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Application of case-based learning in medical student education: a meta-analysis

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Abstract. – OBJECTIVE: To evaluate the effectiveness of case-based learning (CBL) in medical students' education through meta-analysis.

MATERIALS AND METHODS: PubMed, Cochrane Library, Elsevier and other databases were searched to find randomized controlled trials (RCTs) of CBL teaching methods and other teaching methods published from January 1, 1995, to October 1, 2020. All included studies used the Cochrane risk bias assessment tool, and Review Manager software, version 5.3 (Copenhagen, Denmark), was used for the meta-analysis and systematic review.

RESULTS: A total of 8 studies were included with a total of 939 students, including 480 in the CBL group and 459 in the control group. Compared with other teaching methods, CBL teaching can improve medical students' academic performance (p=0.03) and case analysis ability (p<0.001).

CONCLUSIONS: CBL is an active teaching method that is effective for educating medical students and helps to improve their performance and case analysis ability.

Key Words:
Case-based learning, Education, Medical students, Meta-analysis.

Introduction

At present, medical education is changing. An increasing number of educators are coming to realize the importance of the combination of theory and clinical medicine, which is called vertical integration[1]. The application of cases in teaching has shown its value in many fields. Case-based learning (CBL) is such a teaching method[2].

CBL is a special type of problem-based learning (PBL) that takes the learner as the center and guides students' study and exploration through cases. These cases combine theory with practice, allowing students to apply knowledge to cases and preparing students for clinical practice. Since the birth of CBL in 1908, this method has been used in a variety of disciplines, often in the form of face-to-face teaching, group teaching, and online teaching[3,4]. Although many students and educators believe that CBL is an effective teaching method[2,4,5], there is still no definite evidence to prove that CBL is better than other education methods in medical education[4]. The purpose of this study is to objectively evaluate the effect of CBL on the learning outcomes of medical students through a systematic review and meta-analysis of RCTs.

Materials and Methods

Search Strategy

Two researchers independently searched PubMed, Cochrane Library, Elsevier and other Internet databases and collected clinical RCTs of CBL and other educational methods applied in medical student education. Manual searches and reference tracking of the bibliographies of the included studies were also performed, and requests to authors for the full texts and original data were made. Document retrieval time: January 1, 1995, to October 1, 2020. Keywords searched: case-based learning, case-based teaching, case study teaching, case method learning.

Inclusion and Exclusion Criteria

Literature inclusion criteria: (1) Research type: RCTs with a group design; (2) Research objects: undergraduate medical students and interns; (3) Intervention measures: the experimental group adopts CBL teaching, and the control group adopts simulated teaching, lecture-based learning (LBL), CD-ROM teaching, or traditional

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learning;(4) Research purpose: to explore the effectiveness of teaching methods; and (5) Outcome indicators: theoretical knowledge, case analysis.

Exclusion criteria: (1) Studies without complete data; (2) Duplicate articles; (3) Articles that did not involve outcome indicators, etc.; and (4) Articles for which outcome indicators cannot be found.

Study Selection

The study selection was carried out in accordance with the PRISMA process, and the study was considered qualified only if it met the inclusion criteria. The two researchers read the abstracts and the full texts of the studies independently after excluding obviously irrelevant literature and then determined which studies to include according to the selection and exclusion criteria. Any questions and disagreements were discussed and resolved by all authors.

Bias Evaluation

Two investigators (X.Y. C and Y.H.) independently evaluated the studies, extracted information on the methods and results, and assessed the risk of bias in the RCTs included in the meta-analysis using the Cochrane risk bias assessment tool.

Data Extraction and Quality Assessment

All documents included in this meta-analysis were full-text articles. Data were collected as completely as possible by carefully reading the full text and references. If the data were uncertain or missing, the original author was contacted to obtain complete data. Studies for which a sufficient amount of original data could not be obtained were excluded from the meta-analysis. The characteristics and main findings of all the included studies were independently recorded in a table by two investigators, and the Cochrane risk of bias tool was used to evaluate the quality of the included RCTs.

Statistical Analysis

Review Manager software, version 5.3 (Copenhagen, Denmark), was used to analyze the data. Continuous variables are presented as standardized mean difference (SMD) and 95% confidence interval (CI). In this meta-analysis, $\alpha=0.05$, that is, $p<0.05$, was judged to be statistically significant. I^2 indicates the size of the heterogeneity, and the value range is 0-100%; the larger the value is, the greater the heterogeneity[6].

Results

The PRISMA flowchart is shown in Figure 1. Sixteen randomized controlled trials[7-22] on CBL were found comparing CBL with other teaching methods used to educate medical students. The characteristics of the 16 RCTs are shown in Table I. However, only 8 of them[7-14] were eligible for inclusion in this meta-analysis. These studies included 939 students, with 480 in the CBL group and 459 in the control group. There were 3 studies comparing CBL and simulated teaching and 5 studies comparing CBL and traditional learning. The data and results of all the studies showed low risk of bias. Five studies did not specify the randomization method, and the blinding of participants and personnel in seven studies had medium to high risk of bias, but five blinded the evaluators to the results. The results of the risk of bias assessment are shown in Figure 2.

As shown in Figure 3, 8 studies compared the impact of CBL with that of other methods on student performance. There was a high degree of heterogeneity among the studies ($I^2=89\%$, $p<0.00001$). A random effects model showed that CBL can improve academic performance

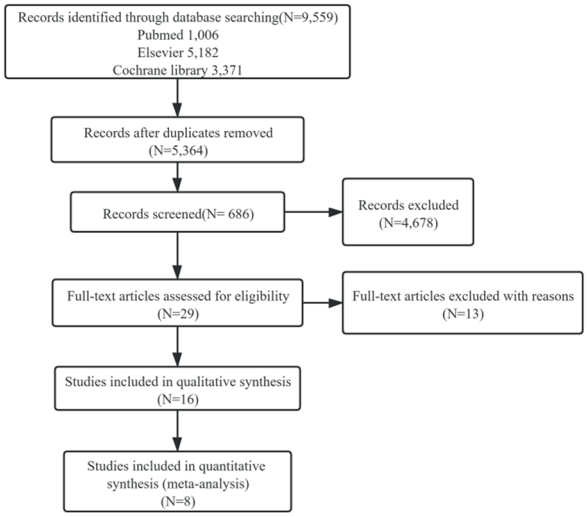

Figure 1. The PRISMA flow chart of the literature selection for the meta-analysis.

Table I. Characteristics of 16 RCTs. CBL, Case-Based Learning; PBL, Problem-Based Learning; LBL, Lecture-Based Learning.

Author (year of publication)	Country	Type of study	Research object	Experimental group (N)	Control group (N)	Whether to include meta-analysis	Result	
							Academic record	Student evaluation
Alhazmi and Quadri[7]	Saudi Arabia	Randomized controlled trial	97 dental undergraduates	CBL (47)	LBL (48)	YES	Positive results	Positive results
Aluisio et al[8]	USA	Randomized, controlled, crossover trial	60 nursing students	CBL (17); Simulated teaching (16)	Simulated teaching (16); CBL (17)	YES	Positive results	Not evaluated
Bi et al[9]	China	Randomized controlled trial	80 first-year graduate students in oncology	CBL (40)	LBL (40)	YES	Positive results	Positive results
Kamat et al[10]	India	Randomized controlled trial	179 second-year bachelor of medicine and bachelor of surgery students	CBL (96)	Traditional learning (83)	YES	Positive results	Not evaluated
Chin et al[11]	Malaysia	Randomized, controlled, crossover trial	174 pharmacy students	CBL (87); Simulated teaching (87)	Simulated teaching (87); CBL (87)	YES	Negative results	Negative results
Liu et al[12]	China	Randomized controlled trial	41 dental undergraduates	CBL (20)	Traditional learning (21)	YES	Positive results	Not evaluated
Schwartz et al[13]	USA	Randomized controlled trial	102 fourth-year medical students	CBL (52)	Simulated teaching (50)	YES	There was no significant difference	Not evaluated
Xakeliis et al[14]	USA	Randomized controlled trial	96 second-year medical students	CBL (32)	CD-ROM learning (32)	YES	There was no significant difference	Not evaluated
Grauer et al[15]	USA	Randomized controlled trial	110 third-year veterinary students	CBL/PBL (55)	LBL (55)	NO	There was no significant difference	Each has its own advantages and disadvantages
Krupat et al[16]	USA	Randomized controlled trial	64 medical and dental student volunteers	CBL (32)	PBL (32)	NO	There was no significant difference	Positive results

Continued

Table I *(Continued)*. Characteristics of 16 RCTs. CBL, Case-Based Learning; PBL, Problem-Based Learning; LBL, Lecture-Based Learning.

Author (year of publication)	Country	Type of study	Research object	Experimental group (N)	Control group (N)	Whether to include meta-analysis	Result	
							Academic record	Student evaluation
Reittinger et al[17]	USA	Randomized controlled trial	26 thirty-eight internal medicine residents	Standard education and CBL (16)	Standard education (10)	NO	Positive results significant difference	There was no
Roca et al[18]	Spain	Randomized controlled trial	74 second-year nursing students	CBL (26)	PBL (25); Traditional learning (23)	NO	CBL is lower than PBL but higher than Traditional learning	Not evaluated
Sarac and Ok[19]	Turkey	Randomized controlled trial	90 university students	CBL (30)	Traditional learning (30); Web-based instruction (30)	NO	Positive results	Not evaluated
Tao et al[20]	China	Randomized controlled trial	60 graduate dental interns	CBL (30)	Traditional learning (30)	NO	Positive results	Positive results
Eyck et al[21]	USA	Randomized controlled trial	83 fourth-year medical students	CBL (41)	Simulated teaching (42)	NO	Negative results	Not evaluated
Waydhas et al[22]	Germany	Randomized controlled trial	614 university medical students	Specific predefined timetable, course book and CBL (136)	Traditional learning (478)	NO	Not evaluated	Positive results

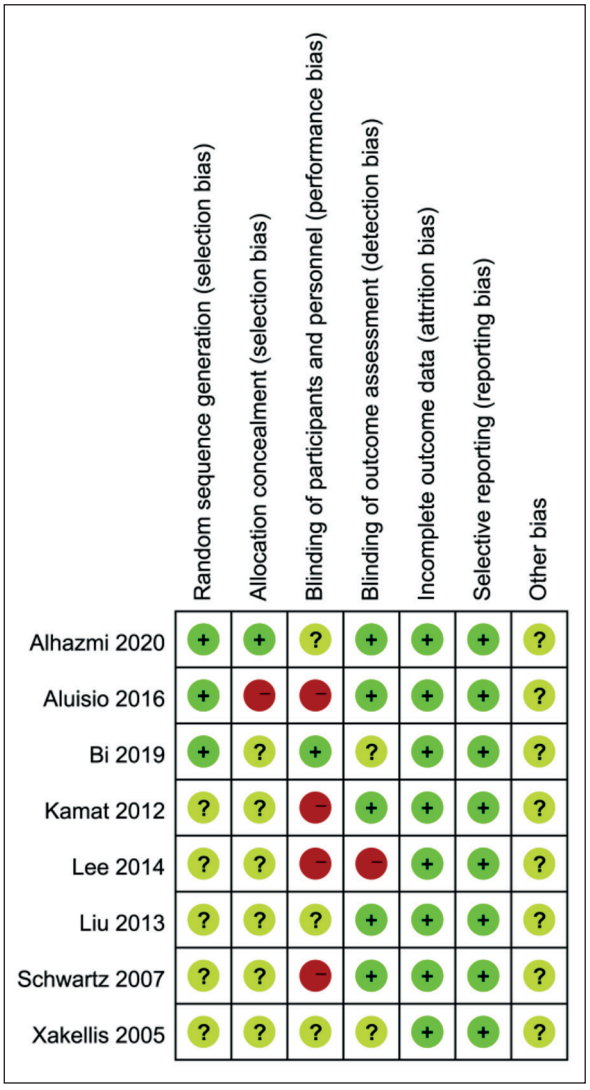

Figure 2. The results of the risk of bias assessment.

to a greater degree than other teaching methods [SMD and its 95% CI were 0.46 (0.04-0.88), p=0.03]. The included studies were subjected to subgroup analysis. Three of the studies compared CBL and simulated teaching. There was a high degree of heterogeneity between the studies (I^2=78%, p=0.001), and random effects models showed that there was no significant difference in academic performance between CBL and simulated teaching [SMD and its 95% CI were 0.24 (-0.16-0.65), p=0.24]. Five of the studies compared CBL with traditional learning, and there was a high degree of heterogeneity among the studies (I^2=92%, p<0.00001). Random effects models showed no significant difference in academic performance between CBL and traditional learning [SMD and its 95% CI were 0.62 (-0.10-1.35), p=0.09]. A funnel chart indicated that no publication bias could be detected (Figure 4).

As shown in Figure 5, 4 studies compared the impact of CBL with that of other teaching methods on case analysis skills. There was high heterogeneity among the studies (I^2=85%, p<0.00001). The results showed that compared with other teaching methods, CBL can improve students' case analysis ability [SMD and its 95% CI were 0.68 (0.34 -1.01), p<0.0001]. A funnel chart indicated the absence of publication bias (Figure 6).

Seven of the eight studies[15-22] that were not included in the meta-analysis assessed the impact of CBL teaching on academic performance. Three studies showed no significant difference between CBL and the control group, 3 studies showed positive results, and 1 study showed negative results[15-21]. Grauer et al[15] found that there was no significant difference in academic performance between CBL and LBL, but the performance of students in the CBL group on difficult problems was significantly higher than that of students in the LBL group (p<0.003). Krupat et al[16] and Reittinger et al[17] found that the CBL group showed better academic performance than the control group, but there was no significant difference between the two (p>0.05). Roca et al[18] found that the ability of CBL to improve performance was greater than that of traditional learning but worse than that of PBL (p=0.000). Sarac et al[19] and Tao et al[20] found that CBL improved student performance better than the control treatment (p<0.01). However, research by Ten et al[21] found that compared with simulated teaching, CBL has a poorer ability to improve student performance (p<0.05).

Of the 16 RCTs, 8 reported students' subjective evaluation of CBL teaching[7,9,11,15-17,20,22]: 5 showed positive results, 1 showed advantages and disadvantages of the two teaching methods, 1 showed no significant difference, and 1 showed negative results. Alhazmi et al[7] and Bi et al[9] found that students in the CBL group reported higher satisfaction than students in the LBL group (p< 0.05), and Bi et al[9] found stronger learning motivation and self-learning ability in the CBL group. Research by Krupat et al[16] showed that students in the CBL group had more positive evaluations of the learning experience. Tao et al[20] found that students are more interested in CBL. Waydhas et al[22] found that most students believe that CBL can improve learning motivation and the preclass preparation rate. Grauer et al[15] found that CBL improves the ability to solve problems but has lower

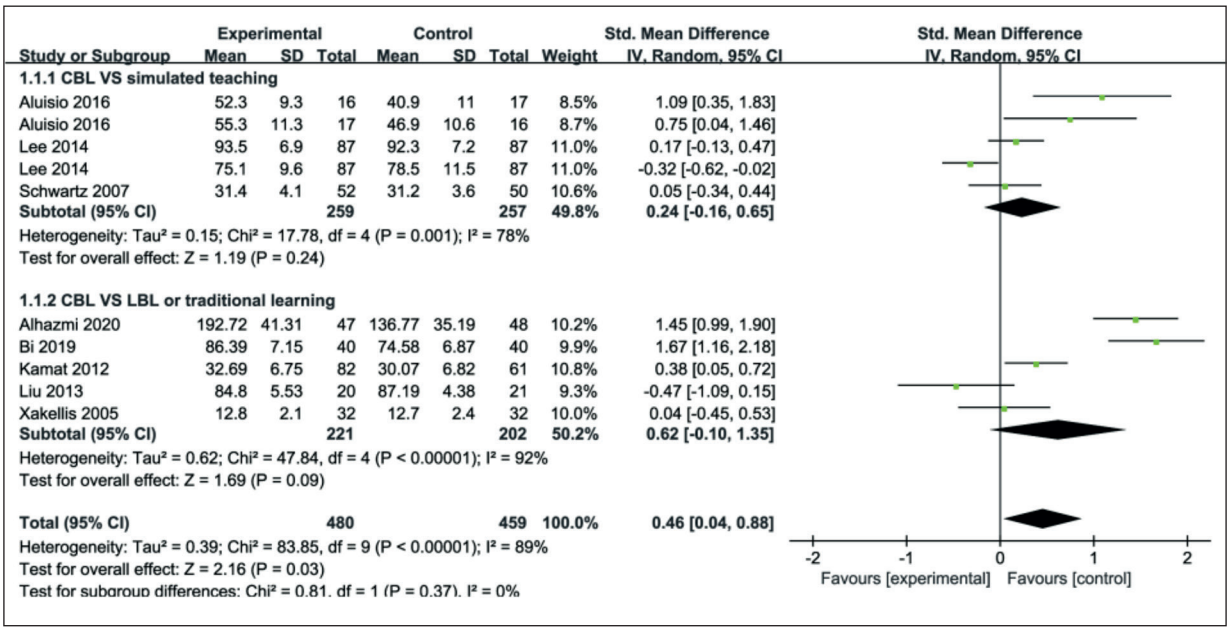

Figure 3. The influence of CBL on students' academic performance was investigated by random effects analysis. The forest map shows the average difference between the CBL and control groups. Squares and horizontal lines indicate the mean difference and 95% CI for each trial; the size of each square is proportional to the statistical weight of the trial in the meta-analysis. Diamonds indicate the estimated effect derived from the meta-analysis, with the center indicating the point estimate and the left and right points indicating the 95% CIs. SD, standard deviation; CI, confidence interval; CBL, case-based learning; LBL, lecture-based learning.

expectations and effectiveness than traditional learning. Reittinger et al[17] showed that CBL can improve the self-confidence of students more than the control treatment (21.2% *vs.* 14.4%), but there was no significant difference between the two (p=0.19). Chin et al[11] found that compared with the simulated teaching group, the CBL group had higher satisfaction.

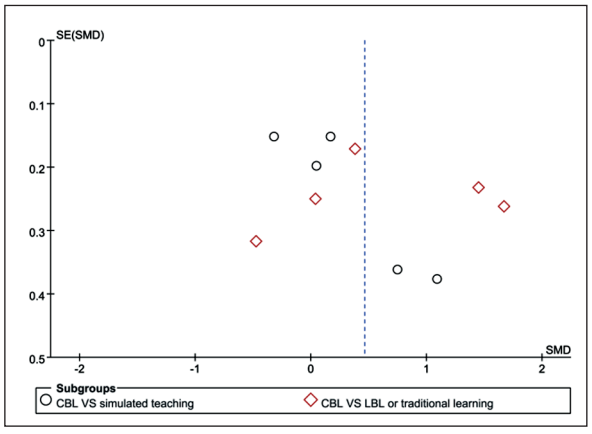

Figure 4. The funnel chart of publication bias in RCTs measuring the impact of CBL on students' academic performance. Each point represents a separate study included in the meta-analysis. Squares indicate studies assessing the effects of CBL compared with simulated teaching. Diamonds indicate studies assessing the effects of CBL compared with LBL or traditional learning. SE, standard error; MD, mean difference; SMD, standardized mean difference; CBL, case-based learning; LBL, lecture-based learning.

Discussion

At present, 16 RCTs have explored the effectiveness of CBL teaching compared with other teaching methods used to educate medical students. The purpose of this meta-analysis is to clarify the role of CBL compared with other teaching methods in the education of medical students. The results of this meta-analysis show that CBL can improve students' academic performance and case analysis ability, and CBL teaching is effective as a method for educating medical students. However, in the subgroup analysis of learning performance, there was no significant difference between CBL and simulated teaching or traditional learning, which may be related to the small number of studies and research samples included in the subgroup analysis. It is difficult to carry out systematic analysis in many respects because the indicators used to evaluate CBL, and other teaching methods are not uniform. Through descriptive analysis, this study

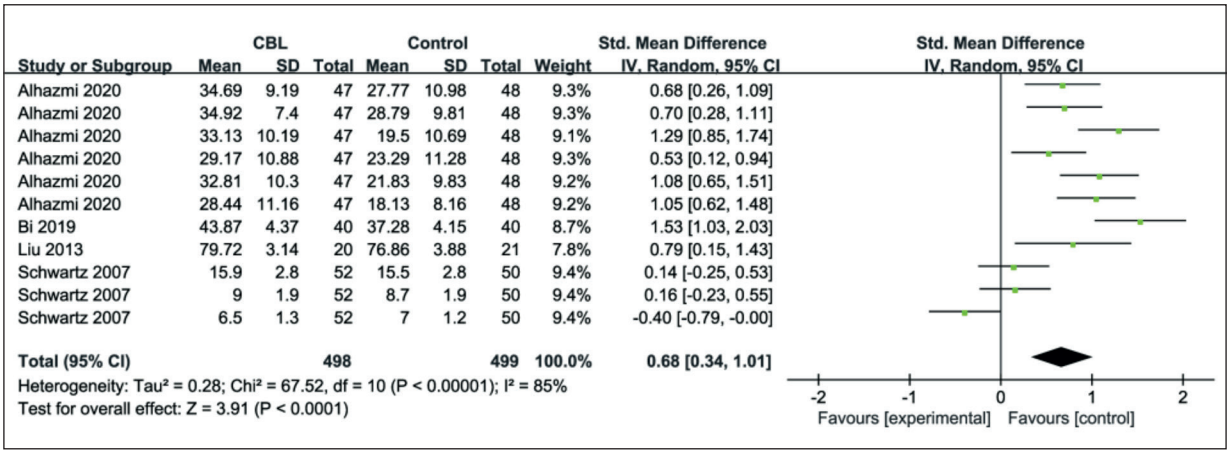

Figure 5. The influence of CBL on students' case analysis ability was investigated *via* random effects analysis. The forest map shows the average difference between the CBL and control groups. Squares and horizontal lines indicate the mean difference and 95% CI for each trial; the size of each square is proportional to the statistical weight of the trial in the meta-analysis. Diamonds indicate the estimated effect derived from the meta-analysis, with the center indicating the point estimate and the left and right points indicating 95% CIs. SD, standard deviation; CI, confidence interval.

found that compared with traditional learning, CBL can improve learning performance[7,9,10,12,17-20], but compared with PBL and simulated teaching, it has no obvious advantages[7,9,10,12,17-20]. In terms of students' subjective evaluation, CBL was rated positively. Some studies have found that CBL can improve students' satisfaction[7,9], learning enthusiasm, self-study ability and problem-solving ability[9,15,20,22]. A related BEME systematic review[4] found that CBL can enhance students' learning enthusiasm, promote their understanding of theoretical knowledge and increase their enjoyment of learning. CBL also helps teachers use their teaching time more efficiently and provides them with a better teaching experience.

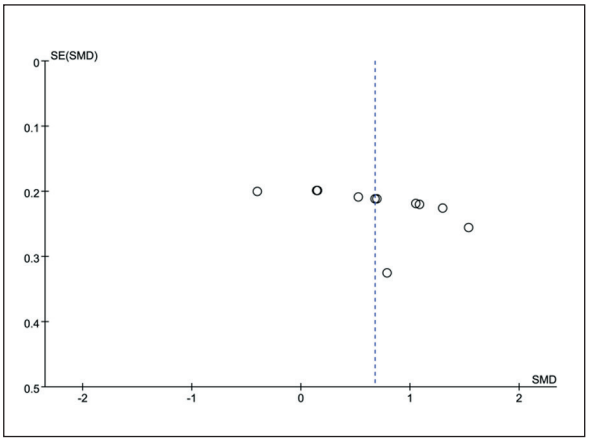

Figure 6. The funnel chart of publication bias in RCTs measuring the impact of CBL on students' case analysis ability. Each point represents a separate study included in the meta-analysis. Squares indicate studies assessing the effects of CBL compared with the control treatment. SE, standard error; MD, mean difference; SMD, standardized mean difference.

At present, there is no clear international definition of CBL, and researchers from different countries have put forward definitions of CBL with different details but the same core[3,4,23-26]. We believe that CBL is an active teaching method that takes students as the center, cases as the bridge and inquiry as the driving force to help students connect the theoretical knowledge in books with complex clinical situations, allowing them to integrate their knowledge and adapt to clinical practice earlier.

At present, traditional teaching methods cannot meet the needs of medical education. New teaching methods are constantly being tested and improved by educators. For example, flipped classrooms have a better learning effect than traditional teaching[27]; situational teaching can enhance clinical ability, improve self-confidence and reduce pressure[28]. Moreover, CBL is also in continuous progress and development; it not only takes a variety of forms but can also be integrated with other teaching methods. Compared with traditional teaching, the combination of CBL and PBL can improve students' academic performance and case analysis ability[29]; compared with a single traditional teaching mode, CBL has a better learning effect and is more popular with students[30]. Medical education has been developing and pros-

pering, but it still needs to be improved to meet the needs of different specialties and different types of medical education.

The study has four major limitations. First, due to the inconsistency of the research samples, the influence of regional education level, students' knowledge reserve and professional differences may have led to significant heterogeneity. Second, the use of the same teaching method but different implementation forms may have led to significant heterogeneity due to differences in the difficulty of test questions and cases. Third, few studies were included in the analysis, and the sample size of the research was very small. Fourth, the analysis explored only the impact of CBL on students' academic performance and case analysis ability, and there was no systematic analysis of satisfaction and knowledge retention ability. Therefore, the effectiveness of CBL for teaching medical students needs further research.

Conclusions

In general, CBL improves students' academic performance and case analysis ability. CBL is positively evaluated as a teaching method. These findings show that CBL teaching has important value in medical students' education.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Acknowledgements

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