Effectiveness of Team-Based Learning Compared with Lecture-Based Learning in Clinical Medicine: A Meta-Analysis

Bing-Rui Lu[1], Shu-Hong Huang[2], Xu-Ying Shi[1], Guo-Xiang Li[1], Qing Yin[3] and Zhi-Gang Sun[1]

[1]*Department of Thoracic Surgery, Central Hospital Affiliated to Shandong First Medical University, Shandong, China*
[2]*School of Clinical and Basic Medical Sciences, Shandong First Medical University, Shandong, China*
[3]*Department of Medical Education, Central Hospital Affiliated to Shandong First Medical University, Shandong, China*

ABSTRACT

A comprehensive comparison and evaluation of the effects of team-based learning (TBL) and lecture-based learning (LBL) in clinical medical education (CME) was conducted. A thorough search was carried out over PubMed, Embase, Web of Science, and Cochrane Library databases for publications about the utilisation of TBL and LBL in clinical medicine. The search was performed until 20 September 2023. After the initial screening of the literature, following the inclusion and exclusion criteria, extracting data and evaluating the methodological quality, a meta-analysis was performed using RevMan 5.3 software and Stata 17.0 software. Thereby, nine studies were included. TBL was superior to LBL in total scores (SMD = 0.84, 95% CI: 0.19~1.48, p = 0.012), with significant differences in short-term theoretical scores (SMD = 0.46, 95% CI: 0.22~0.70, p <0.001), practice scores (SMD = 0.88, 95% CI: 0.17~1.58, p = 0.015), student satisfaction (SMD = 1.13, 95% CI: 0.97~1.29, p <0.001), and long-term theoretical scores (SMD = 1.12, 95% CI: 0.73~1.51, p <0.001). The TBL teaching model appears to be superior to the LBL teaching model in all aspects of clinical medicine education, including total scores, short-term theoretical scores, practice scores, long-term theoretical scores, and student satisfaction. However, these findings need further confirmation from high-quality studies.

Key Words: *Team-based learning, Clinical medicine, Lecture-based learning.*

How to cite this article: Lu BR, Huang SH, Shi XY, Li GX, Yin Q, Sun ZG. Effectiveness of Team-Based Learning Compared with Lecture-Based Learning in Clinical Medicine: A Meta-Analysis. *J Coll Physicians Surg Pak* 2025; **35(09)**:1165-1172.

INTRODUCTION

Clinical medical education (CME) is an important factor for cultivating medical talents. It involves the imparting and cultivation of medical knowledge, skills, and attitudes. With the development of medical science and technology and the change in social demand, CME also needs constant reforms and innovations. Teaching methods, the core element of the teaching process, directly affect teaching quality. Therefore, exploring and choosing suitable teaching methods is a key to improving the level of CME.

The traditional teaching mode is mainly lecture-based learning (LBL), which is teacher-centred, lecture-centred, typically delivered through large-class full-course, indoctrinated instruction. LBL teaching mode can impart a large amount of basic knowledge and theory, ensuring the integrity and comprehensiveness of the teaching content. It is also suitable for beginners and the early stages of teaching. However, it also has certain disadvantages, such as rigid teaching content, lack of student engagement, neglect of student individuality and creativity, hurdles in cultivating student self-learning and teamworking skills, and difficulty in adapting to the diversity and complexity of CME.

Team-based learning (TBL) is another teaching method developed in the 1980s in the USA for business colleges, aimed at improving learning results of large lecture-based classes.[1] TBL means a way of learning that involves active participation and small groups collaboration. It allows students to use what they have learned through a series of tasks that included individual work, team-work, and instant feedback.[2]

TBL stimulates students' curiosity, motivates them to study before the class, collaborate in a team, and enhances their critical thinking skills, which are strongly related to their problem- solving capacity and academic achievement.[3]

Despite the increasing use of TBL in CME,[4] many medical schools around the world have also adopted TBL teaching method.[5,6] Recently, researchers are exploring TBL in health professions education, including pharmacology, medicine, midwifery, and nursing.[7-12] However, the research on the effects and influencing factors of TBL remains neither systematic nor sufficiently comprehensive. Although some literature has

Correspondence to: Dr. Zhi-Gang Sun, Department of Thoracic Surgery, Central Hospital Affiliated to Shandong First Medical University, Jinan, Shandong, China
E-mail: sunszg@126.com

Received: April 06, 2024; Revised: November 16, 2024; Accepted: December 04, 2024
DOI: https://doi.org/10.29271/jcpsp.2025.09.1165

evaluated the impact of TBL in CME,[13] there studies are limited in terms of quality and methodology, making it difficult to get a more dependable outcome. Therefore, this meta-analysis was conducted to evaluate the overall impact of TBL and provide strong proof and guidance for the improvement and development of CME.

METHODOLOGY

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses, (PRISMA) guidelines, were followed in this meta-analysis.[14] This agreement was registered with the International Registry of Prospective Systematic Reviews (PROSPERO) (https://www.crd.york.ac.uk/prospero, CRD4202452 3672). A comprehensive search of databases, including PubMed, Embase, Web of Science, and Cochrane Library, was conducted. The search was updated until 20 September 2023. A combination of MeSH terms (team-based learning, clinical medicine) and related keywords was used in designing the search strategy. No language filters were applied to the papers during the search process.

Inclusion criteria were as follows: The study was either a randomised or non-randomised; the participants were clinical medicine students or resident physicians; TBL and LBL methods were used independently in group teaching, while lectures were meant for large group teaching; and the study reported clearly defined outcome measures with well-documented numerical data.

Data extraction was carried out by two reviewers independently, and any discrepancies found were resolved by a third researcher. Each study yielded information such as first author's name, year of publication, study design, age, speciality, total number of students (TBL/LBL), and outcome assessment.

This exercise aimed to assess the quality of the studies. The reviewers used the Cochrane Collaboration's tool, which evaluate the risk of bias based on seven criteria: random sequence generation, allocation concealment, blinding, missing data, selective reporting, and other potential sources of bias.[15] Assessors rated each criterion as low, high, or unclear risk based on the description of the research. If there was disagreement between assessors, this was resolved through discussion. In addition to the randomised trials, three non-randomised trials were also included. The assessors used the Newcastle-Ottawa scale to assess the quality of the research, which has several items, such as the number of participants, randomisation, blinding, allocation concealment, control of significant factors, control of incomplete data bias, and assessment of outcomes. The scale is scored out of 11, and research that scores 5 or more is considered high-quality research.

This study was meta-analysed using Stata 17.0 software and RevMan 5.1 software. The learning impact was analysed using the standardised mean difference (SMD) and its 95% confidence interval (CI). If the differences were small ($p \geq 0.10$ and $I^2 \leq 50\%$), data were combined using a fixed-effects model.[16,17] Sensitivity analyses were used to determine whether excluding certain studies would change the results. Funnel plots, Begg's test, and Egger's test, were employed to ascertain if publication bias was an issue.[18,19] Results were considered statistically significant if $p < 0.05$.

RESULTS

The initial search yielded 1,033 articles. Inclusion criteria were applied to screen them, and nine pieces of literature were finally included.[20-28] The process and results are shown in Figure 1, and the basic characteristics of these studies are presented in Table I.

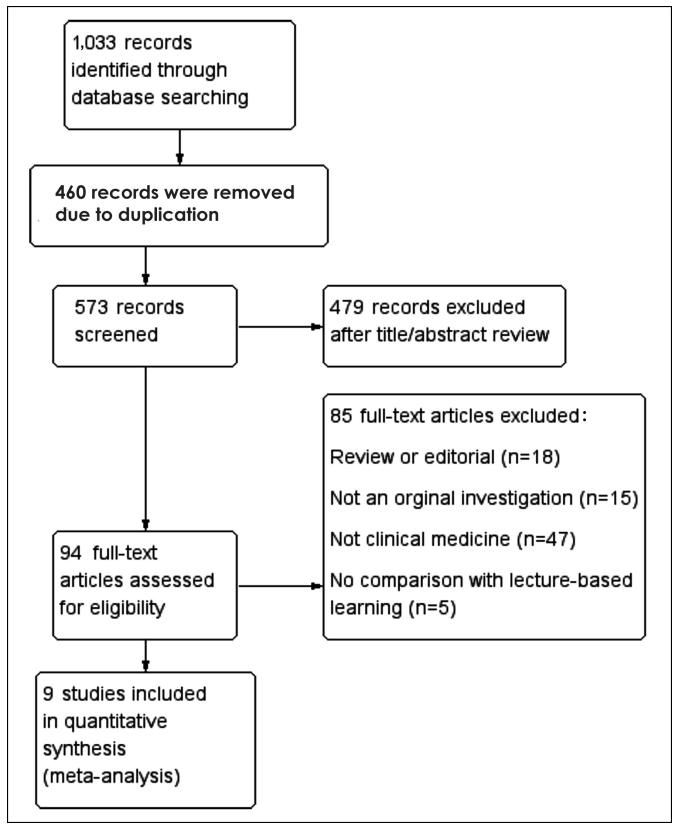

Figure 1: Flow diagram of meta-analysis.

Table II shows the methodological quality of the three included studies, all of which were taken from peer-reviewed journals. Quality scores ranged from 6 to 10. These studies frequently used methods to protect against bias, such as allocation concealment, controlling for significant factors, and controlling for incomplete data bias. However, none of the studies mention whether outcome assessors and data collectors were blinded to the grouping of the subjects, and only two studies used randomisation. All studies assessed outcomes through theoretical examination scores and questionnaires. Figure 2 shows the assessment of the risk of bias for the six papers. As per the Cochrane Collaboration, all studies appeared to be free of bias from other sources of bias. Overall, most of the included papers showed a low risk of bias and high methodological quality (Figure 2).

Table I: The basic characteristics of included studies.

Years	Settings	Study types	Ages		Numbers		Outcomes
			Control groups	TBL groups	Control groups	TBL group	
2017	Turkiye	Non-randomised controlled trials	24.9+2.9	24.3+3.2	141	158	1. End-of-clerkship exam scores; 2. Retention test scores; 3. Satisfaction scores.
2018	USA	Randomised cross-over controlled trials	N/A	N/A	8	8	Test scores (% correct), 1. Application; 2. Recall; 3. Combined (recall and application) short-term exam scores, long-term exam scores.
2019	Germany	Prospective single-centre randomised controlled trials	21(21-31)	21(19-29)	33	19	1. Theoretical knowledge; 2. Objective Structured Clinical Examination (OSCE).
2023	Brazil	Non-randomised controlled trials	N/A	N/A	29 29 30	31 30 28	1. ITE (Internal Medicine In-Training Examination).
2022	Saudi Arabia	Randomised cross-over controlled trials	21.9+1.5	25.1+1.3	17 18 19 18	18 17 18 19	1. The difficulty indices of the clinical reasoning questions; 2. Marks (percentage of total).
2022	China	Randomised controlled trials	22.29+0.24	22.53+0.23	15	15	1. The CCS scores; 2. Overall clinical competence; 3. Overall satisfaction.
2017	Turkiye	Prospective controlled follow-up trial	22.8+2.6	22.8+2.6	163	163	1. The mean end-of- clerkship exam score; 2. Student satisfaction score.
2016	USA	Randomised controlled trials	N/A	N/A	24 55 59	24 51 56	1. Knowledge test scores (pre-test, immediate post-test, remote post-test).
2014	China	Randomised controlled trials	21.6+2.25	22.0+1.76	43	43	1. The theoretical test scores; 2. The practice test scores; 3. The total scores.

Table II: The methodological quality of the three included studies.

First author (Publication year)	Student numbers	Randomisation	Blinding	Allocation concealment	Control for important factors	Control for incomplete data bias	Assessment of outcome	Total quality scores
Levent Ozgonul 2019 [24]	3	0	0	0	2	1	1	7
Alimoglu MK 2017 [27]	3	0	0	0	2	1	2	8
Gerald Schynoll 2021 [28]	3	0	0	1	2	1	1	8

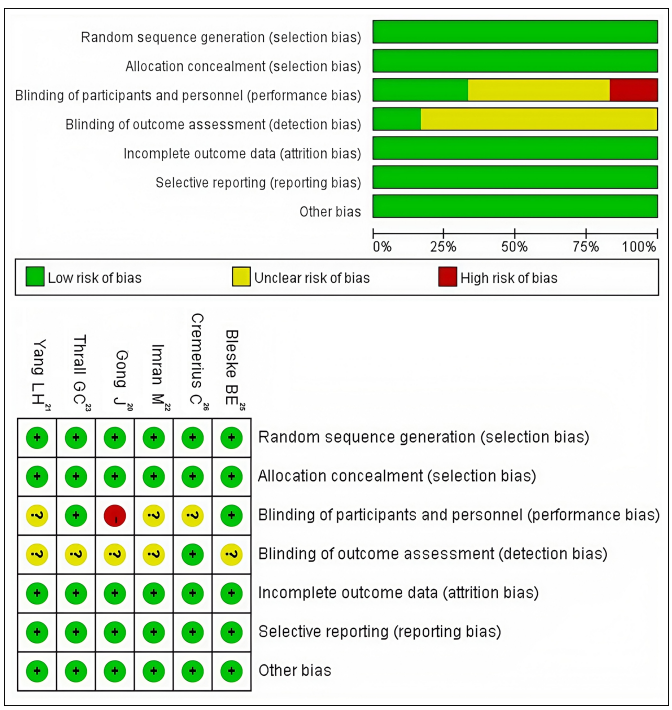

Figure 2: The assessment of bias for the six articles.

In three articles, researchers compared the total scores of 279 students.[21,25,28] The total score comprised marks from the practitioner examination as well as combined practical and theoretical assessments. Where significant differences existed among the results ($p < 0.001$, $I^2 = 84.0\%$), a random-effects model was used to synthesise the data. The total scores of students in the TBL group were significantly higher than those of students in the LBL group (SMD = 0.84, 95% CI: [0.19~1.48], p = 0.012; Figure 3A).

The researchers collected eight articles (containing eleven studies), with a total of 1,059 cases participating in the study.[20-27] Short-term results refer to tests administered immediately after the course. These included the accuracy of theoretical answers, final exam scores, and the percentage of correct answers to recall questions. A statistical heterogeneity existed among the results of the different studies ($p = 0.001$, $I^2 = 65.3\%$); therefore, a random effects model was used to synthesise and analyse the data. The short-term theoretical knowledge scores of students in the TBL group were higher than those of students in the LBL group (SMD = 0.46, 95% CI: [0.22~0.70], p <0.001; Figure 3B).

Five articles (containing eight studies), with a total of 328 cases participating in the study, were collected.[20-22,25,26] Their clinical competence was assessed using surgical skills, case analysis, and other clinical items. The practice scores of students in the TBL group were higher than those in the LBL group (SMD = 0.88, 95% CI: [0.17~1.58], p = 0.015; Figure 3C).

Three articles (containing three studies), with a total of 696 students participating in the study, were collected.[20,24,27] As shown in the graph, students in the TBL group were more satisfied with their learning patterns than those in the LBL group (SMD = 1.13, 95% CI: [0.97~1.29], p <0.001; Figure 3D).

The researchers collected four articles (containing five studies) with a total of 1,015 cases participating in the study.[23-25,27] Long-term results refer to tests that were administered sometime after the programme ended. These included knowledge retention scores, one or two years after the test scores. Students in the TBL group had higher long-term theoretical knowledge scores than those in the LBL group (SMD = 1.12, 95% CI: [0.73~1.51], p <0.001; Figure 3E).

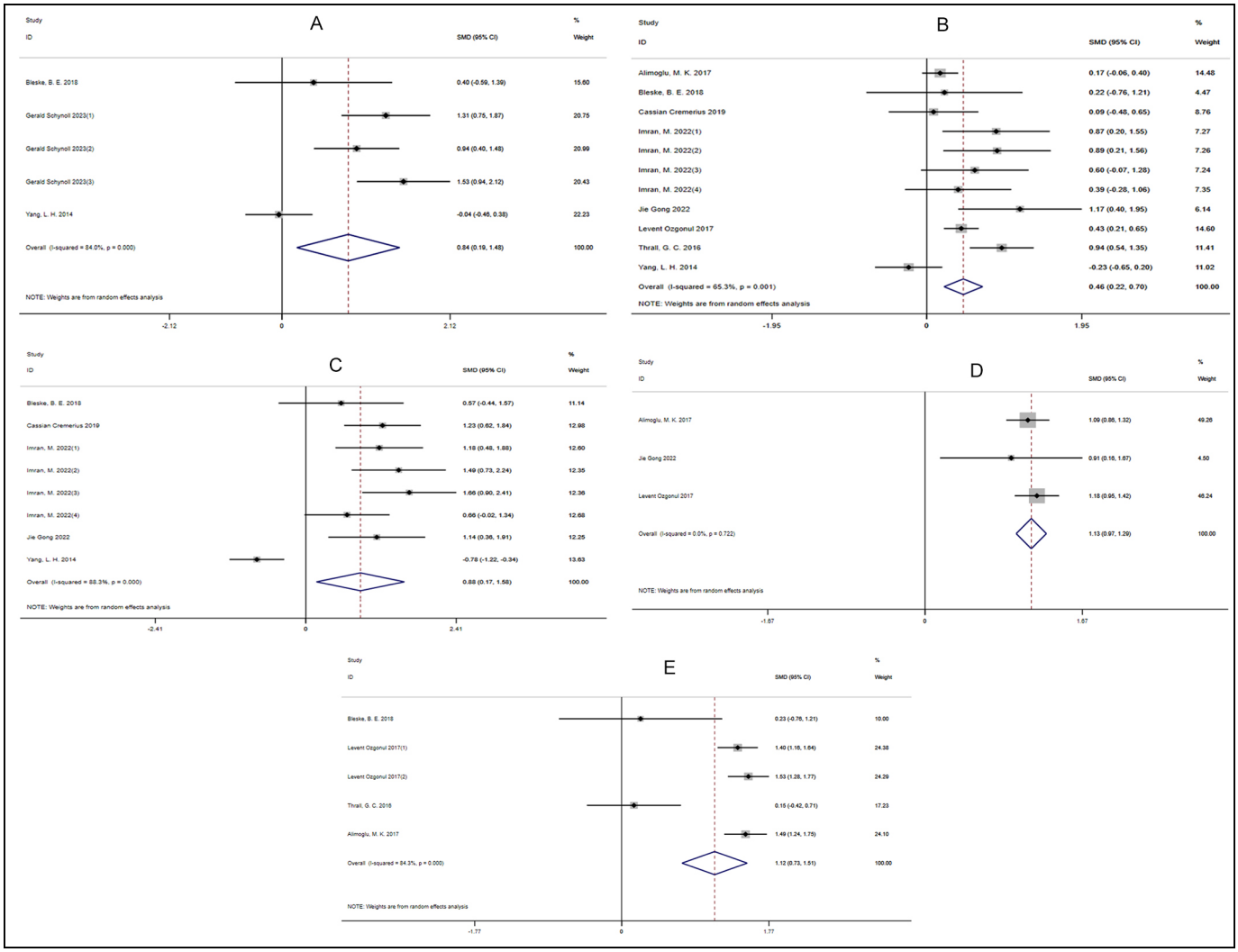

Figure 3: (A) Meta-analysis result for the total scores (B) Meta-analysis result for short-term theoretical knowledge scores (C) Meta-analysis result for practice scores (D) Meta-analysis result for student satisfaction (E) Meta-analysis result for long-term theoretical knowledge scores.

Due to the high degree of heterogeneity among outcomes, sensitivity analyses were conducted to assess the reliability of the results (Figure 4). After excluding the most heavily weighted study, the combined effect size favoured the intervention group for total and practice scores (SMD = 1.14, 95% CI: [0.74, 1.54], p = 0.652; SMD = 1.16, 95% CI: [0.88, 1.43], p = 0.652).[21] After excluding the most weighted study, similarly the combined effect size favoured the intervention group for both short-term theoretical knowledge and long-term scores (SMD = 0.48, 95% CI: [0.18, 0.78], p = 0.369; SMD = 1.40, 95% CI: [1.16, 1.64], p = 0.021).[24] Finally, even after excluding the most weighted study, the combined effect size favoured the intervention group in terms of student satisfaction (SMD = 1.16, 95% CI: [0.94, 1.39], p = 0.369).[27]

Due to the limited number of articles included in this meta-analysis, funnel plots were only drawn for outcome metrics, which included at least 10 studies, of which only the short--term theory scores met the criteria. Funnel plots were used to detect publication bias in the short-term theoretical scores. The funnel plot was symmetrically distributed, indicating no publication bias.[29]

DISCUSSION

In recent years, as TBL teaching has matured, an increasing number of studies have emphasised its significant impact on medical education. Based on these studies, corresponding meta-analyses were conducted on the TBL teaching mode, including articles in both nursing and medical education.[30] The result showed that TBL was more effective than LBL in improving students' knowledge, attitudes, and skills in medical education.[31] However, these studies did not demonstrate advantages in terms of long-term knowledge retention, clinical reasoning, or clinical skills. Therefore, further research was conducted to particularly address the impact of the TBL teaching model on CME. This study aimed to provide new avenues for reforming teaching models for undergraduate students and residents.

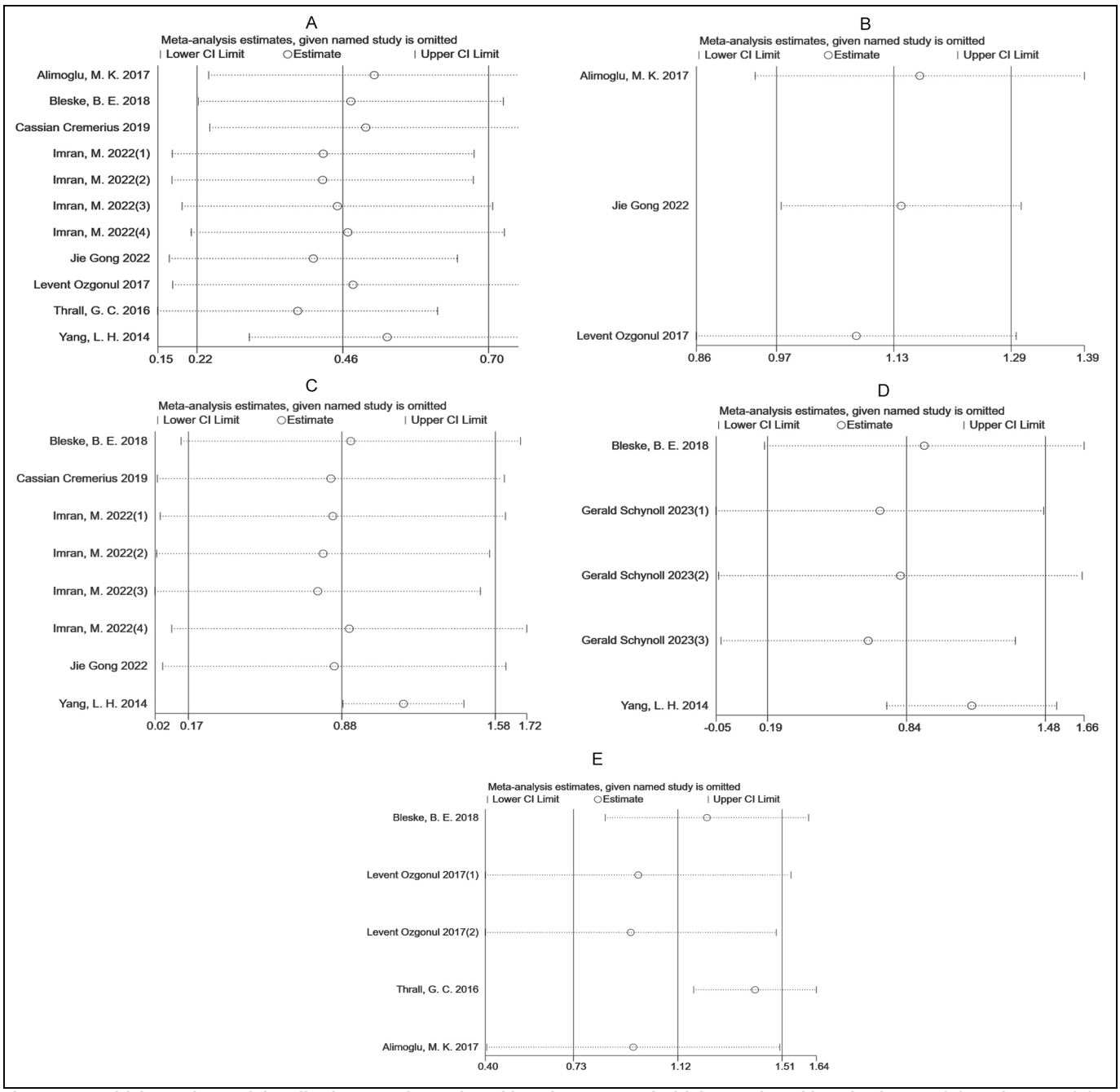

Figure 4: Sensitivity analyses of the effectiveness of team-based learning compared with lecture-based learning in CME: (A) total scores; (B) short-term theoretical knowledge scores; (C) practice scores; (D) student satisfaction; (E) long-term theoretical knowledge scores.

In this meta-analysis, after combining the effect sizes, it was found that the outcomes in the TBL group were better than those in the LBL group. These results were similar to those reported in the meta-analysis by Zhang *et al*.[31] Moreover, in this study, it was found that the TBL group was better than the LBL group in the retention of long-term theoretical knowledge. Some studies showed that TBL could effectively improve students' long-term knowledge retention and critical thinking skills, as well as their learning motivation and teamwork.[32]

There was a significant improvement in the short-term theoretical scores of students in the TBL group compared to those in the LBL group, consistent with the findings of Chen *et al*.[30] TBL refers to a team-based learning method that emphasises students' autonomous pre-class learning, in-class teamwork and application-based exercises. It improves students' motivation, participation, and comprehension.[33] In contrast, LBL teaching is mainly based on lectures and passive student listening, which may result in negative, superficial, exam-oriented learning. Therefore, TBL can stimulate students' interests in learning, cultivate clinical thinking and competence, and promote both deep and active learning.[34]

TBL emphasises application-based exercises and in-class teamwork, which can improve students' clinical thinking and practical skills. In addition, it can enhance students' motivation in the learning process because it emphasises their autonomous pre-class learning, in-class teamwork, and application-based exercises, encouraging them to focus more on the application of knowledge rather than just mastering it.[35] TBL can also improve students' clinical competence by using application problems based on real-world situations and allowing students to simulate realistic clinical scenarios. This approach helps students in acquiring clinical knowledge and skills, while also improving their innovation and clinical decision-making abilities.[36]

More importantly, the TBL group was favoured in the retention of long-term theoretical knowledge and had significant statistical significance, which was not analysed in previous studies. TBL can cultivate students' metacognitive ability and knowledge transfer ability. Motivation is an important factor affecting knowledge retention. The higher the motivation, the easier the knowledge is to be remembered. In addition, TBL can also cultivate students' teamwork ability because it propels students to discuss, interact, cooperate, solve problems or complete tasks within the group.[37] Teamwork skills can promote students' social learning — that is, the joint construction of knowledge and understanding through communication and cooperation with others. Social learning can increase students' participation and interest, thereby improving knowledge retention.

TBL is a teaching mode that emphasises students' active cooperative, and application-based learning. It improves their learning outcomes and abilities through group discussion, assessments, and feedback. This method can improve their interest, performance, autonomy, teamwork skills, knowledge, clinical thinking, and decision-making and communication abilities in the learning process.[38] TBL can also cultivate students' innovation, awareness, and critical thinking and promote their in-depth understanding and application of knowledge. For teachers, TBL can change their educational concept and teaching role — from being traditional transmitters of knowledge to serving as guides and tutor of student learning. It can also improve their teaching quality and satisfaction and enhance their professional development and research ability. When extended to the resident level, TBL can effectively improve the quality of standardised training and teaching satisfaction. It also helps residents master clinical knowledge and skills, thereby improving their overall clinical competence.

The future development of TBL is full of hope and challenges. TBL can be combined with other teaching modes to develop more flexible and effective teaching strategies — such as the combination of TBL with PBL (problem-based learning), CBL (case-based learning), FC (flipped classroom), SBL (situation-based learning), to fully utilise the strengths of various teaching modes and meet different teaching objectives and learning needs.[39-41] Moreover, TBL can leverage information technology and network platforms to achieve online or blended teaching models. It expands the coverage and influence of teaching, improves convenience and interactivity, and enhances innovation and diversity in teaching.

This meta-analysis synthesises the results of several independent studies, improving the overall validity and consistency of the study; however, it has certain limitations and shortcomings. This analysis includes only published studies, ignoring unpublished or lower-quality studies, which may lead to overestimation or underestimation of the effect value. The studies involved in this study have differences in terms of design (randomised controlled trials and non- randomised controlled trials), methodology, quality, population, and intervention, which could affect the comparability and credibility of the findings. Although, the sensitivity analyses suggested that these results were relatively stable; however, some limitations were identified. Other factors that may affect the results — such as study quality, subgroup analysis, and dose-effect — were not considered. Additionally, other sensitivity analysis strategies — such as the sensitivity range method, meta-regression, and reweighting method — were not used. Therefore, future studies should use other sensitivity analysis methods to further verify these results and uncover more influencing factors and mechanisms. The symmetry of the funnel plot was difficult to determine because of the relatively insufficient number of original articles for this meta-analysis. Finally, there were corresponding shortcomings in data extraction, and the criteria for the measurement of outcomes in the literature of these original studies were inconsistent. Moreover, it had some specific limitations as well: TBL may be implemented in different ways and with inconsistent quality across studies, leading to differences in findings. Its effectiveness can be influenced by factors such as subject matter, curriculum, teachers, students, and other variables, making comprehensive comparisons and evaluations challenging. The effects of TBL may change over time; and therefore, they need to be tracked and observed.

Some suggestions for future research include: increasing the quality of assessment and the consistency of TBL implementation; exploring the best implementation strategies and standards for TBL; expanding the scope of its application and impacts, under different conditions, on disciplines, curricula, teachers, and students; focusing on its long-term effects — such as evaluation of knowledge, skills, attitudes, and behaviours of students; explore the synergistic effects and optimal combination of TBL with other teaching methods — such as PBL and CBL.

CONCLUSION

This meta-analysis compared the effectiveness of TBL and LBL teaching methods in CME, and the results showed that the outcomes of TBL was more effective than LBL indicating that TBL could effectively improve student's learning performance, satisfaction, theoretical knowledge and practical skills in CME.

Therefore, to improve teaching quality and its impacts, the application of TBL is recommended in CME.

FUNDING:
This work was supported by Shandong Province Undergraduate Teaching Reform Research Project (Grant No. M2023352), Shandong First Medical University Course Ideological and Political Education Research Project in 2024 (No. KZ2024014 and No. KZ2024015), and Shandong First Medical University Campus Education and Teaching Reform Research Project Approval Project in 2022 (Grant No. XM2022159).

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
BRL: Study design, data acquisition, analysis, and manuscript writing.
SHH, XYS, GXL: Result interpretation and contribution to discussion.
QY, ZGS: Study design and overall accountability for the work.
All authors approved the final version of the manuscript to be published.

REFERENCES

1. Burgess AW, McGregor DM, Mellis CM. Applying established guidelines to team-based learning programs in medical schools: A systematic review. Academic medicine. *J Assoc Am Med Coll* 2014; **89(4)**:678-88. doi: 10.1097/ACM.0000000000000162.
2. Parmelee D, Michaelsen LK, Cook S, Hudes PD. Team-based learning: A practical guide: AMEE guide no. 65. *Med Teach* 2012; **34(5)**:e275-87. doi: 10.3109/0142159X.2012.651179.
3. Morrison G, Goldfarb S, Lanken PN. Team training of medical students in the 21st century: Would flexner approve? Academic medicine. *J Assoc Am Med Coll* 2010; **85(2)**:254-9. doi: 10.1097/ACM.0b013e3181c8845e.
4. Wiener H, Plass H, Marz R. Team-based learning in intensive course format for first-year medical students. *Croat Med J* 2009; **50(1)**:69-76. doi: 10.3325/cmj.2009.50.69.
5. Searle NS, Haidet P, Kelly PA, Schneider VF, Seidel CL, Richards BF. Team learning in medical education: Initial experiences at ten institutions. *Acad Med* 2003; **78(10 Suppl)**:S55-8. doi: 10.1097/00001888-200310001-00018.
6. Parmelee DX, Michaelsen LK. Twelve tips for doing effective team-based learning (TBL). *Med Teach* 2010; **32(2)**:118-22. doi: 10.3109/01421590903548562.
7. Ofstad W, Brunner LJ. Team-based learning in pharmacy education. *Am J Pharm Educ* 2013; **77(4)**:70. doi: 10.5688/ajpe77470.
8. Reimschisel T, Herring AL, Huang J, Minor TJ. A systematic review of the published literature on team-based learning in health professions education. *Med Teach* 2017; **39(12)**:1227-37. doi: 10.1080/0142159X.2017.1340636.
9. Dearnley C, Rhodes C, Roberts P, Williams P, Prenton S. Team based learning in nursing and midwifery higher education; a systematic review of the evidence for change. *Nurse Educ Today* 2018; **60**:75-83. doi: 10.1016/j.nedt.2017.09.012.
10. Sakamoto SR, Dell'Acqua MCQ, Abbade LPF, Caldeira SM, Fusco SFB, Avila MAG. Team-Based Learning: A randomized clinical trial in undergraduate nursing. *Rev Bras Enferm* 2020; **73(2)**:e20180621. doi: 10.1590/0034-7167-2018-0621.
11. Lee KE. Effects of team-based learning on the core competencies of nursing students: A quasi-experimental study. *J Nursing Res* 2018; **26(2)**:88-96. doi: 10.1097/jnr.0000000000000259.
12. Kim HR, Song Y, Lindquist R, Kang HY. Effects of team-based learning on problem-solving, knowledge and clinical performance of Korean nursing students. *Nurse Educ Today* 2016; **38**:115-8. doi: 10.1016/j.nedt.2015.12.003.
13. Sterpu I, Herling L, Nordquist J, Rotgans J, Acharya G. Team-based learning (TBL) in clinical disciplines for undergraduate medical students-a scoping review. *BMC Med Educ* 2024; **24(1)**:18. doi: 10.1186/s12909-023-04975-x.
14. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, *et al*. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. *BMJ* 2009; **339**:b2700. doi: 10.1136/bmj.b2700.
15. Higgins JP, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, *et al*. The Cochrane collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011; **343**:d5928. doi: 10.1136/bmj.d5928.
16. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986; **7(3)**:177-88. doi: 10.1016/0197-2456(86)90046-2.
17. Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. *J Natl Cancer Inst* 1959; **22(4)**:719-48.
18. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. *Biometrics* 1994; **50(4)**:1088-1.
19. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997; **315(7109)**:629-34. doi: 10.1136/bmj.315.7109.629.
20. Gong J, Du J, Hao J, Li L. Effects of bedside team-based learning on pediatric clinical practice in Chinese medical students. *BMC Med Educ* 2022; **22(1)**:264. doi: 10.1186/s12909-022-03328-4.
21. Yang LH, Jiang LY, Xu B, Liu SQ, Liang YR, Ye JH, *et al*. Evaluating team-based, lecture-based, and hybrid learning methods for neurology clerkship in China: A method-comparison study. *BMC Med Educ* 2014; **14**:98. doi: 10.1186/1472-6920-14-98.
22. Imran M, Halawa TF, Baig M, Almanjoumi AM, Badri MM, Alghamdi WA. Team-based learning *versus* interactive lecture in achieving learning outcomes and improving clinical reasoning skills: A randomized crossover study. *BMC Med Educ* 2022; **22(1)**:348. doi: 10.1186/s12909-022-03411-w.
23. Thrall GC, Coverdale JH, Benjamin S, Wiggins A, Lane CJ, Pato MT. A randomized controlled trial of team-based learning *versus* lectures with break-out groups on knowledge retention. *Acad Psychiatry* 2016; **40(5)**:755-60. doi: 10.1007/s40596-016-0501-7.
24. Ozgonul L, Alimoglu MK. Comparison of lecture and team-based learning in medical ethics education. *Nurs Ethics* 2019; **26(3)**:903-13. doi: 10.1177/0969733017731916.

25. Bleske BE, Remington TL, Wells TD, Klein KC, Tingen JM, Dorsch MP. A randomized crossover comparison between team-based learning and lecture format on long-term learning outcomes. *Pharmacy (Basel)* 2018; **6(3)**:81. doi: 10.3390/pharmacy6030081.
26. Cremerius C, Gradl-Dietsch G, Beeres FJP, Link B, Hitpaß L, Nebelung S, *et al*. Team-based learning for teaching musculoskeletal ultrasound skills: A prospective randomised trial. *Eur J Trauma Emerg Surg* 2021; **47(4)**:1189-99. doi: 10.1007/s00068-019-01298-9.
27. Alimoglu MK, Yardım S, Uysal H. The effectiveness of TBL with real patients in neurology education in terms of knowledge retention, in-class engagement, and learner reactions. *Adv Physiol Educ* 2017; **41(1)**:38-43. doi: 10.1152/advan.00130.2016.
28. Schynoll G, Perog J, Feustel PJ, Smith R. Curriculum transition from lecture-based to team-based learning is associated with improved performance on internal medicine in-training examination. *J Grad Med Educ* 2021; **13(5)**:691-8. doi: 10.4300/JGME-D-20-01164.1.
29. Sterne JA, Sutton AJ, Ioannidis JP, Terrin N, Jones DR, Lau J, *et al*. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ* 2011; **343**:d4002. doi: 10.1136/bmj.d4002.
30. Chen M, Ni C, Hu Y, Wang M, Liu L, Ji X, *et al*. Meta-analysis on the effectiveness of team-based learning on medical education in China. *BMC Med Educ* 2018; **18(1)**:77. doi: 10.1186/s12909-018-1179-1.
31. Zhang Q, Tang X, Zhao Y, Wang Z. Team-based learning *vs*. lecture-based learning in nursing: A systematic review of randomized controlled trials. *Front Public Health* 2022; **10**:1044014. doi: 10.3389/fpubh.2022.1044014.
32. McInerney MJ, Fink LD. Team-based learning enhances long-term retention and critical thinking in an undergraduate microbial physiology course. *Microbiol Educ* 2003; **4**:3-12. doi: 10.1128/me.4.1.3-12.2003.
33. Whitley HP, Bell E, Eng M, Fuentes DG, Helms KL, Maki ED, *et al*. Practical team-based learning from planning to implementation. *Am J Pharm Educ* 2015; **79(10)**:149. doi: 10.5688/ajpe7910149.
34. Burgess A, van Diggele C, Roberts C, Mellis C. Team-based learning: design, facilitation and participation. *BMC Med Educ* 2020; **20(Suppl 2)**:461. doi: 10.1186/s12909-020-02287-y.
35. Ji H, Zhu K, Shen Z, Zhu H. Research on the application and effect of flipped-classroom combined with TBL teaching model in WeChat-platform-based biochemical teaching under the trend of COVID-19. *BMC Med Educ* 2023; **23(1)**:679. doi: 10.1186/s12909-023-04623-4.
36. Burgess A, Bleasel J, Haq I, Roberts C, Garsia R, Robertson T, *et al*. Team-based learning (TBL) in the medical curriculum: Better than PBL? *BMC Med Educ* 2017; **17(1)**:243. doi: 10.1186/s12909-017-1068-z.
37. Haj-Ali R, Al Quran F. Team-based learning in a preclinical removable denture prosthesis module in a United Arab Emirates dental school. *J Dent Educ* 2013; **77(3)**:351-7.
38. Haidet P, Fecile ML. Team-based learning: a promising strategy to foster active learning in cancer education. *J Cancer Educ* 2006; **21(3)**:125-8. doi: 10.1207/s15430154jce2103_6.
39. Burgess A, Matar E, Roberts C, Haq I, Wynter L, Singer J, *et al*. Scaffolding medical student knowledge and skills: Team-based learning (TBL) and case-based learning (CBL). *BMC Med Educ* 2021; **21(1)**:238. doi: 10.1186/s12909-021-02638-3.
40. Feng Y, Zhao B, Zheng J, Fu Y, Jiang Y. Online flipped classroom with team-based learning promoted learning activity in a clinical laboratory immunology class: Response to the COVID-19 pandemic. *BMC Med Educ* 2022; **22(1)**:836. doi: 10.1186/s12909-022-03917-3.
41. Kang KA, Kim SJ, Oh J, Kim S, Lee MN. Effectiveness of simulation with team-based learning in newborn nursing care. *Nurs Health Sci* 2016; **18(2)**:262-9. doi: 10.1111/nhs.12245.