particular focus on at-risk populations, such as students from low-income backgrounds, or those with pre-existing mental conditions.^{85,86} Effective coordination between academic and healthcare departments is crucial to ensure that vulnerable groups can access necessary support.⁸⁷ Understanding the root causes of anxiety among medical students can inform the development of targeted interventions. Transparent communication about institutional plans is particularly critical for those in healthcare fields. During periods requiring heightened transparency and resource availability, clear

communication can reduce student uncertainty and anxiety, thereby enhancing learning outcomes.^{13,88}

Furthermore, the role of university faculty as key influencers in shaping optimal learning environments and career trajectories cannot be overstated. Alongside efforts to improve technological accessibility and faculty expertise in remote instruction, there is an urgent need to develop psychological support mechanisms to mitigate the ongoing academic pressures faced by students.⁵⁹

Discussion

Based on the critical appraisal of the studies analysed, the current narrative review synthesises high-quality evidence related to online medical education during the COVID-19 pandemic while addressing potential research biases through cross-study verification. Existing research on online medical education tends to favour a singular viewpoint, only describing the positive or negative attitudes of students or teachers, but neglecting to analyse the inherent differences between the attitudes of the two main stakeholders, and the underlying causes behind the difference, as well as the impact of such differences on the optimisation of online medical education strategies. Therefore, there is a need for a more comprehensive, multidimensional investigation to deeply understand the overall effects of online medical education, and address the existing gaps in research.

Through a thematic synthesis of existing research on online medical education during the pandemic, the current narrative review provides a comprehensive analysis of its practical application effects and puts forward targetted optimisation suggestions, which has important implications for the future development of online medical education. The review took a multi-stakeholder and multi-disciplinary approach, considering the opinions and demands of different groups and systematically describing the heterogeneous impacts of online medical education on medical students across different disciplines, making up for the deficiency of single perspective analysis in existing relevant research. These contributions are likely to increase awareness of online medical education and promote its future development and progress.

Technological advancements, the continuous evolution of the internet, and growing market demand have continuously propelled the development and progress of online medical education.⁸⁹ Additionally, the COVID-19 pandemic played a significant role in the development of online medical education, as many medical schools were compelled to halt in-person classes in adherence to the government's safety guidelines and pandemic prevention

policies.⁴ Medical studies have shown that online education provides more flexibility in terms of time and space, and enables medical schools to maintain maximum teaching progress while reducing the risk of virus transmission between medical college students and teachers.^{51,55}

The included studies span multiple regions and reveal marked regional differences in online medical education outcomes, rooted in resource endowments and educational infrastructure. In developed countries, robust digital resources and technical support fully leverage online learning's strengths; core challenges lie in simulating clinical practice and addressing student anxiety over reduced hands-on training. In developing countries, socioeconomic gaps create critical barriers, like unreliable hardware, poor connectivity and inadequate teacher training, limiting teaching quality and basic simulation capabilities despite successful teaching continuity. Asian contexts reflect unique variation: Chinese institutions have mitigated the digital divide through integrated platform use and institutional support, while Southeast Asian programmes have struggled with rural network gaps that threaten learning continuity for remote students.^{16,20-47} This heterogeneity confirms that online medical education optimisation requires regionally tailored strategies, not a one-size-fits-all approach.

Several students displayed significant autonomy in their learning process during online medical education.⁶² Online medical education gives students access to more medical education resources than before.⁹⁰ The significance of online medical education is increasingly apparent due to its accessibility and flexibility.⁶⁴ Against the backdrop of the COVID-19 pandemic, online medical education is gradually becoming a popular teaching method to maintain the progress of medical colleges and universities. In the future, online medical education will continue to evolve and have a more substantial impact. However, there is room for improvement in other aspects of online medical education, such as clinical practice and online course delivery.^{7,10,68} Online medical education requires students to develop practical skills and cultivate clinical diagnostic thinking literacy.⁸ Online medical teaching can affect teaching quality since teachers need to receive timely feedback on class progress, and students must maintain 24-hour attention.^{10,69}

Particular attention should be given to the mental health issues of medical students in online medical education since they experience higher levels of psychological pressure, anxiety and depression than students in other fields.^{12,13} Medical students often experience anxiety

about their future career prospects, participation in continuing education, lack of confidence in online teaching, and inadequate clinical practice, which can lead to anxiety and depression.^{8,67} Therefore, it is crucial to identify the sources of psychological problems and address them to improve the mental wellbeing of medical students.

In the post-pandemic era, online medical education has significant room for improvement. To achieve the desired effects of online medical education, schools, hospitals, teachers and relevant departments and institutions should fully consider the views presented in the current review, consider the opinions and needs of all stakeholders, and develop more effective strategies for online medical teaching through collaborative efforts. The development of online education during the pandemic has brought many positive changes to the field of education, which is continuing to develop after the pandemic, pushing education to be more adaptable to diverse needs and rapidly changing environments.

The current findings can guide efforts to enhance the quality of medical education by overcoming current shortcomings. By improving the quality of online medical education, learners can more effectively master medical knowledge and skills. Further, by expanding the coverage of medical education and implementing digital inclusive measures, more individuals can be facilitated to access high-quality medical education, thereby reducing disparities based on regional and socioeconomic factors. The innovative education model encourages institutions to adopt creative teaching methods, enhancing both the appeal and practicality of education. In the face of future challenges, the current review contributes to efforts aimed at advancing a robust online medical education system, preparing for potential disruptions and changes that may occur down the line.

The current narrative review has several inherent limitations. First, the analysis was limited to published high-quality empirical studies, and grey literature was not included, which may have led to the omission of some practical application information and on-site experience of online medical education. Second, the critical appraisal of the included studies was based on the general evaluation criteria of medical education empirical research, and there was no unified quantitative evaluation scale for heterogeneous research designs. This may have caused a certain degree of subjective judgment in the identification of potential research biases, although cross-validation with multiple studies was done to reduce such subjectivity. Third, the review did not specifically explore the online medical education experience of

special groups, such as medical students with disabilities and those with pre-existing mental health conditions, and the unique challenges and needs of these groups have not been fully addressed, which can be further supplemented in subsequent research. Fourth, the review did not conduct a stratified analysis of research results based on factors, such as students' medical subject orientation, race and educational background, and the heterogeneous demands of different subgroups still remain unexplored.

Future research on online medical education should focus on these research gaps, and carry out in-depth and targeted exploration by combining more diverse research materials and adopting more refined research designs.

Conclusion

A comprehensive examination of online medical education can help in fully harnessing its benefits and overcome its drawbacks, thereby contributing to the ongoing progress and development of the medical education system as a whole. The in-depth analysis of students' and teachers' perceptions towards online medical education based on critically appraised high-quality evidence led to a balanced overview of its advantages and disadvantages. The comprehensive, multi-dimensional analysis provided a systematic reference for the subsequent development of online medical education and improvement. The integrated application of online and offline blended teaching was found to have been widely recognised as the optimal development direction of medical education in the post-pandemic era. Therefore, it is crucial to further explore and optimise the blended teaching model for medical education, focus on developing a more efficient and targeted blended teaching framework, and establish a reasonable proportion of online and offline teaching time adapted to the characteristics of different medical disciplines. This will help in fully harnessing the advantages of online medical education in terms of resource sharing and flexible learning, while making up for its deficiencies in practical teaching, and ultimately promoting the cause of medical education.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: The Teaching and Research Project of Anhui Province the Anhui Province Graduate Education Quality Engineering Project; and the Virtual Simulation Experimental Teaching course of Anhui Medical University, Anhui, China; and Quality Engineering Project

of the Education Department of Anhui Province (2024jxjygl007).

References

1. Kang S, Peng W, Zhu Y, Lu S, Zhou M, Lin W, et al. Recent progress in understanding 2019 novel coronavirus (SARS-CoV-2) associated with human respiratory disease: detection, mechanisms and treatment. *Int J Antimicrob Agents*. 2020;55:105950. doi:10.1016/j.ijantimicag.2020.105950.
2. To KK-W, Sridhar S, Chiu KH-Y, Hung DL-L, Li X, Hung IF-N, et al. Lessons learned 1 year after SARS-CoV-2 emergence leading to COVID-19 pandemic. *Emerg Microbes Infect*. 2021;10:507-35. doi:10.1080/22221751.2021.1898291.
3. Habas K, Nganwuchu C, Shahzad F, Gopalan R, Haque M, Rahman S, et al. Resolution of coronavirus disease 2019 (COVID-19). *Expert Rev Anti Infect Ther*. 2020;18:1201-11. doi:10.1080/14787210.2020.1797487.
4. Alsoufi A, Alsuyihili A, Msherghi A, Elhadi A, Atiyah H, Ashini A, et al. Impact of the COVID-19 pandemic on medical education: medical students' knowledge, attitudes, and practices regarding electronic learning. *PLoS One*. 2020;15:e0242905. doi:10.1371/journal.pone.0242905.
5. O'Doherty D, Dromey M, Lougheed J, Hannigan A, Last J, McGrath D. Barriers and solutions to online learning in medical education: an integrative review. *BMC Med Educ*. 2018;18:130. doi:10.1186/s12909-018-1240-0.
6. Ward JP, Gordon J, Field MJ, Lehmann HP. Communication and information technology in medical education. *Lancet*. 2001;357:792-6. doi:10.1016/S0140-6736(00)04173-8.
7. Chenbhanich J, Slavotinek A, Tam A. Impact of the COVID-19 pandemic on medical genetics and genomics training: perspective from clinical trainees. *Am J Med Genet A*. 2022;188:1997-2004. doi:10.1002/ajmg.a.62736.
8. Fayngersh A, Sudyn A, Jain N, Asri R, Traba C, Matassa D, et al. Learning in the pandemic: medical students' perceived effects of COVID-19 on their clinical experiences and career choices during the internal medicine clerkship. *Med Sci Educ*. 2022;32:907-15. doi:10.1007/s40670-022-01589-8.
9. Ford TR, Fix ML, Shappell E, Egan DJ, Mannix A, Bailitz J, et al. Beyond the emergency department: effects of COVID-19 on emergency medicine resident education. *AEM Educ Train*. 2021;5:e10568. doi:10.1002/aet2.10568.
10. Falahchai M, Babaei Hemmati Y, Hasanzade M. Dental care management during the COVID-19 outbreak. *Spec Care Dentist*. 2020;40:539-48. doi:10.1111/scd.12523.
11. Jupina M, Sidle MW, Rehmeyer Caudill CJ. Medical student mental health during the COVID-19 pandemic. *Clin Teach*. 2022;19:e13518. doi:10.1111/tct.13518.
12. Rana T, Hackett C, Quezada T, Chaturvedi A, Bakalov V, Leonardo J, et al. Medicine and surgery residents' perspectives on the impact of COVID-19 on graduate medical education. *Med Educ Online*. 2020;25:1818439. doi:10.1080/10872981.2020.1818439.
13. Theoret C, Ming X. Our education, our concerns: the impact on medical student education of COVID-19. *Med Educ*. 2020;54:591-2. doi:10.1111/medu.14181.
14. George PP, Papachristou N, Belisario JM, Wang W, Wark PA, Cotic Z, et al. Online eLearning for undergraduates in health professions: a systematic review of the impact on knowledge, skills, attitudes and satisfaction. *J Glob Health*. 2014;4:010406. doi:10.7189/jogh.04.010406.
15. Dost S, Hossain A, Shehab M, Abdelwahed A, Al-Nusair L. Perceptions of medical students towards online teaching during the COVID-19 pandemic: a national cross-sectional survey of 2721 UK medical students. *BMJ Open*. 2020;10:e042378. doi:10.1136/bmjopen-2020-042378.

16. Li W, Gillies R, He M, Wu C, Liu S, Gong Z, et al. Barriers and facilitators to online medical and nursing education during the COVID-19 pandemic: perspectives from international students from low- and middle-income countries and their teaching staff. *Hum Resour Health*. 2021;19:64. doi:10.1186/s12960-021-00609-9.
17. Wilcha R-J. Effectiveness of virtual medical teaching during the COVID-19 crisis: systematic review. *JMIR Med Educ*. 2020;6:e20963. doi:10.2196/20963.
18. Alghamdi S, Ali M. Pharmacy students' perceptions and attitudes towards online education during COVID-19 lockdown in Saudi Arabia. *Pharmacy (Basel)*. 2021;9:169. doi:10.3390/pharmacy9040169.
19. Alamer A, Alharbi F. Synchronous distance teaching of radiology clerkship promotes medical students' learning and engagement. *Insights Imaging*. 2021;12:1-11. doi:10.1186/s13244-021-00984-w.
20. Ali M, Alihyani M, Abdulaziz A, Alansari S, Faqeh S, Kurdi A, et al. What just happened? Impact of on-campus activities suspension on pharmacy education during COVID-19 lockdown: a students' perspective. *Saudi Pharm J*. 2021;29:59-66. doi:10.1016/j.jsps.2020.12.008.21.
21. Armon S, Benyamini Y, Grisaru-Granovsky S, Avitan T. Online obstetrics and gynecology medical students clerkship during the COVID-19 pandemic: a pilot study. *Med Sci Educ*. 2021;31:457-61. doi:10.1007/s40670-020-01181-y.
22. Banovac I, Katavić V, Blažević A, Bičanić I, Hladnik A, Kovačić N, et al. The anatomy lesson of the SARS-CoV-2 pandemic: irreplaceable tradition (cadaver work) and new didactics of digital technology. *Croat Med J*. 2021;62:173-86. doi:10.3325/cmj.2021.62.173.
23. Chandrasinghe P, Siriwardana R, Kumarage S, Munasinghe B, Weerasuriya A, Tillakaratne S, et al. A novel structure for online surgical undergraduate teaching during the COVID-19 pandemic. *BMC Med Educ*. 2020;20:324. doi:10.1186/s12909-020-02236-9.
24. Conway NB, Tempest HG, Fortun J. Remote learning and its impact on newly matriculated medical students. *Cureus*. 2021;13. doi:10.7759/cureus.17223.
25. Cygan H, Bejster M, Tribbia C, Vondracek H. Impact of COVID-19 on public health nursing student learning outcomes. *Public Health Nurs*. 2022;39:481-7. doi:10.1111/phn.12978.
26. Generali L, Iani C, Macaluso GM, Montebugnoli L, Siciliani G, Console U. The perceived impact of the COVID-19 pandemic on dental undergraduate students in the Italian region of Emilia-Romagna. *Eur J Orthod*. 2021;25:621-33. doi:10.1111/eje.12640.
27. Gopalan C, Butts-Wilmsmeyer C, Moran V. Virtual flipped teaching during the COVID-19 pandemic. *Adv Physiol Educ*. 2021;45:670-8. doi:10.1152/advan.00061.2021.
28. Haftador AM, Shirazi F, Mohebbi Z. Online class or flipped-jigsaw learning? Which one promotes academic motivation during the COVID-19 pandemic? *BMC Med Educ*. 2021;21:499. doi:10.1186/s12909-021-02929-9.
29. Hattar S, AlHadidi A, Sawair FA, Alraheam IA, El-Ma'aita A, Wahab FK. Impact of COVID-19 pandemic on dental education: online experience and practice expectations among dental students at the University of Jordan. *BMC Med Educ*. 2021;21:151. doi:10.1186/s12909-021-02584-0.
30. Herr L, Jih MK, Shin J, Chae YK, Lee HS, Choi SC, et al. The perspective of undergraduate dental students on web-based learning in pediatric dentistry during the COVID-19 pandemic: a Korean multicenter cross-sectional survey. *BMC Med Educ*. 2021;21:505. doi:10.1186/s12909-021-02928-w.
31. Idris F, Zulkipli IN, Abdul-Mumin KH, Ahmad SR, Mitha S, Rahman HA, et al. Academic experiences, physical and mental health impact of COVID-19 pandemic on students and lecturers in health care education. *BMC Med Educ*. 2021;21:542. doi:10.1186/s12909-021-02968-2.
32. Jiang X, Ning Q. The impact and evaluation of COVID-19 pandemic on the teaching model of medical molecular biology course for undergraduates majoring in pharmacy. *Biochem Mol Biol Educ*. 2021;49:346-52. doi:10.1002/bmb.21471.
33. Kang YJ, Kim DH. Pre-clerkship students' perception and learning behavior of online classes during coronavirus disease 2019 pandemic. *Korean J Med Educ*. 2021;33:125-31. doi:10.3946/kjme.2021.194.
34. Alabdulwahhab KM, Kazmi SY, Sami W, Almujeel KN, Alanazi MH, Alanazi KF, et al. Use of online resources by undergraduate medical students at College of Medicine, Majmaah University, Kingdom of Saudi Arabia. *PLoS One*. 2021;16. doi:10.1371/journal.pone.0255635.
35. Kim TH, Kim JS, Yoon HI, Lee J, Lee JJB, Byun HK, et al. Medical student education through flipped learning and virtual rotations in radiation oncology during the COVID-19 pandemic: a cross-sectional research. *Radiat Oncol*. 2021;16:204. doi:10.1186/s13014-021-01927-x.
36. Li L, Wu H, Xie A, Ye X, Liu C, Wang W. Students' initial perspectives on online learning experience in China during the COVID-19 outbreak: expanding online education for future doctors on a national scale. *BMC Med Educ*. 2021;21:584. doi:10.1186/s12909-021-03005-y.
37. Liu Y, Zhang Y, Qiao W, Zhou L, Coates H. Ensuring the sustainability of university learning: case study of a leading Chinese university. *Sustainability*. 2020;12:6929. doi:10.3390/su12176929.
38. Loda T, Löffler T, Erschens R, Zipfel S, Herrmann-Werner A. Medical education in times of COVID-19: German students' expectations—a cross-sectional study. *PLoS One*. 2020;15. doi:10.1371/journal.pone.0241660.
39. Debnath M, Ojha S, Niraula A, Sharma D. Perceptions of medical and allied health students towards online education during the COVID-19 pandemic phases and its future impact in India. *J Eur CME*. 2021;10:1993428. doi:10.1080/21614083.2021.1993428.
40. Manou E, Lazari EC, Thomopoulou GE, Agrogiannis G, Kavantzaz N, Lazaris AC. Participation and interactivity in synchronous e-learning pathology course during the COVID-19 pandemic. *Adv Med Educ Pract*. 2021;12:1081-91. doi:10.2147/AMEP.S317854.
41. Mahdy MA. The impact of COVID-19 pandemic on the academic performance of veterinary medical students. *Front Vet Sci*. 2020;7:594261. doi:10.3389/fvets.2020.594261.
42. Morgado M, Mendes JJ, Proença L. Online problem-based learning in clinical dental education: students' self-perception and motivation. *Healthcare*. 2021;9:541. doi:10.3390/healthcare9050541.
43. Nathaniel TI, Goodwin RL, Fowler L, McPhail B, Black AC Jr. An adaptive blended learning model for the implementation of an integrated medical neuroscience course during the COVID-19 pandemic. *Anat Sci Educ*. 2021;14:699-710. doi:10.1002/ase.2097.
44. Shrivastava KJ, Nahar R, Parlani S, Murthy VJ. A cross-sectional virtual survey to evaluate the outcome of online dental education system among undergraduate dental students across India amid COVID-19 pandemic. *Eur J Dent Educ*. 2022;26:123-30. doi:10.1111/eje.12679.
45. Muflih S, Abuhammad S, Karasneh R, Al-Azzam S, Alzoubi KH, Muflih M. Online education for undergraduate health professional education during the COVID-19 pandemic: attitudes, barriers, and ethical issues. *Res Sq*. 2020. doi:10.21203/rs.3.rs-42336/v1.
46. Lei T, Yu X, Zou M, Wang P, Yuan RH. Delivering an online course in emergency nursing education during the pandemic: what are the effects on students' learning? *Australas Emerg Care*. 2021;24:314-8. doi:10.1016/j.auec.2021.04.002.
47. Thom ML, Kimble BA, Qua K, Wish-Baratz S. Is remote near-peer

- anatomy teaching an effective teaching strategy? Lessons learned from the transition to online learning during the COVID-19 pandemic. *Anat Sci Educ*. 2021;14:552-61. doi:10.1002/ase.2122.
48. Vishwanathan K, Patel GM, Patel DJ. Impact and perception about distant online medical education (tele-education) on the educational environment during the COVID-19 pandemic: experiences of medical undergraduate students from India. *J Fam Med Prim Care*. 2021;10:2216-23. doi:10.4103/jfmpc.jfmpc_2306_20.
 49. Wang K, Zhang L, Ye L. A nationwide survey of online teaching strategies in dental education in China. *J Dent Educ*. 2021;85:128-34. doi:10.1002/jdd.12413.
 50. Rajab MH, Gazal AM, Alkattan K. Challenges to online medical education during the COVID-19 pandemic. *Cureus*. 2020;12:e8966. doi:10.7759/cureus.8966.
 51. Song Y, Wang S, Liu Y, Liu X, Peng A. Online education at the Medical School of Tongji University during the COVID-19 pandemic: a cross-sectional study. *BMC Med Educ*. 2021;21:31. doi:10.1186/s12909-021-02951-x.
 52. Sekine M, Watanabe M, Nojiri S, Suzuki T, Nishizaki Y, Tomiki Y, et al. Effects of COVID-19 on Japanese medical students' knowledge and attitudes toward e-learning in relation to performance on achievement tests. *PLoS One*. 2022;17:e0265356. doi:10.1371/journal.pone.0265356.
 53. Cernicova-Buca M, Dragomir GM. Romanian students' appraisal of the emergency remote assessment due to the COVID-19 pandemic. *Sustainability*. 2021;13:6110. doi:10.3390/su13116110.
 54. Farias Bezerra HK, Passos KKM, Leonel ACLS, Ferreti Bonan PR, Martelli-Júnior H, Machado RA, et al. The impact of the COVID-19 pandemic on undergraduate and graduate dental courses in Brazil. *Work*. 2021;70:31-9. doi:10.3233/WOR-210071.
 55. Savage AJ, McNamara PW, Moncrieff TW, O'Reilly GM. E-learning in emergency medicine: a systematic review. *Emerg Med Australas*. 2022;34:322-32. doi:10.1111/1742-6723.13936.
 56. Lee T, Yoon SW, Fernando S, Willey S, Kumar A. Blended (online and in-person) Women's Health Interprofessional Learning by Simulation (WHIPLS) for medical and midwifery students. *Aust N Z J Obstet Gynaecol*. 2022;62:596-604. doi:10.1111/ajo.13531.
 57. Hasanzade M, Aminishakib P, Mortaz Hejri S, Kharazifard MJ, Siadat H. Reopening of a school of dentistry in the era of COVID-19 pandemic: "step-by-step" approach. *Eur J Dent Educ*. 2023;27:167-73. doi:10.1111/eje.12789.
 58. Kayabınar E, Kayabınar B, Önal B, Zengin HY, Köse N. The musculoskeletal problems and psychosocial status of teachers giving online education during the COVID-19 pandemic and preventive telerehabilitation for musculoskeletal problems. *Work*. 2021;68:33-43. doi:10.3233/WOR-203357.
 59. Casacchia M, Cifone MG, Giusti L, Fabiani L, Gatto R, Lancia L, et al. Distance education during COVID-19: an Italian survey on the university teachers' perspectives and their emotional conditions. *BMC Med Educ*. 2021;21:335. doi:10.1186/s12909-021-02780-y.
 60. Ren T, Wu Y, Han Y, Meng Q, Li L. Brief analysis of online education and teaching of public health and preventive medicine. *Chin J Prev Med*. 2020;54:1344-6. doi:10.3760/cma.j.cn112150-20200511-00713.
 61. Bayham J, Fenichel EP. Impact of school closures for COVID-19 on the US health-care workforce and net mortality: a modelling study. *Lancet Public Health*. 2020;5:e271-8. doi:10.1016/S2468-2667(20)30082-7.
 62. Alrashdi M, Hameed A, Aljabr A. COVID-19 and a call to adapt dental education. *Front Dent Med*. 2021;2:664460. doi:10.3389/fdmed.2021.664460.
 63. Goldberg LR, Crocombe LA. Advances in medical education and practice: role of massive open online courses. *Adv Med Educ Pract*. 2017;8:603-9. doi:10.2147/AMEP.S115321.
 64. Savage DJ. The COVID-19 pandemic as a catalyst for medical education innovation: a learner's perspective. *FASEB Bioadv*. 2021;3:449-55. doi:10.1096/fba.2020-00133.
 65. Alharbi F, Alamer A. Feasibility of radiology online structured oral examination for undergraduate medical students. *Insights Imaging*. 2022;13:124. doi:10.1186/s13244-022-01258-9.
 66. Malshani W, Weerakoon H, Weerakoon K. Ergonomics in online education of medical undergraduates: a challenge to post-COVID transformation in educational activities. *Work*. 2023;74:1-12. doi:10.3233/WOR-220397.
 67. Bachir B, Naji A, Tfayli A. The educational and psychological impact of the COVID-19 pandemic on medical students: a descriptive survey at the American University of Beirut. *Medicine (Baltimore)*. 2021;100:e26646. doi:10.1097/MD.00000000000026646.
 68. Lazarte J, Hegele RA. Dyslipidemia management in adults with diabetes. *Can J Diabetes*. 2020;44:53-60. doi:10.1016/j.cjcd.2019.07.003.
 69. Porpiglia F, Checucci E, Autorino R, Amparore D, Cooperberg MR, Ficarra V, et al. Traditional and virtual congress meetings during the COVID-19 pandemic and the post-COVID-19 era: is it time to change the paradigm? *Eur Urol*. 2020;78:301-3. doi:10.1016/j.eururo.2020.04.018.
 70. Pettit M, Shukla S, Zhang J, Sunil Kumar KH, Khanduja V. Virtual exams: has COVID-19 provided the impetus to change assessment methods in medicine? *Bone Jt Open*. 2021;2:111-8. doi:10.1302/2633-1462.22.BJO-2020-0142.R1.
 71. Saw GK, Chang CN, Lomeli U, Zhi M. Gender disparities in remote learning during the COVID-19 pandemic: a national survey of STEM faculty and students. *Nat Res Educ Equity Divers*. 2020;2. [DOI not verified].
 72. Chand SS, Chand AA, Chand KK. The use of careFiji app for contact tracing during the COVID-19 pandemic: digital gap and challenges faced in Fiji. *Int J Surg*. 2021;93:106023. doi:10.1016/j.ijsu.2021.106023.
 73. Asgari S, Trajkovic J, Rahmani M, Zhang W, Lo RC, Sciortino A. An observational study of engineering online education during the COVID-19 pandemic. *PLoS One*. 2021;16:e0250041. doi:10.1371/journal.pone.0250041.
 74. Hodges CB, Moore S, Lockee BB, Trust T, Bond MA. The difference between emergency remote teaching and online learning. In: *Handbook of Open, Distance and Digital Education*. Leiden: Brill; 2024. p. 511-22. doi:10.1163/9789004702813_021.
 75. Weygandt PL, Jordan J, Caretta-Weyer H, Osborne A, Grabow Moore K. Impact of the COVID-19 pandemic on emergency medicine education: insights from faculty and residents. *AEM Educ Train*. 2021;5:e10603. doi:10.1002/aet2.10603.
 76. Agyei-Nkansah A, Adjei P, Torpey K. COVID-19 and medical education: an opportunity to build back better. *Ghana Med J*. 2020;54 Suppl:86-7. doi:10.4314/gmj.v54i4s.18.
 77. Comas-Quinn A. Learning to teach online or learning to become an online teacher: an exploration of teachers' experiences in a blended learning course. *ReCALL*. 2011;23:218-32. doi:10.1017/S0958344011000152.
 78. Govindarajan S, Rajaragupathy S. Online team-based learning in teaching biochemistry for first year MBBS students during COVID-19 pandemic. *Biochem Mol Biol Educ*. 2022;50:124-9. doi:10.1002/bmb.21598.
 79. Reinhart A, Malzkorn B, Döing C, Beyer I, Jünger J, Bosse HM. Undergraduate medical education amid COVID-19: a qualitative analysis of enablers and barriers to acquiring competencies in distant learning using focus groups. *Med Educ Online*. 2021;26:1940765. doi:10.1080/10872981.2021.1940765.
 80. Stowell JR, Bennett D. Effects of online testing on student exam performance and test anxiety. *J Educ Comput Res*. 2010;42:161-

71. doi:10.2190/EC.42.2.b.
81. Nikas IP, Lamnissos D, Meletiou-Mavrotheris M, Themistocleous SC, Pieridi C, Mytilinaios DG, et al. Shift to emergency remote preclinical medical education amidst the COVID-19 pandemic: a single-institution study. *Anat Sci Educ.* 2022;15:27-41. doi:10.1002/ase.2159.
 82. Shappell E, Egan DJ, Eyre A, Nadel E, Wittels K. Virtual student experiences: a case study of objectives, outcomes, and anticipated consequences. *AEM Educ Train.* 2021;5:e10582. doi:10.1002/aet2.10582.
 83. Chen X, Ran H. Thinking and strategy of medical online open course education under the new coronavirus outbreak. *China High Med Educ.* 2020;6:36-7. doi:10.3969/j.issn.1002-1701.2020.06.019.
 84. Ke J, Cheng Z, Xie Z. Practice and reflection on online education during epidemic prevention and control: a case study of Guangzhou Medical University. *China Med Educ Technol.* 2020;34:3-6. [DOI not verified].
 85. Adams RE, Boscarino JA, Galea S. Social and psychological resources and health outcomes after the World Trade Center disaster. *Soc Sci Med.* 2006;62:176-88. doi:10.1016/j.socscimed.2005.05.008.
 86. Main A, Zhou Q, Ma Y, Luecken LJ, Liu X. Relations of SARS-related stressors and coping to Chinese college students' psychological adjustment during the 2003 Beijing SARS epidemic. *J Couns Psychol.* 2011;58:410-23. doi:10.1037/a0023632.
 87. Martin P, McGrail M, Fox J, Partanen R, Kondalsamy-Chennakesavan S. Impact of the COVID-19 pandemic on medical student placements in rural Queensland: a survey study. *Aust J Rural Health.* 2022;30:478-87. doi:10.1111/ajr.12862.
 88. Kuman Tunçel Ö, Taşbakan SE, Gökengin D, Erdem HA, Yamazhan T, Sipahi OR, et al. The deep impact of the COVID-19 pandemic on medical students: an online cross-sectional study evaluating Turkish students' anxiety. *Int J Clin Pract.* 2021;75:e14139. doi:10.1111/ijcp.14139.
 89. Farooq F, Rathore FA, Mansoor SN. Challenges of online medical education in Pakistan during COVID-19 pandemic. *J Coll Physicians Surg Pak.* 2020;30:S67-9. doi:10.29271/jcpsp.2020.Supp1.S67.
 90. Sandhu P, de Wolf M. The impact of COVID-19 on the undergraduate medical curriculum. *Med Educ Online.* 2020;25:1764740. doi:10.1080/10872981.2020.1764740.

AUTHORS' CONTRIBUTIONS:

YZ, GP, ML, SZ & XL: Concept, design, data acquisition, analysis, interpretation, drafting, revision, final approval and agreement to be accountable for all aspects of the work.