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Research Paper

Effect of the case-based learning method combined with virtual reality simulation technology on midwifery laboratory courses: A quasi-experimental study

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ABSTRACT

Objective: This study aimed to evaluate the effect of case-based learning (CBL) method with virtual reality (VR) simulation technology (CBL-VR) on midwifery laboratory courses.

Methods: A quasi-experimental design was employed. A total of 135 midwifery students were recruited from Nursing College of Guilin Medical University in China from September 2020 to January 2022. Intervention group recruited students from the Class of 2019 ($n = 59$) and control group recruited students from the Class of 2018 ($n = 76$). The intervention group students received the CBL-VR method based on traditional laboratory teaching, the contents of course included four sections: eutocia (6 class hours), dystocia (6 class hours), umbilical cord prolapse (2 class hours), and neonatal asphyxia and resuscitation (4 class hours), 40 min per class hour. The control group students received the traditional laboratory teaching. Students' academic performance, Self-Directed Learning (SDL) Ability Questionnaire, and the education satisfaction questionnaire were used to evaluate the teaching efficacy between two groups.

Results: After intervention, the intervention group students achieved higher scores than the control group in individual operation ability (90.88 ± 2.14 vs. 89.24 ± 3.15), team operation ability (90.97 ± 2.33 vs. 81.28 ± 5.45), and midwifery case analysis ability (88.64 ± 3.19 vs. 86.70 ± 2.56) ($P < 0.01$). Prior to the implementation of the course, there was no difference in the SDL ability scores between the two groups of students ($P > 0.05$). However, following the course intervention, the SDL ability scores of the intervention group were higher than those of the control group (94.78 ± 6.59 vs. 88.12 ± 8.36), and the scores in all dimensions of the intervention group were also higher ($P < 0.05$). Additionally, more than 94% of the students indicated that CBL-VR method developed comprehensive abilities, including independent-study enthusiasm, independent thinking, collaboration, and communication.

Conclusion: Using the CBL-VR method in midwifery lab courses improved students' course performance, SDL ability, and comprehensive ability. Students highly recognized the effectiveness of this approach.

What is known?

- The virtual reality (VR) simulation technology requires additional practice on midwifery education.
- The optimization of teaching strategies is a feasible method for enhancing teaching effectiveness.

What is new?

- Combining case-based learning (CBL) method with VR simulation technology (CBL-VR) on midwifery laboratory course effectively enhanced students' academic performance and self-direction learning ability.
- Students appreciated the CBL-VR method in the midwifery laboratory course, as they felt it enhanced their comprehensive abilities.

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1. Introduction

Midwifery services have developed quickly in recent years with the application of novel midwifery theory and optimized midwifery procedures by healthcare organizations [1]; however, proficient midwives are still important safeguards for the health of mothers and newborns [2,3]. Traditional midwifery education contributes greatly to the cultivation of midwifery talent, but it still has disadvantages, such as insufficient cultivation of thinking ability [4], which is vital for the career development of midwifery students [5,6]. Virtual reality (VR) simulations, serving as an informational platform, are widely applied in nursing education and accelerate students' clinical capacity development [7,8]. Midwifery is a practice-oriented course; therefore, we introduce VR simulation and Case-based Learning (CBL) method into the midwifery laboratory course to enhance the comprehensive midwifery capabilities of midwifery students.

The traditional midwifery laboratory course, which has heavily relied on Lecture-based Learning (LBL) [9] through videos, pictorial tutorials, and manikin simulation, faces shortcomings in intuition, interaction, and reproducibility [10]. The increasing emphasis on maternal privacy rights reduces the practical opportunity for students to perform midwifery operations [11]. Moreover, traditional laboratory teaching is typically focused on learning and training individual operations, which do little to develop midwifery students' comprehensive capabilities. Nursing students hardly make appropriate clinical decisions in real clinical environments, which are more complex than those in teaching materials. Additionally, newly graduated midwives still require long-term training in operations and clinical decision-making ability during their internships. Therefore, it is difficult to train adequately qualified midwives in a short time to satisfy maternal medical needs [12–14]. To remedy the inadequate practical experience of nursing students, it is necessary to provide students with more operation opportunities to enhance their abilities [15]. Simultaneously, the design of midwifery teaching cases also needs to be restructured, focusing on cultivating students' comprehensive capabilities [16].

Thinking ability is a crucial competitiveness for nurses, as it helps them to respond rapidly in complex clinical environments [17] and can be enhanced by improved teaching strategies. Thinking training is vital for cultivating the thinking ability of nursing students [18,19]. CBL designs clinical problems based on clinical cases and inspires students to discuss and solve clinical problems, which also enhances students' comprehensive capabilities such as operation skills, thinking, communication and collaboration ability [16,20,21]. CBLs are widely used in nursing courses such as nursing ethics courses [22], evidence-based nursing courses [23], obstetrics and nursing courses [24], and they demonstrate a feasible method for enhancing students' critical thinking ability by optimizing teaching strategies [25].

Although VR simulation has already been used in many successful applications in nursing education [8,26,27], research on VR simulation-assisted midwifery courses is limited. Therefore, we integrated real midwifery cases into VR simulation to enhance students' comprehensive midwifery capability. This study evaluated the advantages of combining CBL method with VR simulation technology and provided a guiding trajectory for future research on optimizing VR simulation midwifery laboratory courses and other nursing courses.

2. Methods

2.1. Study design and participants

This research was designed as a quasi-experimental study. This study was conducted from September 2020 to January 2022, at Nursing College, Guilin Medical University, Guangxi Zhuang Autonomous Region, China. All the students provided informed consent to participate in the study, and the study could be withdrawn at any time. The sample inclusion criteria were as follows: i) had no learning experience in midwifery course; ii) had no experience in VR simulation technology; iii) provided voluntary informed consent to participate in the study. Participants were excluded if they met the following criterion: student withdrawal from the program.

The sample size was calculated by G*Power 3.1.9.7 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) with the default options and parameters: test = t-tests (means: two groups), effect size = 0.5, α = 0.05, power = 0.8 [28,29]. The calculation results indicated the needed total sample (power = 0.8) was N1 = N2 = 51. Due to the limited number of students admitted to the midwifery major, students in Class 2019 ($n = 59$) were assigned to the intervention groups and Class 2018 to the control groups ($n = 76$), respectively. (Classes 2019 and 2018 were enrolled in 2019 and 2018, respectively.) With proper informed consent obtained, all students from the Class of 2018 and the Class of 2019 were aware of and agreed to participate in this study. The effective sample size of this study met the requirements. There were no significant differences ($P > 0.05$) in general information and major course scores between the two classes.

2.2. Interventions

The midwifery course is the most crucial for midwifery students' education and aims to develop their core competence during their schooling period. We designed an optimized teaching method by introduced CBL method and VR simulation technology into midwifery laboratory course. The content of this CBL-VR midwifery laboratory course includes four sections: eutocia (6 class hours), dystocia (6 class hours), umbilical cord prolapse (2 class hours), and neonatal asphyxia and resuscitation (4 class hours) (40 min per class hour). For the intervention group students, these four lessons were taught using a CBL-VR method, while the remaining lessons from the midwifery laboratory course were conducted using the conventional teaching method. All lessons were taught using traditional teaching methods for the control group of students. Both groups of students were educated by the same teachers, spending same class hours, and using the same book, *Midwifery* (ISBN 978-7-117-24431-2/R·24432).

2.2.1. Intervention group

2.2.1.1. Formation of the teaching team. The teaching team consisted of the midwifery course director, theoretical class teachers, and laboratory class teachers. Three full-time teachers with strong backgrounds in nursing and midwifery designed the course, wrote the midwifery cases, and managed the script. Four part-time hospital teachers with good clinical experience in obstetrics were responsible for writing the midwifery cases, managing the script, and providing feedback on the course design.

2.2.1.2. Establishment of the database of cases. Four midwifery lessons involving nurturing-maternal communication (eutocia, dystocia, umbilical cord prolapse, neonatal asphyxia and resuscitation) were adopted for CBL-VR method. Eutocia was used as an example to demonstrate the design of teaching lessons. We ingeniously integrated midwifery diagnosis and operational training following the chronological progression of eutocia. Common operations in eutocia, such as rinsing the vulva and perineum, infant delivery, intravenous infusion of oxytocin, and uterine massage, were sequentially integrated into the eutocia lesson to simulate the entire delivery procedure. Students were required to make an accurate diagnosis and perform the correct operation using the information following the eutocia's progress. One teacher prepared the above basic design of the eutocia lesson and then optimized it according to the discussion of the teaching team. Final approval for the eutocia lessons' design came after thorough discussion and careful revision by the teaching team. Consisting of two senior VR engineers, the software support team developed and maintained the CBL-VR software (Fig. 1A–C). After experiencing the beta version of the CBL-VR software, the teaching team revised software based on their feedback. The design of the remaining lessons was similar to that of eutocia lesson. For the convenience of learning, the lesson umbilical cord prolapse can be accessed outside the laboratory using campus network (https://qdtcfz.glmc.edu.cn/). The CBL-VR software was equipped with instant feedback function, enabling immediate correction of operational errors when activated.

2.2.1.3. Implementation of CBL-VR method. A eutocia lesson was used to demonstrate the implementation of CBL-VR method. 1) Before class. All students first logged in to the training mode of the CBL-VR software. The participants needed to learn the theoretical knowledge of eutocia, which was designed to resemble an engaging yet rigorous game. Then, students started practicing midwifery procedures, including delivering babies and manually extracting placentas, receiving instant feedback during practicing. Subsequently, students needed to finish the entire midwifery procedure without instant feedback function. 2) During class. First, the students received a brief theoretical lecture on eutocia, which was presented by the teachers. Pictures, videos, and manikins were the main teaching tools to demonstrate eutocia operations. Second, the students were requested to complete the learning, training, and examination of eutocia operations on the CBL-VR platform (Fig. 1 D). Third, to practice eutocia operations, students were required to conduct offline training in teams, a team consisting of 4-5 members. One student played the role of a mother, while the others played the role of midwives. The midwives discussed the mother's labor status and delegate eutocia operations accordingly. They worked together to complete all delivery operations, such as rinsing the vulva and perineum, delivering the baby, administering intravenous infusion of oxytocin, and performing uterine massage. Fourth, students briefly discussed the precautions and skills of midwifery operations. Then, the teacher provided a brief summary summarizing the achievements and shortcomings of the students' performance. 3) After class. All students were encouraged to review the knowledge and operations of the eutocia lesson after the laboratory class.

2.2.2. The control group

The control group students were taught with the LBL teaching method, which typically involves using presentations, videos, pictorial tutorials, and manikin simulations as the main teaching tools. Before the class, students were instructed to preview the eutocia lesson using the midwifery book. Traditional teaching methods included the teacher's lecture presentations, students' mimicking and discussions, and summaries. Afterwards, students were encouraged to review the concepts and procedures of the lesson.

2.3. Instruments

2.3.1. General information questionnaire

A general information questionnaire was used to collect students' general information, including age, gender, medical nursing score (100 points), and surgical nursing score (100 points) [30].

2.3.2. Academic performance evaluation form

The assessment of academic performance involved three main parts: an individual operation score (100 points), a team operation score (100 points), and a case analysis score (100 points). The examiners included teachers from the teaching team, and they conducted face-to-face scoring of operation performance and case analysis ability according to standard midwifery operation procedures. A higher score indicates better academic performance. Individual operation examinations were held one week after the laboratory course. Students needed to complete all the single operations of the infant delivery in sequence. The individual operation scores included three main parts: preparation (10 points), operation procedure (80 points), and composite score (10 points). The team operation examination was held two weeks after the laboratory course. Students needed to form teams (4–5 members) to analyze midwifery cases and assign tasks reasonably. The team operations score included six main parts: preparation (5 points), operation procedure (55 points), emergency response (10 points),

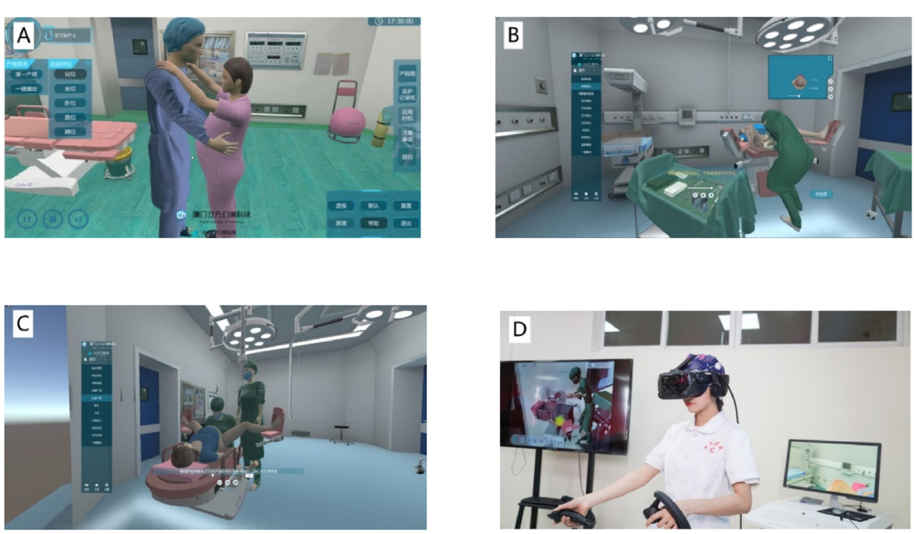

Fig. 1. User interface (UI) design and user experience of the case-based learning method with virtual reality (CBL-VR) teaching system. A–C: UI design of the CBL-VR teaching software. D: A student is using the CBL-VR teaching equipment.

teamwork (10 points), nursing records (10 points), and communication (10 points). Cases analysis examination was performed three weeks after the laboratory course. Students needed to form teams (4–5 members) to analyze the examination cases thoroughly using the given information. All students were asked to provide their answers, including those about the analysis process, midwifery diagnosis, corresponding operations, and precautions, in PowerPoint® format. The case analysis examination score (100 points) included five parts: objective (10 points), case report (20 points), case analysis (30 points), courseware design (20 points), and composite score (20 points).

2.3.3. Self-Directed Learning Ability Questionnaire

The SDL Ability Questionnaire was developed by Lin and Jiang [31] and used to assess two groups of students' SDL ability before and after the intervention in this study. The questionnaire included: self-management capability (10 items), information processing capability (11 items), and collaboration capability (7 items), three dimension, 28 items. This questionnaire used a 5-point Likert scale, with higher scores for positive options and lower scores for negative options. The total score ranged from 28 to 140, with higher scores indicating greater SDL ability. The split-half reliability and Cronbach's α coefficient of the SDL ability questionnaire were 0.766 and 0.863, respectively, indicating that this questionnaire had high validity and reliability.

2.3.4. Education satisfaction questionnaire

Based on published study [32], a teaching system satisfaction questionnaire was designed to assess intervention group students' satisfaction with CBL-VR method. This customized questionnaire consisted of 7 items: study interest, independent study enthusiasm, independent thinking ability, analyzation and execution ability, collaboration ability, self-expression ability, and communication ability. Each question had three answers: absolutely approved, moderately approved and unapproved, representing the degree of satisfaction in students' abilities enhancement through the CBL-VR method. Students were invited to complete a satisfaction questionnaire based on their actual experience during learning. Higher approved rate (absolutely approved rate + moderately approved rate) means higher education satisfaction.

2.4. Data collection

Before the intervention, teachers presented the course content, teaching methods, and course purpose to students. The electronic questionnaire platform, "Wenjuanxing" (https://www.wjx.cn/), was used to collected students' general information, SDL ability data, and education satisfaction data. Before the course, both groups of students were required to fill out the general information questionnaire. They were also required to complete the SDL ability questionnaire before and after the intervention. Moreover, students in the intervention group were invited to complete the education satisfaction questionnaire at the end of the intervention. During the course examination, teachers recorded the academic performance data in real-time.

2.5. Data analysis

SPSS 26.0 (IBM Corporation, Armonk, NY, USA) was used for data analysis in this study. The Kolmogorov–Smirnov test was used to assess the normality of the data distribution. Continuous variables normally distributed were expressed as mean and standard deviation, while those not normally distributed were presented as medians. Categorical variables were presented as the frequency and percentage. Data comparison was performed using the independent sample t-test for normally distributed data, the Mann–Whitney U test for nonnormally distributed data, and the chi-square test for categorical variables. A P value < 0.05 was considered to indicate statistical significance.

2.6. Ethical considerations

This study was approved by the Ethics Committee of Guilin Medical University (Application ID: GLMC20210504). All intervention group and control group students provided informed consent to participate in this study.

3. Results

3.1. Participants' characteristics

A total of 135 students provided informed consent to participate in this study. All of them participated in the entire education program. In the intervention group, 59 students were all female; in the control group, 75 females and one male were included. Both groups of students were aged 19–23 and had taken midwifery classes during their fifth school term. All the students had finished public, fundamental, and some specialist courses before participating in this program. Comparisons of age, medical nursing class score, and surgical nursing class score are shown in Table 1. No significant

Table 1
Comparison of age, and medical and surgical nursing scores between the two groups.

Variables	Intervention group ($n = 59$)	Control group ($n = 76$)	t	P
Age	21.30 ± 0.75	21.27 ± 0.74	0.337	0.737
Medical nursing score	79.85 ± 4.65	81.29 ± 6.22	−1.486	0.140
Surgical nursing score	80.15 ± 4.59	81.59 ± 5.68	−1.586	0.115

Note: Data are *Mean* ± *SD*.

Table 2
Comparison of academic performance between the two groups.

Group	Individual operation ability score	Team operation ability score	Case analysis ability score
Intervention group ($n = 59$)	90.88 ± 2.14	90.97 ± 2.33	88.64 ± 3.19
Control group ($n = 76$)	89.24 ± 3.15	81.28 ± 5.45	86.70 ± 2.56
t	3.604	13.96	3.823
P	<0.001	<0.001	<0.001

Note: Data are *Mean* ± *SD*.

difference was found in age, medical nursing score, and surgical nursing score ($P > 0.05$) between the two groups of students.

3.2. Effect of CBL-VR method on students' academic performance

After the midwifery laboratory class, the intervention group students had higher scores on all the items, including the individual operation ability score ($t = 3.604$, $P < 0.001$), team operation ability score ($t = 13.96$, $P < 0.001$) and case analysis ability score ($t = 3.823$, $P < 0.001$), indicating that CBL-VR method effectively improved students' academic performance (Table 2). Additionally, team operation ability demonstrated the most remarkable improvement compared to individual and case analysis ability.

3.3. Effect of CBL-VR method on students' self-directed learning ability

No difference in SDL ability was found between the two groups of students before the course ($t = 0.112$, $P = 0.911$) (Table 3). Interestingly, the intervention group students had greater SDL scores than the control group students after the course ($t = 5.024$, $P < 0.001$) (Table 3). Additionally, the intervention group students had greater scores for all components of SDL ability, including self-management capability score ($t = 5.104$, $P < 0.001$), information processing capability score ($t = 2.403$, $P = 0.018$), and collaboration capability score ($t = 4.300$, $P < 0.001$) (Table 3).

3.4. Effect of CBL-VR method on education satisfaction

According to the statistical analysis, CBL-VR method was highly appreciated by the intervention group students (Table 4). All the items received an approval rate of more than 94% (including absolutely and moderately approval), indicating that this CBL-VR method received high educational satisfaction. Additionally, all the students in the intervention group acknowledged that their collaboration ability had been enhanced.

4. Discussion

Our study indicated that CBL-VR method effectively enhanced students' individual and team operation abilities, which have also been supported by previous studies [7,8,33]. Shih et al. reported a VR training portal-A catheter course for oncology nurses [8]. VR teaching significantly improved nurses' port-A catheter curved needle injection skills. The training error rate was negatively associated with practice frequency. For midwifery students, infant delivery operation training is inaccessible during school because of its high risk. VR simulation equipment addressed this limitation by offering students a friendly, risk-free, immersive midwifery environment [34], increasing their delivery operation training opportunities.

Additionally, CBL-VR software can be executed on a campus network outside the classroom, increasing the students' opportunities to train their operation skills. The instant feedback function of the CBL-VR software helped students promptly correct their incorrect operation. Therefore, in this present study, CBL-VR method enhanced students' operation ability by increasing training opportunities and real-time correction.

A systematic review and meta-analysis indicated that VR simulation teaching did not significantly enhance critical thinking ability [35]. Therefore, we combined CBL method and VR simulation teaching to address this shortcoming. In our study, the intervention group students had higher scores on the comparison of midwifery case analysis ability, which indicated that CBL-VR method may be benefit for students' thinking ability. A midwifery case analysis examination requires students to make a diagnosis by referring to maternal biological and psychological changes, to make treatment plans by organizing midwifery operations and assigning tasks to teammates, and to present analysis results through discussion among teammates and full articulation of their perspectives. This examination procedure embodied the principles of critical thinking in midwifery practice: analysis, constructive application, problem-solving, evaluation of care, collaboration/negotiation, facilitating shared decision-making, communication, and transforming knowledge [36,37]. Therefore, in this study, the team-based midwifery case analysis examination may facilitate students' thinking ability development.

Table 3
Comparison of self-directed learning ability between the two groups.

Stage	Group	Self-management capability score	Information procession capability score	Collaboration capability score	Total score
Before intervention	Intervention group ($n = 59$)	31.14 ± 3.88	33.88 ± 4.85	21.58 ± 3.19	86.59 ± 9.56
	Control group ($n = 76$)	31.20 ± 3.96	34.68 ± 4.60	20.89 ± 3.67	86.78 ± 9.25
	t	0.091	0.982	1.132	0.112
	P	0.928	0.328	0.260	0.911
After intervention	Intervention group ($n = 59$)	34.69 ± 3.05	36.54 ± 3.34	23.54 ± 2.31	94.78 ± 6.59
	Control group ($n = 76$)	31.75 ± 3.53	34.95 ± 4.16	21.42 ± 3.19	88.12 ± 8.36
	t	5.104	2.403	4.300	5.024
	P	< 0.001	0.018	< 0.001	< 0.001

Note: Data are *Mean* ± *SD*.

Table 4
The satisfaction with CBL-VR method among students in the intervention group ($n = 59$).

Capability improvement	Absolutely approved	Moderately approved	Unapproved
Study interest	39 (66.11)	19 (32.20)	1 (1.69)
Independent-study enthusiasm	32 (54.24)	26 (44.07)	1 (1.69)
Independent thinking	33 (55.93)	25 (42.38)	1 (1.69)
Analyzation and execution ability	34 (57.63)	24 (40.68)	1 (1.69)
Collaboration ability	39 (66.10)	20 (33.90)	0 (0.00)
Self-expression ability	26 (44.07)	30 (50.85)	3 (5.08)
Communication ability	35 (59.32)	23 (38.99)	1 (1.69)

Note: Data are n (%). CBL-VR = case-based learning method with virtual reality.

In this study, CBL-VR method effectively enhanced students' SDL ability by improving their self-management, information processing, and collaboration capabilities. A previous study indicated that teaching strategies incorporating individual and small group learning with teachers' guidance greatly improved nursing students' SDL ability [38]. Therefore, implementing single-user and multiuser modes in teaching software, including team-based operation examinations and case analysis examinations in our CBL-VR method strategies, maybe the most effective promoter of students' SDL ability. Learning interest was also a driver of students' SDL ability [38]. The results of education satisfaction survey showed that more than 98% of the intervention group students agreed that CBL-VR method increased their interest in learning. Hence, the improvement in students' SDL in our study may be attributed to the immersive midwifery environment provided by the VR simulation equipment and the rigorous gaming mode of the software used during learning.

5. Limitations

This study only recruited nursing students from Nursing College, Guilin Medical University, therefore, future research should expand the sample to include other nursing students from other schools/colleges/universities. Additionally, a very small number of students experienced motion sickness or dizziness when using VR equipment, which may have affected their learning interest and satisfaction with VR simulation teaching.

6. Conclusion

In brief, CBL-VR in a midwifery laboratory course remedied the disadvantages of traditional teaching methods and effectively enhanced midwifery students' academic performance and SDL ability. Midwifery students highly appreciated CBL-VR method on midwifery courses because they felt that comprehensive ability improved. This research will be helpful for the development of VR teaching on midwifery education.

CRediT authorship contribution statement

Lingyun Zhao: Methodology, Conceptualization, Validation, Investigation, Data curation, Writing - original draft, Project administration, Resources, Supervision, Funding acquisition, Writing - review & editing, Formal analysis. **Xiaohong Dai:** Methodology, Conceptualization, Validation, Investigation, Data curation, Resources, Supervision, Writing - review & editing. **Siyu Chen:** Methodology, Conceptualization, Validation, Investigation, Data curation, Resources, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

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