Exploration and Application of Three-stage Strengthening Mode based on Massive Open Online Course to Improve Students' Competence in Electrocardiogram Interpretation Skills

Simin Huang[1,*], Feifei Wang[1,*], Chunting Lu[2,*], Jing Yang[1], Jianhua Zhang[1], Shengming Liu[1] & Jun Guo[1]

[1] Department of Internal Medicine, the First Affiliated Hospital of Jinan University, Guangzhou, China

[2] Science and Education Office, the First Affiliated Hospital of Jinan University, Guangzhou, China

* These authors contributed equally to the work.

Correspondence: Shengming Liu, Department of Internal Medicine, the First Affiliated Hospital of Jinan University, Guangzhou, China. E-mail: tlsm@jnu.edu.cn; Jun Guo, Department of Internal Medicine, the First Affiliated Hospital of Jinan University, Guangzhou, China. E-mail: dr.guojun@163.com

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Abstract

Electrocardiogram (ECG) is a widely common diagnostic test in clinical practice. However, research has shown that residents and medical students cannot analyze ECG skillfully. In this study, we explore a three-stage strengthening mode based on massive open online course (MOOC) to improve students' competence in ECG interpretation skills. We carry out the first stage in a diagnostics course, in which instructors adopted online and offline blended mode for the teaching method of ECG with clinical medicine students in grade 2018 based on MOOC. We compare scores of ECG interpretation skills for 91 students in grade 2018 with 81 students in grade 2016 to evaluate the effect. The second stage concerns studying internal medicine, in which we divide students in grade 2018 into two groups with 49 students in group A and 42 students in group B. Group A strengthened their ECG interpretation skills when learning about heart diseases. The third stage pertains to rotation in the internal medicine department in the internship period. Some students in group A continued to receive intensive training. Students in group B had no reinforcement arrangement in the second and the third stage. Students in grade 2018 took graduation tests at the end of their internship. We use the scores on ECG interpretation skills in the graduation examination to evaluate the strengthening effect between group A and group B. The result of the first stage shows that scores on ECG interpretation skills in the final exam in grade 2018 were 19.32 ± 4.62 points, which is higher than those of grade 2016, whose points were 16.89 ± 5.30 (total scores in both grades were 30 points). Difference is statistically significant. Scores on the graduation examination in group A were 38.89 ± 16.81 points, and those of group B were 26.86 ± 15.43 points (total score was 60 points), with statistical difference between these two groups. The three-stage strengthening mode based on ECG MOOC is an effective method to improve students' ECG interpretation skills. Results show that an online and offline blended teaching strategy is superior to the traditional lecture method. Repeated practice is necessary for improving ECG interpretation competence. Students in the strengthening program group had better grades in the graduation examination.

Keywords: electrocardiogram (ECG), ECG competency, medical education, massive open online course (MOOC)

1. Introduction

Electrocardiogram (ECG) is a widely used diagnostic tool in clinical practice and plays an important role in diagnosing and evaluating patients' condition. Although scholars constantly update the methods for diagnosing heart diseases, ECG is still an irreplaceable test for heart diseases. Therefore, adequate ECG interpretation competence is particularly important for medical professionals to make correct decisions, especially for doctors in cardiovascular departments, emergency departments, and intensive care units. ECG competency means that health professionals master ECG basic knowledge, identify normal and abnormal characteristics of ECGs, and apply this tool in clinical situations (Kashou, et al., 2020). ECG is one of the most commonly misinterpreted tests in clinics (Kashou et al., 2020). In a review, Cook, Oh, and Pusic found that the accuracy of ECG interpretation varied widely, ranging from 4% to 95% (2020). Misinterpretation of ECG can lead to improper clinical decision-making, which can waste medical resources and result in adverse outcomes (Breen, et al., 2022; Vishnevsky, et al., 2022), especially in patients with

myocardial infarction (Sarda & Thute, 2022).

Although the competency to interpret ECG accurately is a necessary basic skill for every doctor, the complicated and difficult principle of ECG and abnormal ECG phenomena is always an insurmountable obstacle for medical students and clinicians. Both medical students and clinicians generally agree that the ability to interpret ECG is one of the most challenging parts of various exams, such as final exams or internal medicine or cardiology professional exams (Grzegorz, et al., 2015). Residents and medical students lack confidence to interpret ECG (Ei-Baba, et al., 2023; Yokoyama et al., 2023). There are significant gaps in ECG interpretation accuracy among medical students and professionals (Kashou et al., 2023; Perrichot et al., 2023). Researchers found that medical students' and practitioners' competency to recognize primary parameters in emergency and common abnormal ECGs was insufficient (Ng & Christensen, 2023; Vishnevsky et al., 2022). Data from China regarding the clinical licence examination in Anhui province in 2014 were not ideal; the pass rate of ECG interpretation was 63.60% in students who passed the exam, whereas the pass rate in students who failed the exam was only 22.33% (Zhai, et al., 2016). Undergraduate interns of clinical medicine majors from 14 medical colleges and universities in Guangdong, Hainan, and Guangxi provinces participated in the National Clinical Skills Competition for Medical College Students in South China in 2016, which was organized by Jinan University. Scores in ECG interpretation were 59.80 points (total score was 100 points, unpublished). Our previous studies also showed that ECG accuracy was still a weak point for undergraduates (Wang et al., 2022). These studies suggest that ECG interpretation competence is a weak skill for medical students. If the foundation is not well laid at the undergraduate stage, and there is no reinforcing arrangement at the resident stage, it is unlikely that students will be able to interpret ECGs accurately when they work.

Many teachers think that ECG teaching has many problems, such as excessive content, abstractions, and comprehension difficulties, insufficient hours for teaching, and no expert supervision (Amini, et al., 2022; Kashou et al., 2023; Li et al., 2020). Researchers have explored teaching modes to improve ECG interpretation skills in recent years, especially since the rise of the Internet. The modes have also undergone great changes. Lecture was the most traditional teaching method before the Internet (Alamrani, et al., 2018; Wen, et al., 2023). In addition, tutors have adopted three-dimensional teaching mode (Xie, 2023), workshop (Mres, et al., 2020), mind mapping (Xu, et al., 2021), self-drawing (Lei, et al., 2019), problem-based learning and case-based learning (Feng, et al., 2022; He, et al., 2024), and peer learning (Ko, et al., 2022) in ECG teaching, which improved students' interest, self-learning ability, self-confidence, and teaching effect. Some scholars proposed that combining different measures based on the traditional method could motivate students' learning enthusiasm and improve the learning effect, thus having a lasting impact on students (Liang et al., 2019; Wang et al., 2022). Teacher Li et al. used integrated teaching methods to teach ECG in diagnostics, their results showing that the experimental group had higher scores in ECG interpretation skills and satisfaction than those of the control group (2020). Cheng, Zhao, Huang, and Yu assayed a "TACG" (theory, animation, case, group learning activities) model to teach ECG, finding that test scores and satisfaction scores were higher in the experimental group than in the control group (2023).

The development of the Internet has provided more resources and choices for ECG learning and has also effected a change from face-to-face learning in the classroom to a blended learning mode combining in-person and online teaching. In the digital era, making full use of web sources has become the new model (Das et al., 2022; Kashou et al., 2023). Most students hold a positive attitude toward online learning resources (Nilsson, et al., 2019). Web-based learning could increase learners' interest and enhance their learning effectiveness (Kashou et al., 2024; Lin, 2023). For important or difficult courses, e-learning is a good complement to face-to-face teaching (Keis et al., 2017). Research has shown that web-based blended learning is more effective than lectures (Viljoen, et al., 2020).

Although many researchers have confirmed that traditional teaching methods and blended teaching modes are conducive to improving ECG teaching effects, some scholars think that no single standard method for educators to teach ECG interpretation skills, a mode containing novel and creative teaching, should be considered (Ali et al., 2023; Breen et al., 2022; Kaye, et al., 2024). In one study, e-learning was a good choice for ECG learning, but it did not replace theory-oriented face-to-face courses adequately (Keis et al., 2017).

Current researchers of ECG teaching focus on exploring teaching modes at a certain stage and evaluating the effectiveness or exploring the testing time, for example, pre- and post-intervention (Ei-Baba et al., 2023; Holland et al., 2023; López-Prado et al., 2023). There are few studies focused on the modes and effects of multistage strengthening projects in ECG teaching. In this study we explored the effect of MOOC-based multistage strengthening mode in ECG teaching for undergraduate students to establish a scientific and lasting ECG teaching system. The study consisted of three stages. The first stage was to explore and evaluate the effect of online and offline blended teaching mode based on MOOC in a diagnostics course with clinical medicine students in grade 2018.

In the second stage, we strengthened ECG interpretation ability through the internal medicine curriculum. We divided students in grade 2018 into two groups with 49 students in group A and 42 students in group B. Group A strengthened their ECG interpretation skills when learning about heart diseases. The third stage was in the internship period. Some students in group A continued to receive intensive training. We further strengthened ECG interpretation skills, especially rotation in the cardiovascular department and ECG department. Students in group B had no reinforcement arrangement in the second and the third stage. Students in grade 2018 took graduation tests at the end of their internship. We used the scores for ECG interpretation skills in the graduation examination to evaluate the multistage strengthening effect between group A and group B.

2. Materials and Methods

2.1 Participants

We enrolled 91 students majoring in clinical medicine (5-year program) in grade 2018, with 44 males and 47 females.

2.2 Teaching Arrangement

The 91 students completed basic medicine courses from the first year to the first semester of the third year. In the second semester, they studied diagnostics. ECG is an important chapter and includes theoretical study and practical study. The former is 6 hours (45 minutes/class hour), and the latter is 4 hours. In the fourth year, students completed internal medicine, which included ECG knowledge in myocardial infarction, arrhythmia, and other diseases. In the fifth year, students entered clinical practice, which lasted for 3 weeks in the department of cardiology and ECG. During this process, they needed to finish tasks under supervision, such as on-duty, teaching rounds, case discussion, and other clinical practice. During rotation in the ECG department, students needed to finish the ECG test for patients, involving connecting ECG leads and presenting reports. Graduation assessment was in May of each year, with ECG as one of the exam contents, each student being required to write ECG characteristics and draw conclusions from one picture. The total score was 60 points. Figure 1 shows the schedule for the three-stage ECG teaching arrangement.

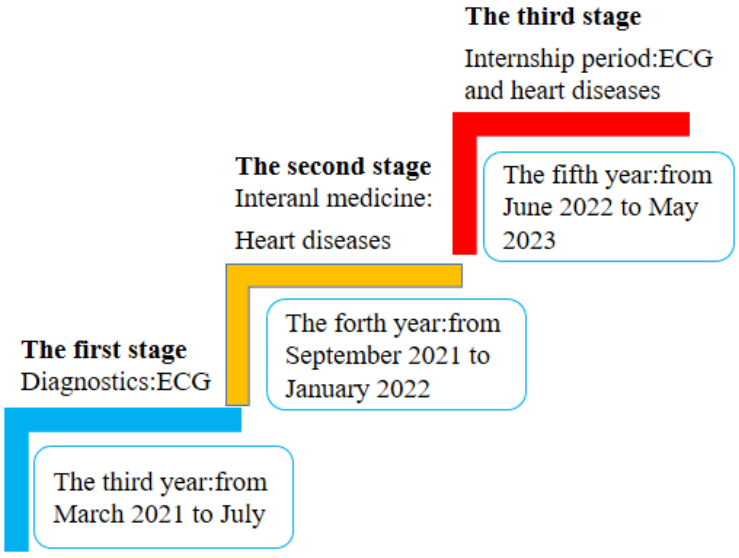

Figure 1. Schedule for three-stage ECG teaching arrangement

2.3 Study Flow

At different stages, we established teaching resources and evaluation indexes in combination with course contents and teaching objectives. We arranged for the secretary to track students' learning process, answer their questions, and provide feedback. The first stage was in the diagnosis course, which was taught via an online and offline hybrid method based on ECG MOOC. We took the results of the final ECG examination and questionnaire survey for the 91 students from grade 2018 as evaluation indexes to evaluate the effect of the blended teaching mode based on ECG MOOC by comparing ECG scores of 81 students in grade 2016 from the same major. The second stage was studying internal medicine. In this stage, we divided students into two groups. Only 49 students in group A received the strengthening schedule. Another 42 students in group B did not accept the strengthening program. The third stage

was the internship period. We strengthened their ECG interpretation skills on real patients and through exercises. In group A, 46 students went to hospitals for internships, while all students in group B gained the internship qualification. In group A, 38 students studied in the ECG department when they rotated in the cardiovascular department. Eight students in group A and 42 students in group B did not rotate in the ECG department. We used the scores for the graduation examination in ECG to assess the multistage effect by comparing students' performance in group A and group B, as well as results for students who rotated in the ECG department and did not rotate.

The research program for each stage included resources construction, teaching process implementation, teaching effect evaluation, and feedback (Figure 2). Among them, we built resources for the second and third stages using the guide to the ECG test in the Licence Examination of China Clinical Qualification Examination. Figure 3 displays the research flow of this study.

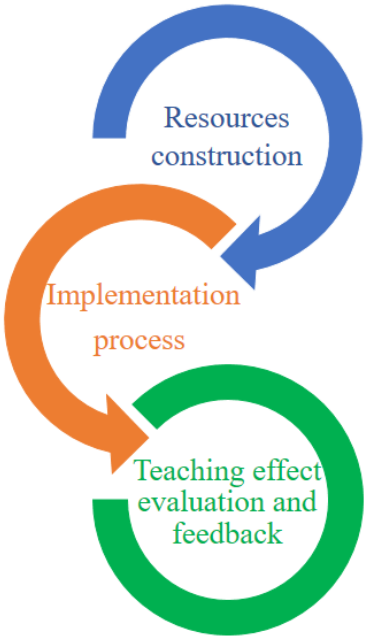

Figure 2. Research program for every stage

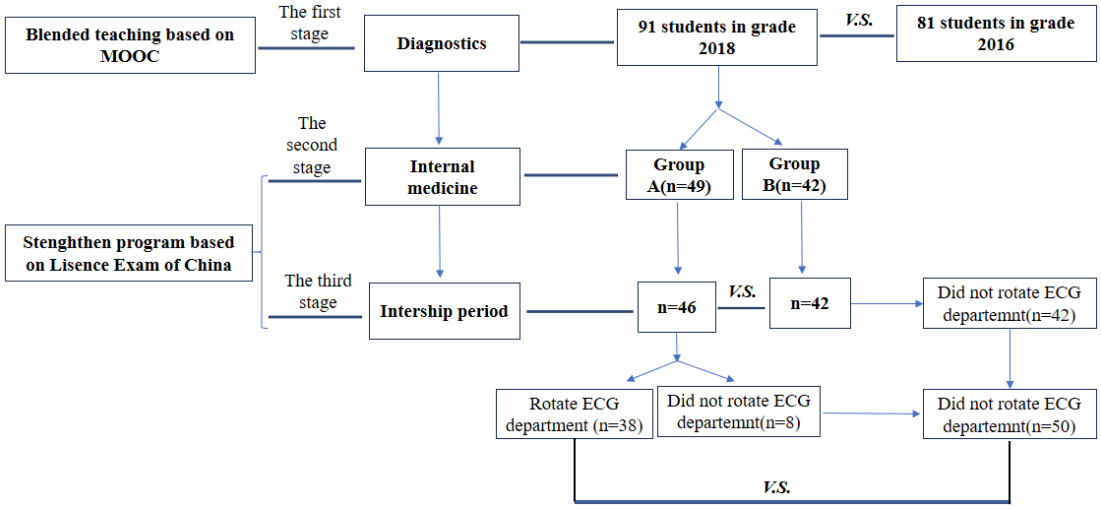

Figure 3. Research flow of this study

2.4 Statistical Methods

We used SPSS 22.0 software for statistical analysis. We expressed quantitative data as mean ± standard deviation (M ± SD). For comparison between grades and groups, we analyzed the distribution of data first. We used t-test for data with normal distribution, and we used nonparametric statistics for data with non-normal distribution. We considered

$P < 0.05$ statistically significant. We expressed qualitative data as frequency (percentage).

3. Research Details of Every Stage

3.1 Process and Results of the First Stage

In this stage we studied diagnostics; ECG is one of the important chapters of the course, and the teaching time was from March to July 2021. Combined with our practice, it is a key stage in which to cultivate good analytical thinking for a beginner. Compared with history taking, physical examination, and laboratory and auxiliary examination, class hours for ECG are fewer but are intensive in contents. Therefore, we adopted a blended teaching mode combining online and offline learning based on ECG MOOC in this stage.

3.1.1 Teaching Resources Construction

Our team obtained a program for an online open course project at Jinan University, meaning we had financial support to film videos, each lasting no more than 15 minutes. We studied the contents carefully, and by combining the diagnostics textbook, our teaching experience, and students' existing problems, we reorganized the teaching contents of ECG (Figure 4). For example, we synthesized Chapters 1, 2, and 8 in the diagnostics textbook, which concern the basic knowledge of ECG, to introduce the knowledge to learners. The videos highlighted three features. First, we integrated the physiology and anatomy associated with ECG to help students understand the difficult imagination theories well. Second, we strengthened the steps and methods of ECG analysis to train beginners to formulate good analytical ideas. Almost all the pictures in the videos were of real patients in our hospital. During the process, our team highlighted the basic elements of ECG analysis, such as rhythm, heart rate, PR interval (the time between the origin of the P wave and the origin of the QRS wave), QRS time (the time from the start of the QRS wave to the end of the QRS wave), QT interval (the time from the beginning of the QRS wave to the end of the T wave), and electrical axis. Third, we integrated all images into clinical cases, so that the learning process became more three-dimensional and more interesting. We then checked and uploaded the videos in China University MOOC (the link for our course was https://www.icourse163.org/course/JNU-1463153164). We uploaded and distributed all the videos, courseware, exercises, and final exam required to finish within deadline.

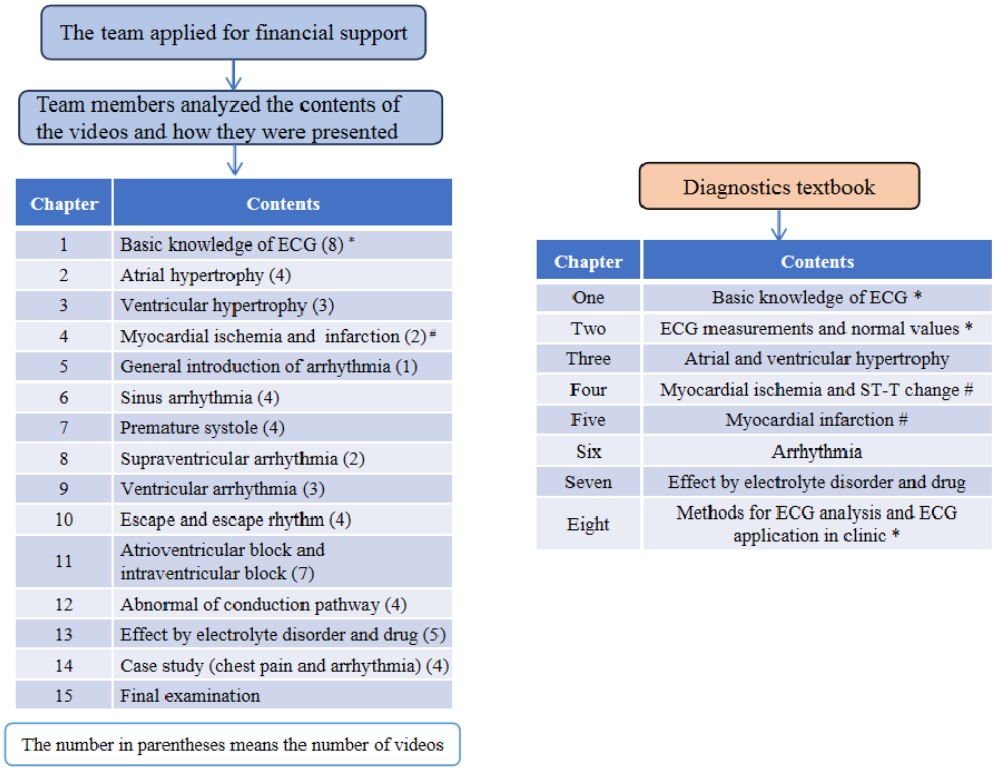

Figure 4. Reorganizing the contents of ECG course

3.1.2 Implementation Process

(1) Teacher–student Communication Platform

We established a WeChat group and invited students and teachers to join and communicate at any time.

(2) Online Study

Students joined the class set up in the MOOC platform. We required them to complete videos, answer questions, and undertake a unit assessment. The system would record their performance automatically (Figure 5), and the secretary would check it every week. The secretary checked students' performance weekly and answered their questions. Students could ask questions at any time in the MOOC discussion boards and WeChat group. As Figure 5 shows, only a small number of students completed videos on the website within deadline. Because many students buffered the videos on the memory card of their mobile phones, they then watched the videos normally even if there was no network.

Figure 5. Students' performance of videos

(3) Process of Offline Teaching

1) Exercises for Training ECG Interpretation Skills

We sent exercises to students every week. All pictures were from the ECG department and cardiovascular department of our hospital and were 12–18 leads. According to teaching objectives and our experience, we summarized the analysis contents into 15 questions and asked students to analyze ECG according to the 15 questions (Wang et al., 2022). We issued pictures using the principle of going from simple to complex, such as normal ECG first and then abnormal ECGs; abnormal ECGs also started from simple, such as sinus bradycardia and sinus tachycardia, and then going to atrial hypertrophy and ventricular hypertrophy, myocardial infarction, and arrhythmia. Through the standardization of 15 questions and repeated practice, students gradually formed the thinking of ECG analysis, namely: (1) remembering normal value; (2) finding abnormality by comparing with normal value; (3) according to the meaning represented by abnormal value, narrowing diagnostic scope and finally drawing the correct conclusion. We explained and corrected all pictures in class in the practical part.

2) Teaching Process In-class

This included a theoretical part and practical part. The theoretical part lasted 6 hours. The contents included the basic knowledge of ECG, ECG measurement and normal values, atrial hypertrophy and ventricular hypertrophy, myocardial ischemia, myocardial infarction, arrhythmia, electrolyte disturbance and drug effects on ECG, ECG analysis methods, and clinical applications. In addition, we assigned 4 hours for the practical part: 1 for teaching and practising the connection of ECG leads, and the remaining time to correct, and give feedback on, exercises issued every week.

3.1.3 Evaluation of Effects

We evaluated teaching effects via the ECG scores from the final examination and questionnaire. The final exam in grade 2018 included two parts: theory and ECG interpretation skills. There were 33 questions in the theory exam with one point per question, so the total score available for this part was 33 points. The main contents included

mechanism, ECG characteristics, and pictures characteristics combined with the case. The ECG interpretation skills test included three pictures with 10 points of each image, giving a top score of 30 points. We required students to describe rhythm, heart rate, PR interval, QRS time, QT interval, axis, and other primary parameters and then to write the characteristics and conclusions. In the questionnaire we focused on students' feelings about the blended teaching mode and their competence to analyze ECG.

3.1.4 Control Group

In this stage, the control group was students of the same major in grade 2016. The teaching mode of ECG in grade 2016 was pure offline teaching, which also included a theoretical part and practical part. The textbook, number of hours, and teaching contents in-class for the two grades were the same. The assessment of teaching effect in grade 2016 concerned ECG interpretation skills.

3.1.5 Results

(1) Basic Information

As shown in Table 1, there was no statistical difference in basic information and grade point average (GPA) between the two grades.

Table 1. Comparison of basic information in two grades

Contents	Grade 2018 (n = 91)	Grade 2016 (n = 81)	p-value
Gender (male/female)	44/47	39/42	0.979
Age, years	20.79 ± 0.54	20.84 ± 0.54	0.643
GPA in the first year	3.54 ± 0.45	3.44 ± 0.43	0.140
GPA in the second year	3.32 ± 0.54	3.39 ± 0.51	0.390

(2) Scores for ECG Interpretation Skills

When comparing scores for ECG interpretation skills (total score was 30 points) between two grades, the results showed that scores in grade 2018 were 19.32 ± 4.62 points and were 16.89 ± 5.30 points in grade 2016. The difference between two grades was statistically significant (P = 0.002, Figure 6). The accuracy of diagnosing acute myocardial infarction (AMI) in grade 2018 was about 50%. Students lost points by failing to recognize AMI or failing to write location or stage of AMI. Fewer than one in five students recognized three-degree atrioventricular block and ventricular escape. Many students missed prolonged QT interval.

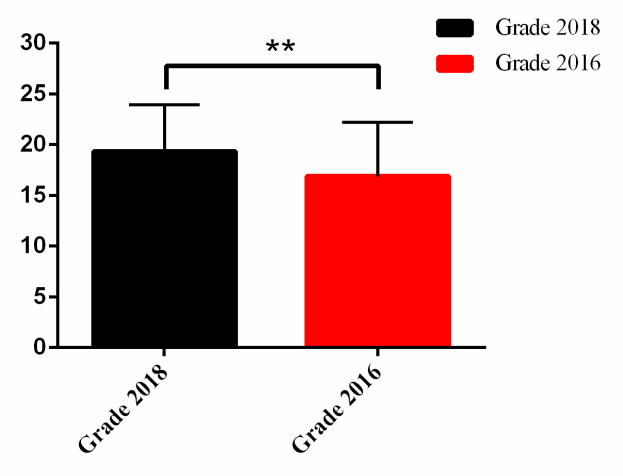

Figure 6. Comparing scores of ECG interpretation skills between two grades

(3) Scores for Theoretical Test

Scores for the ECG theory test in grade 2018 were 21.53 ± 3.78 points (total score was 33 points). Students identified ECG characteristics of AMI, hypokalemia, hyperkalemia, and atrial fibrillation well, and the accuracy rate was more than 90%. The accuracy of diagnosing ventricular tachycardia and ventricular fibrillation was less than 60%. The accuracy of identifying the principle of hypokalemia and hyperkalemia, the meaning of P wave, and the mechanism

of T wave generation was less than 30%.

(4) Questionnaire

At the end of the term, we sent a questionnaire survey about ECG teaching mode to students in grade 2018. Each question had five options, which were strongly agree (5 points), agree (4 points), general (3 points), disagree (2 points), and strongly disagree (1 point). Of the 91 students, 89 completed the questionnaire, giving a completion rate of 97.80%. The first question was whether ECG MOOC was helpful to cultivate ECG analysis thinking and could be an effective supplement to theory study in class. The score was 3.99 ± 0.83 points, among which, 25 students strongly agreed, 42 students agreed, 19 students selected general, 2 students disagreed, and 1 student strongly disagreed (Figure 6). The second question was whether the 15 questions helped clarify analysis clues and strengthened the contents of ECG interpretation procedures. The score was 4.10 ± 0.83 points, with 32 students strongly agreeing, 37 students agreeing, 17 students selecting general, and 3 students disagreeing (Figure 7). The third question concerned their competence to analyze ECG. Eight students (8.99%) thought that they had mastered interpretation skills well, 74 students (83.14%) thought that they had mastered it basically, and 7 students (7.87%) thought that they had not mastered it yet (Figure 8).

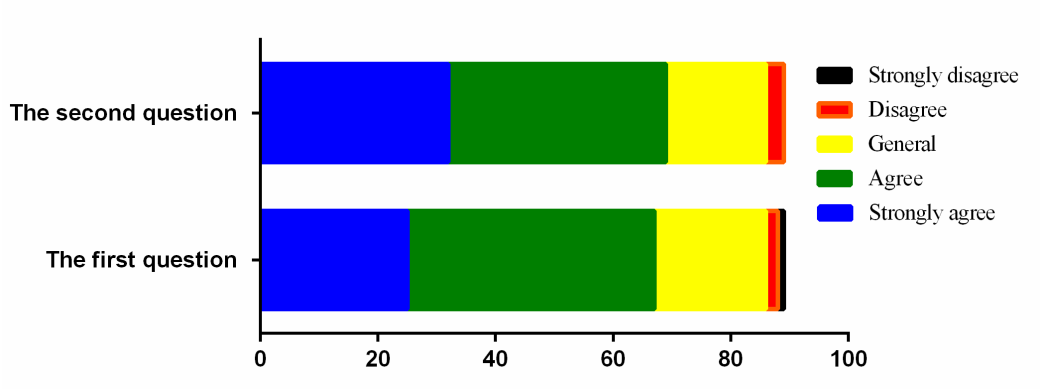

Figure 7. Results of the first and the second question

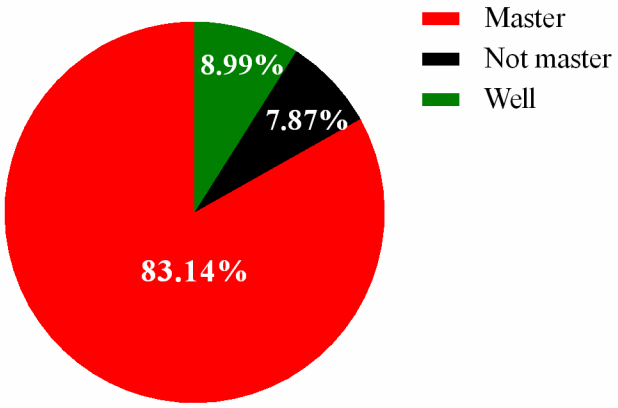

Figure 8. Results of the third question

3.2 Process and Results of the Second Stage

Students in this stage learned internal medicine from September 2021 to January 2022. We divided students in grade 2018 into groups A and B. Students in group A accepted the strengthen training program, but students in group B did not. We described the details of the strengthen program in group A.

Combined with the learning contents of cardiovascular diseases, such as arrhythmia, angina pectoris, and AMI, in this part, the main task was reviewing the abnormal ECG manifestations.

3.2.1 Teaching Resources Construction

We established a picture library based on the licence examination in China for clinical medicine, which included the following categories, namely normal ECG, sinus tachycardia, sinus bradycardia, premature atrial contraction, paroxysmal supraventricular tachycardia, atrial fibrillation, ventricular premature contraction, ventricular tachycardia, ventricular fibrillation, ventricular hypertrophy, AMI, atrioventricular block, left bundle branch block and right bundle branch block. Some of these figures had only one conclusion, while some had two or more conclusions. Each picture provided the patient's history and important physical examination results.

3.2.2 Implementation Process

(1) Teacher–student Communication Platform

We established a WeChat group to provide a platform for teacher–student interaction and communication.

(2) ECG Interpretation Skills Training

Starting from the second week, we sent two to three pictures to students through the Rain Classroom platform for interpretation training every week. We required students to analyze the main parameters such as rhythm, heart rate (atrial rate and ventricular rate), PR interval, QRS time, QT interval, ECG characteristics, and conclusions. Teachers corrected the answers and gave feedback. In this phase, the contents mainly covered the afore mentioned categories of the licence exam.

3.2.3 Evaluation Indexes

We held an ECG examination at the end of the semester. We randomly selected two pictures, each scoring 10 points, for a total of 20 points. We required students to complete the basic parameters and write ECG characteristics and conclusions. At the end of the term, we issued questionnaires to gauge students' competence in ECG interpretation skills.

3.2.4 Results

(1) Scores for ECG Interpretation Skills

Scores for ECG interpretation skills in group A were 13.19 ± 3.95 points. The correct rate with a single diagnosis was high, but the correct rate with complex conclusions was very low, especially for those with more than three conclusions. For AMI, 75% of students recognized it, but some of them failed to locate the infarction site. The accuracy of AMI decreased to 25% when ECG conclusions mixed with other situations. Although 100% of students interpreted ventricular premature beat correctly, if other features were presented, the accuracy deceased to 42.9%.

(2) Questionnaire

Almost half of 49 students completed the questionnaire, and the response rate was 100%. Ten students (20.41%) thought that compared with diagnostics, ECG interpretation skills improved significantly after they accepted intensive training. Over a third of students, 36 (73.47%), thought that there was progress. Three students (6.12%) felt that there had been no progress (Figure 9). Regarding the competence to analyze ECG, three students (6.12%) thought they were more proficient after this semester's study, 44 students (89.80%) had grasped it, and two individuals (4.08%) thought that they had not mastered it yet (Figure 10).

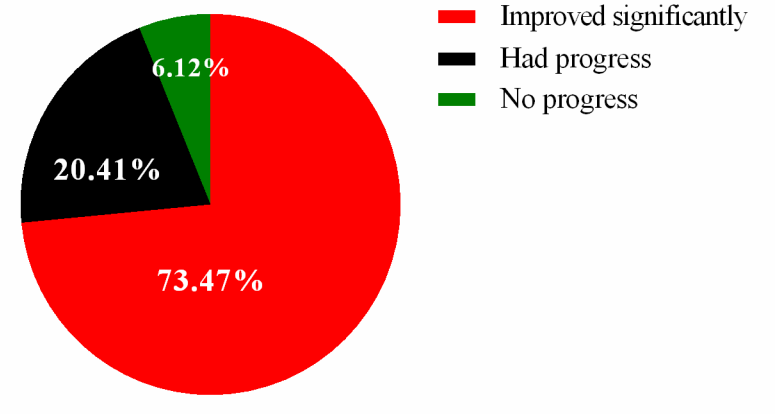

Figure 9. Results of the first question in group A

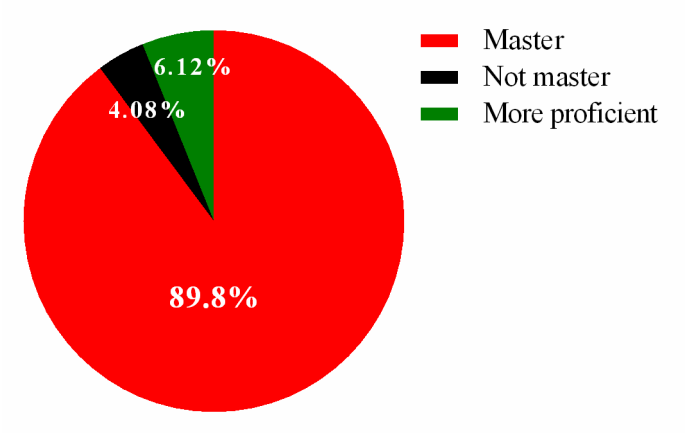

Figure 10. Results of the second question in group A

3.3 Process and Results in the Third Stage

The third stage was the internship rotation period from June 2022 to May 2023. Among 49 students in group A, three of them delayed graduation due to substandard credits, and 46 students obtained internship qualifications. They went to different affiliated hospitals for their internship. In group A1, 23 students practised in the First Affiliated Hospital, and another 23 students, named group A2, practised in other affiliated hospitals. Students in group A1 underwent strengthening training. In this group, 38 students studied in the First Affiliated Hospital, Zhuhai People's Hospital, and Guangzhou Red Cross Hospital, spending 2 weeks in the cardiovascular ward and 1 week in the ECG department. Eight students in group A rotated in the Second Provincial Hospital and practised in the cardiology ward for 3 weeks. All 42 students in Group B had an internship qualification. They practised in the Second Affiliated Hospital and spent 3 weeks in the cardiovascular ward without rotating in the ECG department. The strengthening training plan in group A1 was as follows.

3.3.1 Teaching Resources Construction

The strengthening plan included reviewing basic theories and interpretation skills. The former covered ECG basic knowledge and abnormal ECG features, such as the normal values, the significance of waveform, and features of sinus tachycardia, all of which were multiple choice questions. Some questions had one correct answer, while some had more than one correct answer. We strengthened interpretation competency through analyzing pictures, which included two kinds, one based on the License Examination of Clinical Medicine in China, whereas the others were expanded to other topics. We showed all pictures in the form of subjective questions, with a brief introduction of clinical information and attached answers.

3.3.2 Implementation Process

(1) Teacher–student Communication Platform

We established a WeChat group and invited students to join.

(2) Setting Up a Learning Platform

We set up a class in the Rain Classroom platform and invited students to join. We sent theoretical questions and pictures to students. Each question had answers and explanations. Students reviewed and finished these exercises in their spare time when rotating in the internal medicine department. Students could communicate with teachers at any time in the WeChat group, Rain Classroom platform, and in the ward. The secretary recorded students' performances.

(3) Rotation Arrangement in Cardiovascular Department

Students spent 3 weeks in the cardiovascular department. Of these, they had 2 weeks in the ward and learned to manage common cardiovascular diseases. one week was in the ECG department (Figure 11), where they conducted ECGs for real patients, wrote reports, and participated in lectures.

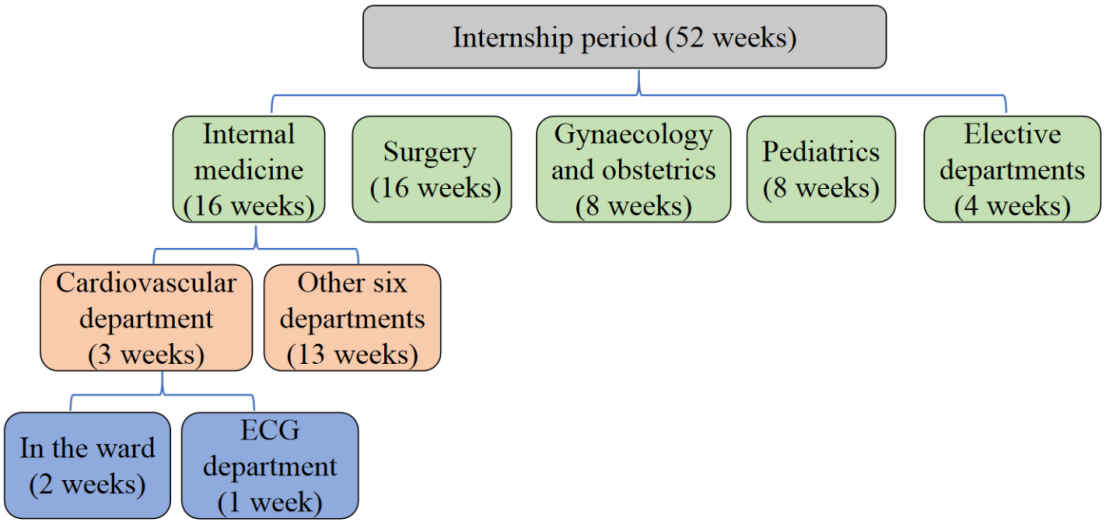

Figure 11. Rotation arrangement in internship period

3.3.3 Evaluation Indexes

We evaluated the second and the third stage effect by graduation scores of ECG. We asked students to write down ECG characteristics and conclusions from a picture. The total score was 60 points in this station.

3.3.4 Results

(1) Comparison of Basic Information between Group A and Group B in Grade 2018

Table 2 shows there were no significant differences between the two groups in gender, age, GPA in the first and third year, scores of diagnostics, clinical basic skills, and ECG test in diagnostics. The GPA in Group B was lower than that in group A in the second year.

Table 2. Comparison of basic information between group A and group B in grade 2018

Contents	group A (n = 49)	group B (n = 42)	p-value
Gender (male/female)	23/26	21/21	0.771
Age, years	21.03 ± 0.49	21.06 ± 0.60	0.795
GPA in the first year	3.52 ± 0.49	3.38 ± 0.35	0.172
GPA in the second year	3.55 ± 0.52	3.32 ± 0.37	0.037
GPA in the first semester of the third year	3.47 ± 0.56	3.43 ± 0.37	0.711
Scores of clinical basic skills	82.02 ± 8.33	81.81 ± 5.94	0.891
Scores of diagnostics	79.57 ± 7.15	79.07 ± 5.52	0.713
Scores of ECG presentation skills in diagnostics	19.43 ± 4.84	19.21 ± 4.42	0.827

(2) Comparison of Graduation Test between Group A and Group B in Grade 2018

In group A, 46 students attended the graduation exam, and ECG scores were 38.89 ± 16.81 points. In Group B, 42 students participated in the exam and scored 26.86 ± 15.43 points. There was statistical difference between the two groups (P = 0.000) (Figure 12).

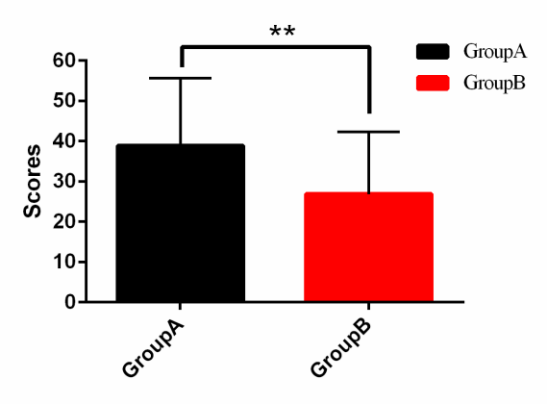

Figure 12. Comparison of graduation test between group A and group B in grade 2018

(3) Comparison Scores between Group A1 and Group A2

Scores for ECG interpretation skills in group A1 were higher (39.52 ± 17.85 points) than those in group A2 with 38.26 ± 16.07 points, but there was no significant difference between the groups (P = 0.974) (Figure 13).

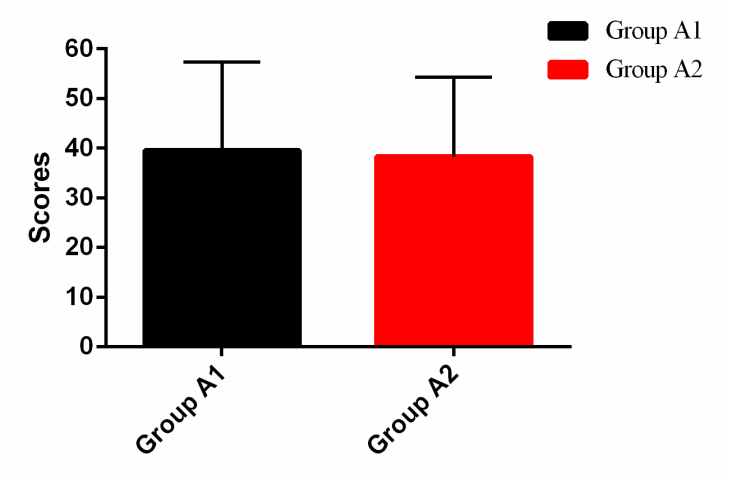

Figure 13. Comparison scores between group A1 and group A2

(4) Comparison Scores in Students Based on Whether They had Rotated in the ECG Department

We compared scores for 88 students in grade 2018 according to whether they had rotated in the ECG department or not. Scores for 38 individuals with rotation were 36.79 ± 17.40 points and 30.38 ± 16.64 points for 50 students without rotation. The comparison between the two conditions was statistically significant (P = 0.045) (Figure 14).

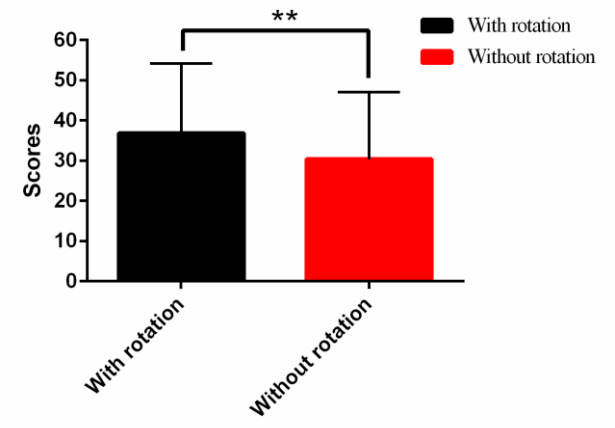

Figure 14. Comparison scores in students based on whether they had rotated in the ECG department

4. Discussion

In this study we explored the ECG teaching mode in undergraduate students majoring in clinical medicine. We focused on guiding and training students to have better ECG analytical thinking and interpret common abnormal ECGs accurately through online and offline blended study and multistage strengthening mode. The highlight of this research was that teaching resources were established in combination with the curriculum objectives and syllabus at each stage. In the implementation process, we used WeChat, Rain Classroom, and other platforms to increase teacher–student interaction. Students and teachers could communicate anytime and anywhere. At the same time, we established the evaluation indexes of each stage to evaluate students' performance. Results showed that scores for ECG interpretation skills in students who accepted the blended teaching mode were higher than for students receiving the traditional offline teaching mode. The difference was statistically significant. After multistage intensive training, students achieved better results in the graduation test.

It is highly important and necessary to learn ECG adequately at the education stage to lay a foundation for a future career. However, from the literature in China and abroad and our practice, students' competence of ECG interpretation in undergraduates is suboptimum. One of the reasons may be the limited hours in class and insufficient formal training in medical education. A survey including 2,515 participants from diverse medical backgrounds showed that 73% of professionals received less than 5 hours of ECG-specific education, while 45% reported no education at all (Kashou et al., 2023). Another survey showed that residents and medical students received ECG training of less than 15 hours (Ei-Baba et al., 2023). In Kashou et al.'s opinion, ECG interpretation skills are related to medical curricula; during the formal medical education, a limited amount of time is allotted to ECG (2020). In Canada, ECG teaching curricula vary greatly in time allotment and teaching methods, and this needs to be unified (Paul, & Baranchuk, 2011). According to current reports, in general, theory and practice hours spent on ECG in diagnostics courses for undergraduate students vary from 12 to 20 hours in China (Hou, et al., 2021; Li et al., 2020; Wang, et al., 2020). In our university, the hours that can be allocated to ECG are only 10, including 6 hours for theory and 4 hours for practice. The number of hours for ECG teaching are limited, but the content is dense, so the classroom teaching is somewhat frantic. It can be seen that the limited teaching hours in medical schools are a common phenomenon in ECG teaching, which may be one of the factors affecting ECG interpretation skills improvement in undergraduate students.

It is of great significance to explore new teaching methods to improve students' interpretation ability and establish correct ECG analytical thinking for future careers (Zeng et al., 2015). Based on insufficient teaching hours and the intense content of ECG, in this study we adopted a multistage strengthening teaching mode to consolidate ECG knowledge through three different periods of diagnostics, internal medicine, and internship stage. In the first and second stage, the basic parameters such as rhythm, heart rate, PR interval and QT interval, axis, and other parameters were emphasized and practised repeatedly. In different curricula, we adopted different teaching modes combined with the teaching objectives of the curriculum. In the first stage, students learn ECG for the first time, adopting a blended teaching mode, which has been proved by many courses to be conducive to improving students' academic performance, learning initiative, and enthusiasm (Dzikowicz & Carey, 2022; Gong et al., 2021; Huang, et al., 2020; Jawaid, et al., 2021). Our practice has proved that the blended teaching mode is helpful in making up for the shortage of classroom teaching. Students spent their spare time to finish online tasks after class. Teachers checked the completion status every week and assigned tasks of interpreting pictures. In the offline practical part, according to the order of waveform, we paid attention to guiding students in mastering the correct analysis steps and strengthening their analytical thinking through modular problems, so that beginners could master the elements of ECG analysis in a short time. Compared with students from the same major in grade 2016, scores for ECG interpretation skills in grade 2018 had improved, and the difference was statistically significant. Students who accepted the blended teaching mode generally had better competence in basic parameters measurement, such as rhythm, heart rate, and PR interval. For the blended teaching mode, besides analyzing the teaching effect from students' examination scores, we also learned students' feelings and assessment through the questionnaire. More than three quarters of students believed that MOOC was helpful for ECG learning. The 15 questions could help clarify ECG analytical thinking. Most students had mastered the main points of ECG analysis, and some students had mastered it skillfully. All these findings suggest that the blended teaching mode is feasible and effective. Although more students preferred face-to-face learning, the blended method seemed more effective (Bazrgar et al., 2023).

The first stage of this study strengthened not only ECG interpretation skills, but also theoretical knowledge through exercises in MOOC. We found that the main difficulty for students in learning ECG was understanding, memory, and application of the principle of ECG. It was helpful for students when they knew these problems (Ohn, et al., 2020). Our results also showed that the accuracy of some topics involving principles and mechanisms, such as the meaning

of P wave and the mechanism of T wave generation, was low, which indicated that it was necessary to strengthen the basic knowledge in the teaching process. In theory examination, the accuracy rate of ventricular fibrillation was less than 60%, which suggested that the ability to recognize fatal ECG needed more attention in the stage of medical education. Interestingly, in the theory exam, more than 90% of students recognized AMI. There was a big difference when comparing the accuracy between the theory exam and interpretation exam. The accuracy of AMI in the interpretation test was only 50%. This may be because the theory test was multiple choice and provided case information. It is easier for students to choose the right answers with the clues of case information. Therefore, multiple choice questions sometimes do not reflect the true interpretation levels. This phenomenon of accuracy separation between theory and interpretation test suggests that the latter is still an ideal model to test ECG interpretation competency, which can highlight problems and weaknesses more comprehensively. Hence, teachers can arrange to strengthen contents in a more targeted way. In addition, the practical time is only 4 hours, and there are many tasks that should be completed. In fact, the amount of interpretation training for students is far from enough, which may be the main reason for the low accuracy in the interpretation exam. It also suggests that the second stage of intensive training should be carried out to improve the accuracy of ECG interpretation, especial identifying life-threatening ECG.

Some researchers found that ECG interpretation competency decreased over time. Two studies showed a significant decline after 8 weeks (Raupach, et al., 2010; Raupach, et al., 2016). In another study, Viljoen et al. reported ECG interpretation skills decreased after 6 months' follow-up (2020). Bojsen et al. conducted a study about short-term (2–4 weeks), medium-term (10–12 weeks) and long-term (18–20 weeks) follow-up before and after the intervention. The results showed that ECG interpretation ability would decline over time, and the rate of decline was 53%–60% (2015). In addition, the recall to interpret ECG varies among different pictures (Krasne, et al., 2021). These studies suggest that we should not only explore methods to improve ECG teaching effect, but also pay attention to consolidate ECG interpretation levels. In fact, like other clinical skills, students need a lot of practice to master ECG interpretation skills and learn the correct analytical thinking. Based on the outcomes in the first stage, we continue to train for ECG interpretation competence in internal medicine and internship stages to help students have lasting interpretation ability.

ECG interpretation competency improved with the number of attending didactic sessions and continuous practice (Cunningham et al., 2024; Kaye et al., 2023; Vishnevsky et al., 2022). In the second and third stages, we established teaching resources based on the License Exam in China and used the scores of the graduation examination as the evaluation index. The performance can be considered as the long-term effect of the second stage. The results showed that students in group A who received intensive training had higher scores than those in group B who did not attend an intensive project. The difference was statistically significant. It suggested that the program to improve and retain the ability of ECG interpretation was effective and necessary. ECG competency improved with the growth of grade, especially after teaching methods invention (Perrichot et al., 2023). When comparing the results of rotating in the ECG department, students who rotated gave good performance. We found that the majority of students who rotated in the ECG department were in group A; this result provided indirect evidence that the strengthening plan in the second stage and rotation in the ECG department were effective. Interestingly, scores for the graduation exam in group A1 and group A2 were not significantly different, although scores in group A1 were higher than in group A2. This means the strengthening plan in the third stage is effective, but the effect is not significant. Of course, we cannot deny the necessity of intensive training in the third stage just because there was no significant difference between group A1 and group A2.

Misdiagnosis of ECG could lead to adverse outcomes, and medical education in many areas lacked organized curricula and assessment indexes to evaluate if students had mastered this necessary skill (Antiperovitch et al., 2018). Assessment mode was more effective than teaching mode in promoting student learning (Raupach et al., 2010). Regardless of the teaching style and mode, the final evaluation was beneficial to maintain students' ECG interpretation ability in the middle period (8 weeks) (Raupach et al., 2016). An appropriate evaluation method is also an important part of a new teaching mode. The most common methods used to evaluate ECG teaching effect are multiple choice questions, interpretation skills, and objective structured clinical examination (Kopeć et al., 2018; Viljoen et al., 2020). The evaluation time included short-term effects, for example, 2 weeks after intervention and medium term, which was 10 weeks after intervention (Holland et al., 2023). In our study, in the first stage, we evaluated the teaching effect by theory exam and practical exam. We conducted these after the end of the semester, which can be considered as the short-term evaluation. We found different results in the same type of category, for example, in AMI, the accuracy rate was higher in the theory exam than in the interpretation exam. This phenomenon also proved the interpretation test was a better way to examine ECG interpretation competence. It can find the

problems and provide clues for teachers to make next plans. So, in the second and the third stage, we tested this competence with interpretation. The evaluation time was in the graduation exam, which can be considered as a long-term effect evaluation. The assessment in the graduation exam requires students to write features and conclusions. We based this decision on students' training programs and performances in the former two stages wherein they mastered the primary parameters well.

5. Limitations

There are some limitations in this study. First, we assigned the exercise pictures in the first stage every week, which extended the learning time for students. However, there was no feedback every week due to no extra hours in normal teaching, the explanation was concentrated in the practical part, and the contents were too intensive. This is one problem that needs improvement in the future. Second, in the second stage, students in group B had not evaluated ECG interpretation skills, so the comparative data of this stage between the two groups were lacking. The third limitation is about the questionnaire. Some questions in the first and second stages were not quantitatively standard, instead being based on the students' feelings, which may be different for everyone. Because their feelings may be related to the questions and pictures they encounter, for example, if students finished the question fluently, they thought they had mastered it. On the contrary, when they had difficulty finishing the exam, they may have thought they had not mastered it. This question needs to be solved in the future.

6. Conclusion

The three-stage strengthening mode based on ECG MOOC is an effective method to improve students' ECG interpretation skills. Online and offline blended teaching strategy was superior to traditional lecture mode, with students having better performance. Repeated practice was necessary for improving ECG interpretation skills. Students accepted the strengthening program yielded better grades in the graduation examination. It is a scientific and lasting teaching system, which is worth promoting and trying. Some limitations need to be further optimized in the future.

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Declaration of Interest

The author has no conflict of interest.

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