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A comparative analysis on the research competency of medical students across the COVID-19 periods

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The ability to conduct research and utilize its findings has been a fundamental competency for medical students, often assessed through the observable research outcomes. This study aims to compare the research competency of medical students before, during, and after the COVID-19 pandemic to explore the future direction of research education in medical schools. We collected information on research outcomes submitted by medical students as graduation requirements during the pre-COVID-19, pandemic, and post-COVID-19 periods based on the duration of social distancing. The research outcomes were classified into two categories: publication of a paper and presentation at a conference. We compared variables such as authorship, type of journal or conference, and type of literature or presentation. The research outcomes submitted by all medical school graduates at their senior year from 2018 to 2023 were included in the analysis. The graduation requirements were usually achieved by publishing a paper (67.5%) with a faculty of clinical medicine (63.5%) in the fourth year (50.0%), regardless of COVID-19 pandemic. The findings highlighted the significant impact of the COVID-19 pandemic on the research outcomes of medical students. Post hoc analysis revealed that while the quality of published papers improved during the COVID-19 pandemic, there was a regression in author contributions in the post-pandemic period. The impact of the COVID-19 pandemic on medical students' experiences with research is likely that the weakened student initiative observed in participating in and conducting research will persist, especially after the pandemic. Therefore, it is imperative to implement strategies to increase motivation and empower medical students to research.

Keywords Medical education, COVID-19, Research competency, Motivation, Supervision

The ability to conduct medical research and utilize the results has been a fundamental competency of healthcare providers since medical school[1]. Its importance has been consistently emphasized throughout the medical community, as well as in the training of physician-scientists who conduct bench-to-bedside translational research[2]. The initial experiences and participation of medical students in medical research facilitate the development of critical thinking and active learning skills[3]. By enhancing their literacy in research, they are more likely to effectively apply evidence-based medicine in their future clinical practice[1,3]. The World Federation of Medical Education (WFME) asserts that, at a minimum, medical students should be instructed in the principles of the scientific method through a research-related curriculum[4,5]. Furthermore, it is recommended that a curriculum be developed that includes elements of original or advanced research to equip medical students with the skills to contribute to the scientific advancement of medicine. Through this curriculum, medical students acquire essential research-related skills, including curiosity, critical appraisal, evidence-based practice, ethics, teamwork, and communication, thereby fostering research competency[6,7].

The global COVID-19 pandemic has precipitated a profound transformation in higher education, including medical schools[8,9]. In response to the necessity of implementing essential measures to combat the pandemic,

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there has been a radical shift to online modalities of teaching, learning, and assessment[8]. These changes have also resulted in significant constraints and delays in research activities within academic institutions and medical facilities[9]. Clinical studies that require face-to-face data collection or interventions are particularly impacted[10]. Consequently, if the principal investigator or supervisor is a healthcare provider working in direct patient care on the frontline, their interaction with students, including providing feedback on the study, is curtailed[9]. Throughout the COVID-19 pandemic, medical students have also encountered several challenges in their academic pursuits, including difficulties in conducting research[9,11,12]. In particular, in-person research was often interrupted or delayed as social distancing was implemented[8], and the rapidly increasing workload of faculty members in medical schools[9], who often serve as advisors and principal investigators on research teams, may have constrained their capacity to lead and guide research activities.

In the context of these challenges, several empirical strategies have been proposed to support medical students in continuing their research training and projects and adapting to the changing educational environment during the COVID-19 pandemic[9,11]. However, few studies have examined the actual changes in the research competency of medical students, including data from the post-COVID-19 period with multivariate analysis, and have proposed action plans based on the results. This study aimed to examine the impact of the COVID-19 pandemic on medical students' research competencies according to the timing of the pandemic: pre-, during-, and post-COVID-19. Research competency was assessed based on observable abilities of medical students, the research outcomes whether publish a paper or present at a medical conference. Furthermore, we aimed to examine the prospective trajectory of research education for medical students, considering the transformed landscape of research competencies in the wake of the pandemic.

Results

Characteristics of medical students' research experience

Data from 83 students from the pre-COVID-19 period, 84 students from the pandemic period, and 85 students from the post-COVID-19 period were used in the analysis (Table 1). The proportions of female students in each period were 49.4% ($n=41$), 34.5% ($n=29$), and 45.9% ($n=39$), respectively. Research-related graduation requirements were most often fulfilled during the senior year across all periods (pre-COVID-19 45.8%; $n=38$; pandemic 63.6%; $n=45$; post-COVID-19 50.6%; $n=43$), followed by fulfillment during the junior year (30.1%; $n=25$, 28.6%; $n=24$, 27.1%; $n=23$, 27.1%, respectively).

Faculty advisors for undergraduate research were more likely to be experts in clinical medicine than in basic medical sciences in all time periods. The number of students who chose to publish a paper was 57 (68.7%) in the pre-COVID-19 period, 53 (63.1%) during the pandemic, and 60 (70.1%) in the post-COVID-19 period, while the number of students who chose to present at a conference was 26 (31.3%), 31 (36.9%), and 25 (29.9%), respectively. When we analyzed the distribution of variables to determine the research competency of the students who chose to publish ($n=170$), such as level of authorship contribution, journal indexing category, and type of literature published, we found significant differences in authorship contribution and indexing category. Regarding the level of authorship contribution, the proportions of students who contributed as first authors or co-authors were 34 (59.6%) vs. 23 (40.4%) in pre-COVID-19, 27 (50.9%) vs. 26 (49.1%) during the pandemic, and 13 (21.7%) vs. 47 (78.3%) in post-COVID-19 ($\chi2=18.877$, $p<0.001$). The indexing category for the journal was analyzed by dividing it into three categories: Science citation index (expanded) (SCI(E))-indexed journals, Korea citation index (KCI)-indexed journals, and other journals. For each journal category, 14 (24.6%), 17 (29.8%), and 26 (45.6%) authors published before the onset of the pandemic, 17 (32.1%), 27 (50.9%), and 9 (17.0%) authors published during the pandemic, respectively, and 34 (56.7%), 25 (41.7%), and 1 (1.7%) author published after the COVID-19 pandemic, respectively ($\chi2=38.988$, $p<0.001$). For those students who chose to present at a conference ($n=82$), differences in distribution were found in the type of conference. The distribution of international, national, and intramural conferences was 10 (38.5%) vs. 12 (46.2%) vs. 4 (15.4%) in the pre-COVID-19 period, 8 (25.8%) vs. 22 (71.0%) vs. 1 (3.2%) during the pandemic, and 4 (16.0%) vs. 21 (84.0%) vs. 0 (0.0%) in the post-pandemic period ($\chi2=14.532$, $p=0.001$).

Comparisons of research outputs and competencies between Pre-, During-, and post-pandemic periods

A comparative analysis by period was conducted on research competencies, with distribution differences confirmed using the chi-square test in the areas of article publication and conference presentation. The results showed that there was a significant difference by period in two competencies related to paper publication: the level of authorship contribution [$F(2,167)=10.430$, $p<0.001$] and the journal indexing category [$F(2,167)=17.875$, $p<0.001$] (Table 2). Post hoc analysis showed that the level of authorship contribution score increased during the post-COVID-19 period (1.78 ± 0.42) compared to the pre-COVID-19 (1.40 ± 0.50) and during the pandemic period (1.49 ± 0.51), indicating a decline in research competency ($p<0.001$). In contrast, in the journal indexing category, scores decreased in the order of pre-COVID-19 (2.21 ± 0.82), pandemic (1.85 ± 0.69), and post-COVID-19 (1.45 ± 0.53), indicating that competency in the relevant area improved (all $p<0.05$). The analysis on the types of academic conferences, reflecting research capabilities in presentations revealed no statistically significant difference across periods ($F(2,79)=0.137$, $p=0.873$).

Discussion

The objective of this study was to identify any change in the research competencies of medical students under the COVID-19 pandemic. The graduation requirements for research competency were typically fulfilled by publishing a paper (67.5%) with a clinical medicine faculty member (63.5%) during the fourth year (50.0%), regardless of COVID-19 pandemic. The study considered the impact of the COVID-19 pandemic on these

		Pre-COVID-19 (*N* = 83)	Pandemic (*N* = 84)	Post-COVID-19 (*N* = 85)
Year of requirement attainment				
1st year	6 (7.2%)		9 (10.7%)	4 (4.7%)
2nd year	14 (16.9%)		6 (7.1%)	15 (17.6%)
3rd year	25 (30.1%)		24 (28.6%)	23 (27.1%)
4th year	38 (45.8%)		45 (63.6%)	43 (50.6%)
Supervisor's area of specialization*				
Basic Medical Science		28 (33.7%)	31 (36.9%)	33 (38.8%)
Clinical Medicine		54 (65.1%)	53 (63.1%)	52 (61.2%)
Research outcomes and competencies				
Publishing Papers (*N* = 170)		57 (68.7%)	53 (63.1%)	60 (70.1%)
Levels of contribution				
Being first author		34 (59.6%)	27 (50.9%)	13 (21.7%)
Being coauthor		23 (40.4%)	26 (49.1%)	47 (78.3%)
Indexing categories				
SCI(E)s		14 (24.6%)	17 (32.1%)	34 (56.7%)
KCIs		17 (29.8%)	27 (50.9%)	25 (41.7%)
Others		26 (45.6%)	9 (17.0%)	1 (1.7%)
Types of journal articles				
Original articles		30 (52.6%)	29 (54.7%)	40 (66.7%)
Review articles		4 (7.0%)	2 (3.8%)	5 (8.3%)
Case reports		23 (40.4%)	22 (41.5%)	15 (25.0%)
Presenting at Conferences (*N* = 82)		26 (31.3%)	31 (36.9%)	25 (29.9%)
Levels of contribution				
Being first author		24 (92.3%)	31 (100.0%)	22 (88.0%)
Being coauthor		2 (7.7%)	0 (0.0%)	3 (12.0%)
Conferences categories				
International		10 (38.5%)	8 (25.8%)	4 (16.0%)
Domestic		12 (46.2%)	22 (71.0%)	21 (84.0%)
Intramural		4 (15.4%)	1 (3.2%)	0 (0.0%)
Types of presentations				
Oral presentations		7 (26.9%)	5 (16.1%)	5 (20.0%)
Poster presentations		19 (73.1%)	26 (83.9%)	20 (80.0%)

Table 1. Characteristics of medical students' research experience. SCI(E), Science Citation Index (Expanded); KCI, Korea Citation Index. *Excluded one missing value.

	Pre-Covid19[a]	Pandemic[b]	Post-Covid19[c]	F	Post hoc
Publishing Papers (*N* = 170)					
Levels of contribution	1.40 ± 0.50	1.49 ± 0.51	1.78 ± 0.42	10.430***	c > a, b
Indexing categories	2.21 ± 0.82	1.85 ± 0.69	1.45 ± 0.53	17.875***	a > b > c
Presenting at Conferences (*N* = 82)					
Conferences categories	1.77 ± 0.71	1.77 ± 0.50	1.84 ± 0.37	0.137	

Table 2. Comparisons of research outcomes and competencies across pandemic periods. Note. In this study, higher scores represent lower research competency in each domain. ***$p < 0.001$.

competencies before, during, and after the pandemic. Students who chose to publish exhibited differing competency trends across the phase of the COVID-19 pandemic. The quality of published papers, as indicated by journal indexing categories, gradually improved during the pandemic, whereas authorship declined in the post-COVID-19 period.

It has been believed that medical education for graduation must be completed with a thesis[13]or, at least, a research program[14]. Scientific production of theses of medical students in SCI(E)-indexed or MEDLINE-indexed journals has been reported in nation-wide studies in French (17.0%)[13], Peru (13.9%)[15], and Morocco (0.8%)[16], and in a single medical school in New Zealand (32.7%)[17], Germany (28.0%)[18], and Finland (23.8%)[19]. In case of research program, the publication rates were vary depending on whether it is mandatory or elective. The publication rates were 27.7% in Netherlands[20]and 31.1% in Peru[15]when the program was mandatory.

In this study, the research outcomes of medical students in SCI(E)-indexed journals were 25.8%, which was similar when it is mandatory for graduation. Meanwhile, the publication rate was very heterogeneous across the medical schools evaluated in France (10.7–24.0%)[13], Peru (0.0–63.6%)[15], and Portugal (1.0–23.9%)[21]. And thus, a structural basis for the highest publication rate were suggested as follows[15]:(1) the smaller number of students, (2) the thesis as a mandatory graduation requirement, (3) the structural regular research curriculum, (4) the scientific promotion environment, (5) the scientific student associations, and (6) the economic funding for research. In the present study, the medical school met just 2 conditions, the small number of students and a mandatory graduation requirement. As there was a regression in authorship contribution in the post-pandemic period, a poor publishing culture[16,22], not attempt to investigate difficult or novel topics, among medical students should be interested. During the COVID-19 pandemic, students likely relied on existing research data to fulfill graduation requirements and meet the submission deadlines for graduation[8,9]. This may have further reduced the interactions between medical students and their advisors, resulting in students being involved as coauthors rather than as first authors and taking an active role in the planning and executing research. By having experienced researchers such as supervisors or faculty advisors conducting research as first authors, the quality of papers may be enhanced, and students may gain some research competencies through observation or simple task-level involvement. However, opportunities for students to acquire competencies through active participation are likely to have been limited during the COVID-19 pandemic. Therefore, the research outcomes might be closely related to the initiative of medical students and the help of their peers[23,24].

The findings of this study corroborate that the pandemic has impacted medical students' research and research-related learning experiences. However, the main finding of this study, which indicates divergent trends in research competencies during the course of the COVID-19 pandemic, should be interpreted with caution. The five stages of the Dreyfus model (novice, advanced beginner, competent, proficient, and expert) can be applied to the acquisition of research competency by medical students[1,23,24]. In the pre-COVID-19 period, students had more opportunities to reach the competent stage by publishing papers as first authors under the guidance of their supervisors upon graduation from medical school. In contrast, in the post-COVID-19 period, there is a concern that students will remain at or below the advanced beginner stage by performing fragmented research tasks.

Notably, this phenomenon was particularly pronounced in the post-COVID-19 pandemic period. While the post-COVID-19 research environment is recovering, it is possible that if students are publishing papers as part of their graduation requirements, their motivation and autonomy in actively engaging in research as first authors have not recovered compared to the voluntary research participation process. In other words, an environment that requires mandatory research-related performance for all may be a factor hindering the growth of medical students' pure motivations[25], such as scientific curiosity and intellectual challenges, which are desired from research education[2,3], or even secondary motivations, such as benefits related to future career decisions, such as specialty selection or faculty recruitment[26]. Thus, achieving the original educational goals for medical research in the post-COVID-19 era necessitates strategies to enhance the motivation of students for engaging in research training, even in a mandatory environment.

Motivation should be understood as an inherent quality of students, not an externally imposed obligation[27]. Even though the majority of medical students in previous studies have indicated that research training is important to them during medical school[25,28], it is possible that they have not clearly understood or discovered their own reasons and implications for its importance. Therefore, rather than just conveying the conventional wisdom of the "benefits of research," it may be necessary to help students understand that their values as human beings and future healthcare professionals are aligned with their participation in research during their medical school education[29]. It seems advisable that this opportunity will be more effective if given to students at the earliest stage of their research experience and if students can periodically reassess their values and create research activity plans that reflect those values[27,29,30]. Furthermore, research participation should provide students with opportunities to cultivate autonomy and self-efficacy, not a simple labor[31]. Regardless of one's role within the research process, it would be ideal to provide feedback to students to ensure that they are performing their essential role in the research and contributing to the overall purpose of the research[25,31]. It can be reasonably assumed that academic advisors will be better positioned to facilitate this process than any other individual[2,25]. However, senior students who have attained a high level of research competence can be expected to act as peer mentors, thereby mutually promoting motivation and autonomy among their fellow students[1,24].

This study is subject to several limitations. Primarily, as the research was conducted by examining the research performance of graduates from one medical school, there may be limitations in generalizing the research results. Furthermore, the data used in the study was restricted to data selected and submitted by graduates, making it challenging to incorporate the full range of research experiences and capabilities of the students. Follow-up studies should consider not only individual characteristics, such as personal backgrounds of students and preferred mentoring styles of supervisors, but also structural factors, including the curricula and policies of various medical schools. Second, this study was conducted retrospectively, which inevitably limits the variables defined as research capabilities and subsequently included in the analysis. In particular, it is difficult to ensure that the journal indexing category is a specialized standard for measuring 'excellent' papers or improving medical students' research capabilities. Third, the long-term effects of the entire medical school education process could not be ascertained because the results of this study were analyzed based on the results of a cross-sectional study conducted at the time of graduation. Therefore, follow-up studies in a larger sample of medical students are needed to prospectively examine various variables related to research competency and the quality of medical education. Furthermore, the impact of these variables on the quality of clinical and community health care and medical research needs to be studied through long-term monitoring.

Despite these limitations, this study is significant because it is the first to identify changes in the research competencies of medical students in the pre-, during, and post-COVID-19 periods and to identify ways to

respond to these changes. We anticipate that follow-up research will develop a more effective curriculum for research-related medical education and instructional methodology. This will serve as the foundation for scientific thinking and best practices for medical students who represent the future of healthcare.

Methods

Research experiences and productivity

Jeju National University Medical School, where this study was conducted, stipulated the requirement for graduation on academic, research, and volunteer competencies based on the WFME recommendations[4,5]and the Accreditation Standards of KIMEE 2019 (ASK2019)[32] of the Korean Institute of Medical Education and Evaluation (KIMEE). Graduation requirements are communicated at admission and must be fulfilled within at least 4 academic-years under a single-major curriculum structure. Students, who want to become medical doctors, have the option of selecting either (1) publishing a paper or (2) presenting at a conference as a fulfillment of research competency and may request a faculty member from their medical school to supervise them through the process. Students may engage in a number of research activities, but typically, only one research outcome that the student deems to be representative of their research experience is submitted for consideration for graduation requirements.

Data collection and analysis

In this study, we defined 2020-2021 as the COVID-19 pandemic period, during which social distancing measures were implemented in South Korea[33], while 2018-2019 was designated as the pre-COVID-19 period, and 2022–2023 as the post-COVID-19 period. Research outcomes were required to be submitted by December of fourth (senior) year, providing a standard timeline for comparison. Research outputs submitted by all graduating students during these periods were retrospectively collected. From the collected data, representing research competencies were identified through expert discussions on conducting and teaching medical research. For each following variable, a ranking was assigned to each sub-variable on a scale of 1 to 3 as follows: For article publications, 1) Level of contribution in authorship: first author (1) or co-author (2); 2) Indexing categories of the journal in which the publication is published: SCI(E) (1), KCI (2), or other journals (3); 3) Type of literature: original article (1), review article (2), or case report (3). For conference presentations, 1) Level of contribution in authorship: first author (1) or co-author (2); 2) Type of conference: international conference (1), national conference (2), or intramural conference (3); 3) Type of presentation: oral (1) or poster (2) presentation. We also checked for the year in which graduation requirements were completed and the advisor's field of specialization. In the case of students who submitted multiple achievements, including article publication and conference presentation, the experience of publishing an article was deemed to be representative data. Within the same category, the highest-performing students' output was selected to represent their research competency. Using the collected data, descriptive statistics were conducted to assess the quality of the students' research experience, and chi-square tests were performed to analyze the differences in distribution by time period and research competency. A one-way analysis of variance (ANOVA) test was conducted to quantitatively compare the research competency variables where differences in distribution were identified by the period of the COVID-19 pandemic, and a post hoc test was performed using Scheffe's method. All collected data were analyzed using SPSS 28.0 (SPSS Inc., Chicago, IL, USA), with a significance level of $p < 0.05$.

Ethics statement

This study was granted an exemption from ethical review by the Institutional Review Board of Jeju National University (Approval No. JJNU-IRB-2024-023), and the requirement for consent to use graduates' personal data for research purposes was waived. All research was performed in accordance with the relevant guidelines and regulations set by the Korea National Institute for Bioethics Policy.

Data availability

The dataset used and/or analysed during the current study available from the corresponding author (S.P.Y.) on reasonable request.

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Author contributions

All authors conceived the idea. S.A.L, J.S.H., K.B.S. and E.K.C. collected the data. E.N. conducted the analyses. E.N. and S.A.L. wrote the original manuscript. S.P.Y. supervised the research. All authors approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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