

Effectiveness of multiple teaching methods in standardized training of internal medicine residents in China: a network meta-analysis

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Abstract

Objective

Standardized training for resident physicians in China has been carried out for 10 years, and various new teaching methods have been widely applied in it. The quality of internal medicine teaching is directly related to whether the trainees can master the corresponding clinical skills well and become qualified clinical physicians. The purpose of this study is to systematically evaluate the effectiveness of all teaching methods in Chinese standardized training of internal medicine residents.

Methods

This study was registered in Inplasy. A comprehensive search of databases, including English and Chinese, was conducted from inception to 30 July 2023. Eligible studies included cohort study and randomized controlled trials (RCT) of all teaching methods in Chinese standardized training of internal medicine residents. A network meta-analysis (NMA) was performed using STATA 16.0. Statistical analysis was done using the mean and standard deviation. The literature quality and risks of bias was assessed using RevMan 5.3.

Results

A total of 74 articles including 5004 Chinese participants were retrieved, involving 13 interventions, of which 65 were RCT and 9 were cohort studies. This study found that the problem-based learning(PBL) + Wechat may be the best choice for improving students' academic performance, practical performance and reducing the number of dissatisfied individuals. The case-based learning(CBL) + Wechat has the most advantages in improving students' theoretical performance and reducing the number of dissatisfied individuals. The PBL + CBL may better improve students' self-learning ability and reduce the number of dissatisfied individuals.

Conclusion

New teaching methods represented by PBL + Wechat, CBL + Wechat, PBL + CBL are more effective in improving the academic performance of Chinese resident physicians in standardized training compared to control therapy, and have gained more recognition from students.

Introduction

The National Health and Family Planning Commission (NHFPC) issued the Guidance on Establishing Standardized Resident Training System on 31 December, 2013 on the premise of drawing lessons from foreign advanced systems, which marked the formal implementation of this system in China^[1]. However, corresponding problems arise as many training bases still practice lecture-based learning method (LBL) to train students, thus students are only learning passively. Due to the lack of familiarity with clinical skills, many students find it difficult to maintain enthusiasm for learning^[2].

In recent years, with the continuous advancement of medical education reform in China, the application of new teaching methods such as problem-based learning (PBL), case-based learning(CBL), team-based learning (TBL) and flipped classroom (FC) have been gradually applied to the medical education^[3-4]. Furthermore, the new teaching methods provide many opportunities to explore their opinion and cultivate self-learning ability^[5-6].

At present, there is no corresponding connection between the researches on various types of teaching methods. As the traditional meta-research only compares two kinds of teaching methods, this makes it difficult to systematically and comprehensively evaluate the advantages and disadvantages of the various teaching methods. To our knowledge, there is no

literature that analyzes the outcome of these new teaching methods, especially in standardized training of residents in China. Network meta-analysis (NMA) is a new type of meta-analysis, which can compare the effectiveness of multiple interventions more intuitively and in detail, while traditional meta-analysis can only compare them in pairs. Based on the application of various new teaching methods in the standardized training of residents in China, in this study, we aimed to conduct a NNA by integrating available direct and indirect evidence to identify the optimal strategy for standardized training of internal medicine residents in China.

Material and methods

This protocol has been registered in INPLASY with the code INPLASY202380121 (doi:10.37766/inplasy2023.8.0121). This meta-analysis was performed based on the PRISMA statement.

Criteria for inclusion and exclusion of systematic reviews

Research type

All studies are controlled but not restricted to the use of randomized or unrandomized methods. The language of studies used was Chinese and English, and the multi-arm experiment data is combined into a two-arm experiment. If the same research is presented in multiple articles, duplicated papers will be excluded during data collection.

Research targets

Our research target audience must be Chinese resident physicians who undergo standardized resident training in the training base. The department of study is confined to the Department of Internal Medicine (DIM), but not limited to a specific specialty within the DIM.

Intervention measures

New teaching methods such as problem-based learning, research-based learning, sandwich teaching method, team-based learning, flipping classroom were investigated. These teaching methods can be implemented on their own or combined, without other controlled measures such as the teaching time. In the situation where any group pairs of investigation both adopted the new teaching methods, they must be of different forms, such as PBL + WeChat and PBL.

Outcome measures

Outcomes collected are Theoretical test scores, Practical test scores, Medical record test scores, Score of autonomous learning ability and Number of dissatisfied people. The data of all these measures were not included in the follow-up data.

Exclusion criteria

(1) Non-prospective studies or retrospective comparative studies, such as case reports, theoretical researches and literature researches. (2) Repeated publication of literature. (3) Non-Chinese or English literature. (4) Non-periodical literature, such as abstracts, conference papers and dissertations. (5) Lack of the above outcome indicators and no baseline data. (6) Intervention measures that are published in less than 3 literatures. (7) Non-RCT or cohort study, the research results are unknown, the data is false. (8) Data statistics not presented in the form of average and standard deviation. (9) The rotation department is not the department of internal medicine.

Search strategy

All comparative studies on the application of new teaching methods from the date of creation to 30 July 2023 were included in the data collection. Databases were collected from the Cochrane Library, PubMed, EMBASE, Web of Science, China National Knowledge Infrastructure(CNKI), Wanfang Academic Journal Full text database(Wanfang), VIP Chinese scientific and technological journal database(VIP), Chinese Biomedical Literature Database(CBM). Manual searches were also conducted to provide supplementary literature. The PubMed database search strategy is shown in Table 1.

Table 1
Search strategy for the PubMed

No.	Search terms
#1	Evidence-Based Medicine[MeSH Terms]
#2	Flipped-class learning[MeSH Terms]
#3	Team-based learning[MeSH Terms]
#4	Sandwich teaching[MeSH Terms]
#5	Research-based learning[MeSH Terms]
#6	Problem-based learning[MeSH Terms]
#7	Case-based learning[MeSH Terms]
#8	Education[MeSH Terms]
#9	#1 OR #2 #3 OR #4 OR #5 OR #6 OR #7 OR #8
#10	((((((((((Evidence-Based Medicine[Title/Abstract]) OR (EBM[Title/Abstract])) OR (Flipped-class learning[Title/Abstract])) OR (Team-based learning[Title/Abstract])) OR (TBL[Title/Abstract])) OR (Sandwich teaching[Title/Abstract])) OR (Research-based learning[Title/Abstract])) OR (RBL[Title/Abstract])) OR (Problem-based learning[Title/Abstract])) OR (PBL[Title/Abstract])) OR (Case-based learning[Title/Abstract])) OR (CBL[Title/Abstract])) OR (Training Programs[Title/Abstract])) OR (Literacy Programs[Title/Abstract])) OR (Programs[Title/Abstract])) OR (Educational[Title/Abstract])
#11	#9 OR #10
#12	Internal Medicine[MeSH Terms]
#13	internal medicine[Title/Abstract]
#14	#12 OR #13
#15	((randomized controlled trial[Title/Abstract]) OR (randomized[Title/Abstract])) OR (placebo[Title/Abstract])
#16	#11 AND #14 AND #15

Selection of studies and data extraction

Two independent researchers (Ye and Liu) screened through the literature and excluded studies based on the inclusion and exclusion criteria before they cross-examine each other's work. In the event of a disagreement, both parties will discuss their decision or invite an independent third party to come to a consensus, while strictly complying with the selection criteria. The data extracted includes: (1) General information regarding the study; (2) Baseline characteristics of the research subject and treatment method used; (3) Key elements of bias risk assessment; (4) Outcome indicators and data.

Risk of bias of the included study

Two researchers (Ye and Liu) independently evaluate the risk of bias of the included studies and cross-examine the results. If two researchers have different opinions regarding the quality of a study, a third author (Wang) will reassess the different opinions. RCT risk bias assessment tool^[7], recommended by the Cochrane Manual 5.1.0, was used for the risk assessment.

Statistical analysis

Stata 16.0 software mvmeta package was used to conduct NMA. The mean and standard deviation of the data collected were used to conduct statistical analysis. RevMan5.3 software was used to assess the literature quality and risk of bias. Binary categorical variables use odds ratio (OR), continuous variables use mean difference (MD), and the 95% confidence interval (CI) was calculated. The heterogeneity between studies is determined by the comparison of prediction interval, and the anomalies

were evaluated by the node splitting method^[8-9]. Similarities between the studies were evaluated by comparing the clinical and methodological characteristics of each study. The league table is used to show the comparison results of the outcome indicators of any two treatment techniques. The significance level of the NMA is $\alpha = 0.05$. If 95% CI crosses 1, it is considered statistically insignificant. If a closed loop is formed among the different treatments, a inconsistency test is required to evaluate the consistency of the results through direct and indirect comparisons. $P \geq 0.05$, $I^2 \leq 50\%$ indicates no statistical heterogeneity and a fixed effects model is selected. In other words, $P < 0.05$, $I^2 > 50\%$ indicates significant heterogeneity. Subgroup analysis, sensitivity analysis, and other methods are used to explore the sources of heterogeneity. When sources of heterogeneity are impossible to exclude, a random effects model is applied. Surface under the cumulative ranking curve (SUCRA) is used to rank the efficacy of the different treatments in a probabilistic manner, and to ultimately determine the optimal treatment plan. Stata16.0 software is used concurrently to draw the publication bias funnel (comparison correction chart).

Results

Literature search

Primary search found 19783 relevant literatures, including PubMed (n = 872), Embase (n = 725), Web of Science (n = 1144), Cochrane Library (n = 1640), CNKI (n = 2508), WanFang Data (n = 6322), VIP (n = 17), and CBM ui(n = 6555). 74 literatures fulfilled the inclusion and exclusion criteria, they are all Chinese documents. These papers are published from 2016 to 2023. A flow diagram of the literature selection process can be seen in Fig. 1.

Study characteristics

A total of 74 studies were included, of which 65 were RCT^[10-74] and 9 studies did not report whether randomization were used^[75-83]. A total of 13 different teaching methods were involved: LBL, PBL, PBL + scenario-based teaching(PBL + SBT), PBL + CBL, CBL, PBL + multi-disciplinary team (PBL + MDT), CBL + clinical pathway(CBL + CP), CBL + FC, PBL + evidence-based medicine(PBL + EBM), PBL + CP, PBL + Wechat, CBL + WeChat and TBL. During data processing subgroup mergers were done using the three-arm experiment, and the data were analysed according to the two-arm experiment. See Supplementary Material S1 for the study characteristic included in the study. The outcomes of the comparison network plots between different teaching method are shown in Fig. 2.

Literature quality evaluation

The literature quality of the 65 RCT studies were evaluated. In terms of random allocation methods, 2 articles were randomly grouped by student number and enrollment order, and were rated as high-risk^[49, 52]. 19 articles were randomly assigned using the random number table method or computer random allocation sequence, and were rated as low-risk^[16-17, 19-20, 22, 27, 29, 32, 48, 51, 53, 56, 59, 62, 67-69, 73-74]. 44 articles only mention randomness, but did not specify the random allocation scheme, and were rated as unclear risk^[10-15, 18, 21, 23-26, 28, 30-31, 33-47, 49-50, 52, 54-55, 57-58, 60, 62-66, 70-72]. For allocation concealment and blinding, 65 studies did not provide detailed reports on hidden and blind allocation schemes and were rated as unclear risks. All 65 research data are complete, and are rated as low risk. The judgment criteria for selective reporting of research results were to cross-examine whether the literature methodology was consistent with the results. For selective reporting, all 65 studies were low-risk. Other sources of bias are unclear. RevMan 5.3 software was used to illustrate the results as shown in Fig. 3. Newcastle-Ottawa-Scale(NOS) was used to evaluate the cohort study, which includes three aspects: selection, comparability and outcome. The results are as shown in Table 2.

Table 2
The Newcastle-Ottawa quality assessment scale to evaluate risk of bias in three domains for cohort study.

Studies	Selection	Comparability	Outcome	Total Score
Li2020	4	1	1	6
Ma2022	4	2	1	7
Chen2021	4	1	2	7
Li2020	3	1	2	6
Meng2020	3	1	2	6
Sun2022	4	1	1	6
Xu2017	3	1	1	5
Cheng2019	4	1	1	6
Chen2023	4	1	1	6

Meta-Analysis

Theoretical test score

In the evaluation of the theoretical test score, 72 studies were included with a total of 4874 standardized training trainees from DIM. When compared to LBL method, PBL + CBL method (SMD = 1.61, 95% CI [1.12, 2.1]), PBL + CP method (SMD = 2.07, 95% CI [0.81, 3.34]), CBL + Wechat method (SMD = 1.74, 95% CI [0.5, 2.99]), PBL + Wechat method (SMD = 2.3, 95% CI [1.19, 3.42]), TBL method (SMD = 1.57, 95% CI [0.28, 2.85]), PBL method (SMD = 1.35, 95% CI [0.78, 1.92]), PBL + EBM method (SMD = 1.28, 95% CI [0.3, 2.25]) and CBL method (SMD = 0.98, 95% CI [0.21, 1.75]) have significant advantages, and the difference is statistically significant ($P < 0.05$). Other statistically significant pairwise comparisons can be found in Supplementary Material S2.

Compared with other teaching methods, PBL + Wechat had the greatest possibility of improving theoretical test score (88%), followed by PBL + CP (80.3%), CBL + Wechat (67.9%) and PBL + CBL (66.1%). Among single teaching methods, TBL (61.7%) and PBL (51.4%) are reflects statistical advantage. Other combination therapies did not show obvious advantages in theoretical test score, as shown in Table 2 and Fig. 4A.

Practical test score

In the evaluation of the practical test score, 55 studies were included with a total of 3485 standardized training trainees from DIM. When compared to LBL method, TBL method (SMD 2.32 95%CI [0.74 3.9]), CBL+CP method (SMD 1.97 95%CI [0.88 3.06]), PBL+Wechat method (SMD 2.15 95%CI [0.02 4.29]), PBL+CBL method (SMD 1.74 95%CI [1.14 2.34]), PBL+CBL method (SMD 1.74 95%CI [1.14 2.34]), PBL+MDT method (SMD 1.66 95%CI [0.16 3.15]), PBL method (SMD 1.43 95%CI [0.88 1.97]), PBL+EBM method (SMD 1.39 95%CI [0.43 2.35]) and CBL method (SMD 1.25 95%CI [0.44 2.05]) have significant advantages, and the difference is statistically significant ($P < 0.05$). Other statistically significant pairwise comparisons can be found in Supplementary Material S3. Compared with other teaching methods, TBL had the greatest possibility of improving practical test score (80.1%), followed by CBL+CP 71.3% PBL+Wechat 71.2% PBL+CBL 64.4% CBL+Wechat 63.6% and PBL+MDT 57.9% . Among single teaching methods, PBL (49.2%) also reflects higher advantage statistically. Other combination therapies did not show obvious advantage in practical test score, as shown in Table 2 and Figure 4B.

Medical record test score

In the evaluation of the practical test score, 27 studies were included with a total of 1746 standardized training trainees for internal medicine residents. The NMA showed that in terms of medical record test score, among the 11 types of teaching methods. When compared to LBL method, we found that PBL + CP method (SMD=4.84, 95%CI [3.08, 6.59]), PBL method (SMD 2.45, 95%CI [1.66, 3.23]), CBL method (SMD 1.91, 95%CI [1.15, 2.67]), CBL + Wechat method (SMD 1.77, 95%CI [0.58,

2.95]), PBL + CBL method (SMD 1.74, 95%CI [0.99, 2.49]) and PBL + MDT method (SMD 1.22, 95%CI [0.05, 2.4]) have significant advantages, and the difference is statistically significant ($P < 0.05$). Other statistically significant pairwise comparisons can be found in Supplementary Material S4. Compared with other teaching methods, PBL + CP (99.9%) had the greatest possibility of improving medical record test score. The single teaching method has been effective in improving the performance of medical record analysis, with the results of PBL (83.4%) and CBL (67.2%). Other combination therapies did not show obvious advantages in medical record test score, as shown in Table 3 and Fig. 4C.

Score of autonomous learning ability

In the evaluation of the score of autonomous learning ability, 9 studies were included with a total of 615 standardized training trainees for internal medicine residents. The NMA showed that in terms of score of autonomous learning ability, among the 5 types of teaching methods. When compared to LBL method, we found that PBL method (SMD=1.98, 95%CI [0.05, 3.91]) and PBL + CBL method (SMD = 1.87, 95%CI [0.49, 3.24]) have significant advantages, and the difference is statistically significant ($P < 0.05$). The results of pairwise comparison can be found in Supplementary Material S5. Compared with other teaching methods, the PBL teaching method has the highest likelihood of improving students' self-learning ability (75.8%), followed by PBL + CBL (74.2%), PBL + MDT (45.2%), and CBL + FC (40.5%). Other combination therapies did not show obvious advantages in medical record test score, as shown in Table 3 and Fig. 4D.

Number of dissatisfied people

At the end of the experiment, the number of dissatisfied people with the various teaching methods mentioned in the article were calculated. 42 studies were included with a total of 2921 standardized training trainees from DIM. When compared to LBL method, we found that PBL + Wechat (OR = 0.06, 95% CI [0.01, 0.27]), TBL (OR = 0.11, 95% CI [0.02, 0.52]), CBL + Wechat (OR = 0.13, 95% CI [0.06, 0.3]), CBL + FC (OR = 0.13, 95% CI [0.02085]), PBL + MDT (OR = 0.18, 95% CI [0.06, 0.5]), PBL + CBL (OR = 0.19, 95% CI [0.12, 0.3]), CBL (OR = 0.19, 95% CI [0.08, 0.44]), PBL + EBM (OR = 0.2, 95% CI [0.06, 0.65]), PBL (OR = 0.24, 95% CI [0.12, 0.47]) and PBL + CP (OR = 0.25, 95% CI [0.11, 0.59]) have significant advantages. It means that the number of students who are unsatisfied with the new teaching method is much less than that of the traditional LBL teaching method, and the difference is statistically significant ($P < 0.05$). The results of pairwise comparison can be found in Supplementary Material S6. Compared with other teaching methods, PBL + Wechat is more likely to satisfy students (89%), while students have the most aversion to the LBL teaching method (0.7%), as shown in Table 2 and Fig. 4E.

Table 3
The SUCRA values of each intervention.

Intervention	Theoretical test scores	Rank	Practical test scores	Rank	Medical record test scores	Rank	Score of autonomous learning ability	Rank	Number of dissatisfied people	Rank
LBL	2.2%	13	5.3%	13	3.6%	11	14.3%	5	0.7%	12
PBL	51.4%	6	49.2%	7	83.4%	2	75.8%	1	38%	9
PBL + SBT	44.2%	8	27.9%	11	—	—	—	—	—	—
PBL + CBL	66.1%	4	64.4%	4	60.7%	5	74.2%	2	52.1%	6
CBL	33.7%	11	42.3%	10	67.2%	3	—	—	50.1%	7
PBL + MDT	38.7%	9	57.9%	6	42.3%	7	45.2%	3	52.2%	5
CBL + CP	34.7%	10	71.3%	2	25.3%	10	—	—	26.7%	11
CBL + FC	32.2%	12	21.7%	12	26.4%	9	40.5%	4	64.3%	4
PBL + EBM	48.9%	7	48.8%	8	31.7%	8	—	—	48%	8
PBL + CP	80.3%	2	46.4%	9	99.9%	1	—	—	37.2%	10
PBL + Wechat	88%	1	71.2%	3	—	—	—	—	89%	1
CBL + Wechat	67.9%	3	63.6%	5	63.6%	4	—	—	69.3%	3
TBL	61.7%	5	80.1%	1	48.8%	6	—	—	72.5%	2

Notes: LBL:Lecture-based Learning; PBL:Problem-based Learning; SBT:Scenario-based Teaching; CBL:Case-based Learning; MDT:Multi-Disciplinary Team; CP:Clinical Pathway; FC:Flipped Classroom; EBM:Evidence-based Medicine;

TBL:Team-based Learning.

Small sample evaluation

The correction comparison funnel plot of theoretical scores, practical scores, medical record analysis scores, and number of dissatisfied individuals shows that all research points are roughly symmetrically distributed on both sides of the midline, indicating a low possibility of publication bias in this study. Some patterns of symmetry on the funnel charts for the score of autonomous learning ability are observed. This suggests that there is a certain level of bias or small sample events occurring. The results are shown in Fig. 5.

Cluster analysis

Cluster analysis is used simultaneously to determine the most promising teaching method among different teaching methods in terms of theoretical scores, practical skills scores, medical record analysis scores, autonomous learning scores, and the number of dissatisfied individuals. As shown in Fig. 6A, the results of cluster analysis suggest that compared with other teaching methods, PBL + Wechat, TBL and CBL + Wechat are beneficial in improving students' theoretical performance and reducing the number of dissatisfied individuals. In contrast, the CBL + CP and LBL method did not see satisfactory advantage in improving students' theoretical performance and reducing the number of dissatisfied individuals. As shown in Fig. 6B, the PBL + Wechat, TBL, and CBL + Wechat method have good benefits in improving students' practical performance and reducing the number of dissatisfied individuals, while the effects of PBL + CP, PBL, and LBL methods are not satisfactory. As shown in Fig. 6C, CBL + Wechat, PBL + CBL, and CBL methods may bring better results in improving students' theoretical performance and reducing the number of dissatisfied individuals. As shown in Fig. 6D, PBL + CBL method is the most effective teaching

method for improving students' self-learning ability and reducing the number of dissatisfied individuals, while the LBL method remains unsatisfactory.

Discussion

Summary of Main Results

To the best of our knowledge, this NMA is the first comprehensive data analysis assessing the effects of 13 teaching methods that were widely used in standardized training of internal medicine residents in China and collecting all available evidence from 74 researches involving 5004 participants. Besides we have confirmed that these new teaching methods have certain advantages compared to the conventional LBL teaching method. This study found that the PBL + Wechat may be the best choice for improving students' academic performance, practical performance and reducing the number of dissatisfied individuals. The CBL + Wechat has the most advantages in improving students' theoretical performance and reducing the number of dissatisfied individuals. The PBL + CBL may better improve students' self-learning ability and reduce the number of dissatisfied individuals.

Interpreting research results

Internal medicine is an important discipline in clinical medicine, with strong applicability, multiple knowledge points, and multiple interdisciplinary aspects. It is also a department that every resident physician must rotate in standardized training. The quality of Internal Medicine teaching is directly related to whether the trainees can master the corresponding clinical skills well and become qualified clinical physicians. In China, resident physicians not only need to undertake clinical work from their corresponding departments, but also learn clinical knowledge from various departments in rotation. The traditional teaching method starts with the teacher gaining experience through their years of conducting ward rounds and treating patients, before imparting their knowledge to the students through lectures in which the students passively absorb what is taught by the teacher. This mode of teaching makes students lack the ability to think independently, unwilling to explore on their own, and unskilled in consolidating their clinical work experience^[84]. Therefore, the standardized training and education of resident physicians in China urgently need to change the teaching mode and awaken students' awareness of self-directed learning.

Our study found that compared to a single teaching method, the combination of multiple methods, such as PBL + Wechat and CBL + Wechat, can achieve better results. We speculate that this may be related to the combined use of multiple methods to achieve the effect of learning from each other's strengths and weaknesses. For example, the PBL method was first developed by the School of Medicine at McMaster University in Canada. It is a new teaching model that is problem-oriented and emphasizes students' active participation. Unlike traditional teaching methods that only focused on relaying information from the teacher, the PBL method places more emphasis on students' awareness and ability to learn independently^[86]. Previous studies have confirmed that PBL method can effectively improve the academic performance of medical students compared to LBL method^[87]. A previous meta-analysis of standardized training students for Chinese resident physicians showed that the PBL teaching method has a positive impact on students' theoretical knowledge, clinical diagnostic thinking, teamwork ability, problem-solving ability, learning interest, and learning efficiency^[88]. In the process of clinical teaching, the PBL teaching method requires students to independently think about the problems raised by teachers, understand the problems themselves through group discussions or literature review, and teachers play a guiding and supportive role through mutual communication. This teaching method stimulates students' enthusiasm for autonomous learning, allowing them to actively seek answers instead of passively accepting the content taught by the teacher. Due to the traditional teaching method that Chinese students have adopted since young, they need to change their mindset by shifting from passive learning to actively learning to be independent but also being able to communicate and work well in a group. This is indeed a significant challenge for Chinese resident physician standardized training students who face heavy learning tasks and corresponding graduation pressure. The CBL is also a long-standing teaching method, first proposed by Professor James Lorrain Smith of the University of Edinburgh in 1912^[89]. Its core lies in the use of clinical cases for medical teaching. In the process of standardized training for resident physicians, students' clinical practice is extremely important. Students need to frequently go to the bedside to check patients

and inquire about their condition, and learn how to develop this CBL teaching method. The biggest difference between CBL teaching method and traditional LBL teaching method is that it provides students with a real clinical environment, allowing them to position themselves as clinical doctors^[3]. Based on real clinical cases learned, students provide treatment plans after consulting relevant literature, thereby strengthening their understanding and understanding of the disease. Previous researches have showed that the CBL method is highly targeted which can better stimulate students' learning enthusiasm, and can better integrate theory and practice^[90-91]. The teaching quality of the CBL method depends on the selected cases, thus placing higher demands on teachers' lesson preparation. However, in the standardized training for resident physicians in China, the teaching teachers are generally doctors who rotate departments and undertake heavy clinical work, thus posing difficulties for teachers^[92].

We also found that with the progress of information technology in China, some new network technologies have been applied to teaching, such as Wechat, the most commonly used social software in China^[93]. The standardized training of Chinese resident physicians is mainly aimed at young people with strong acceptance of new things, and Wechat, as the most important social software for Chinese students, is to some extent a bridge for communication between teachers and students. Using Wechat as the mode of communication, teachers can stay informed of students' learning status in real-time, and teaching activities can be more diverse. Teaching content such as animations and videos can be shared with students at any time, further mobilizing their initiative in learning. At the same time, it is also convenient for students to understand and master the clinical skills learned in standardized training for resident physicians. In the specific teaching process, establish a Wechat group consisting of teachers and students. Teachers regularly publish learning materials in the Wechat group, and then students summarize and analyze relevant issues after reading the materials, and engage in group discussions. Students can upload pictures, videos, and PowerPoint presentations for problem analysis and discussion^[94]. Previous research has shown that WeChat has a positive impact on shaping students' clinical thinking and enhancing their professional literacy, and students have a high level of acceptance^[95].

Limitations

This research still possesses certain limitations. Although we have conducted a literature search in both Chinese and English, Chinese literature was ultimately chosen as the main search engine. However, the reason for this situation may be that we targeted Chinese resident physicians. Second, none of the studies we included have reported on the methods of blindness. At present, there are still certain problems in various randomized controlled studies targeting standardized training students for resident physicians. In terms of blind methods, such studies do not affect patients, but rather medical students. Moreover, the training mode of new teaching methods is completely different from traditional teaching methods, and students communicate with each other, resulting in certain difficulties in achieving complete blindness of subjects. As far as evaluators are concerned, they are usually teachers who rotate departments among students, and each teacher is responsible for teaching and evaluating students' grades. Therefore, it is also difficult to completely blind evaluators. Some methods of setting randomness also have certain problems, which may lead to a certain degree of bias in the research results and reduce the reliability of the conclusions.

In future, more large-scale and well-designed RCT studies should be conducted to increase the frequency in the reporting of accurate results. The learning outcomes of standardized training for internal medicine residents should not only include examination-based scores but also be evaluated from multiple perspectives. Future research should involve more indicators to comprehensively assess the learning outcomes and psychological impact on students, and to also scientifically evaluate the effectiveness of new teaching methods.

Conclusion

This NMA indicates that the use of PBL teaching method alone or in combination is more beneficial for the cultivation of standardized training students for Chinese internal medicine residents, regardless of their theoretical performance or clinical thinking. Interestingly, we found that integrating social software into medical education was a very surprising decision. Wechat, a widely used social app in China, has built a bridge for communication and discussion between students and teachers. The combination of CBL and Wechat is to provide students with a systematic understanding of the international standard treatment

for a certain disease. In summary, the standardized training and teaching of residents within the internal medicine cohort still has room for refinement and there is a necessity to actively alter the teaching techniques, so as to enhance students' mastery, in both clinical knowledge and skills. In conclusion, a large-scale high-quality RCT research remains optimal to evaluate the effectiveness of new teaching methods.

Declarations

Data Sharing Statement

All data generated or analysed during this study are included in this published article and its supplementary information files.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The author reports no conflicts of interest in this work.

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Figures

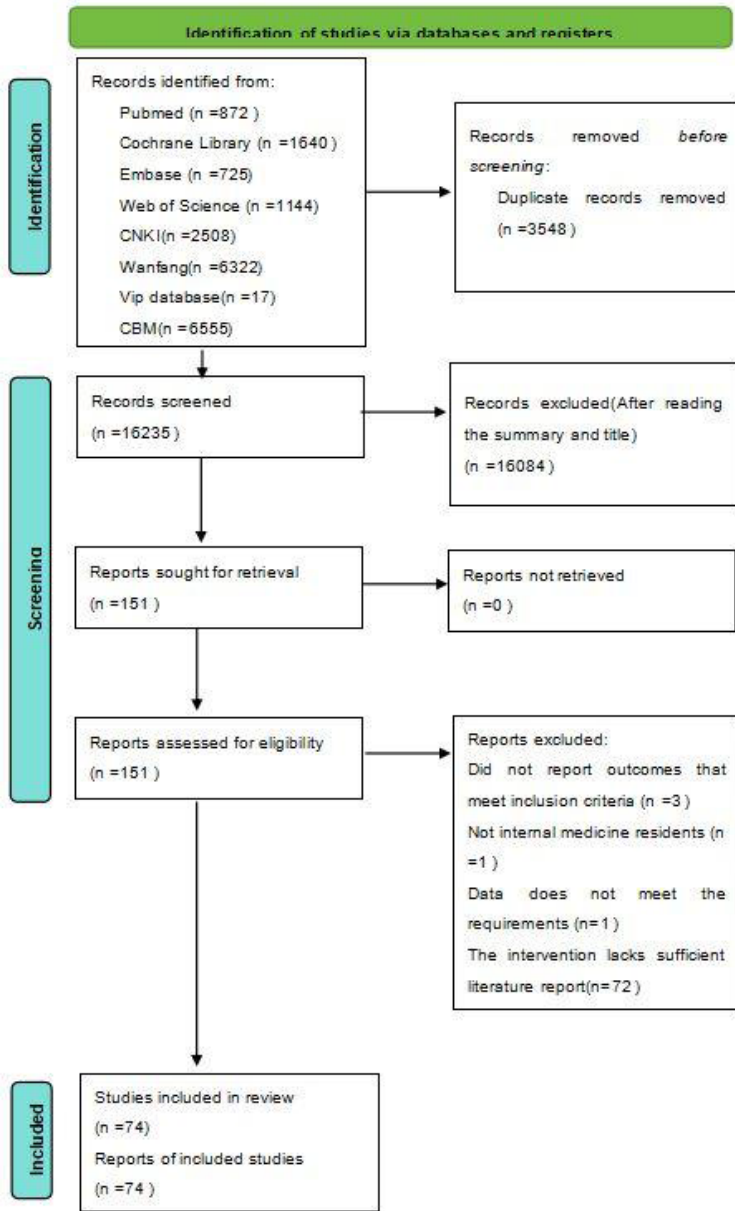


Figure 1

Document screening process and results

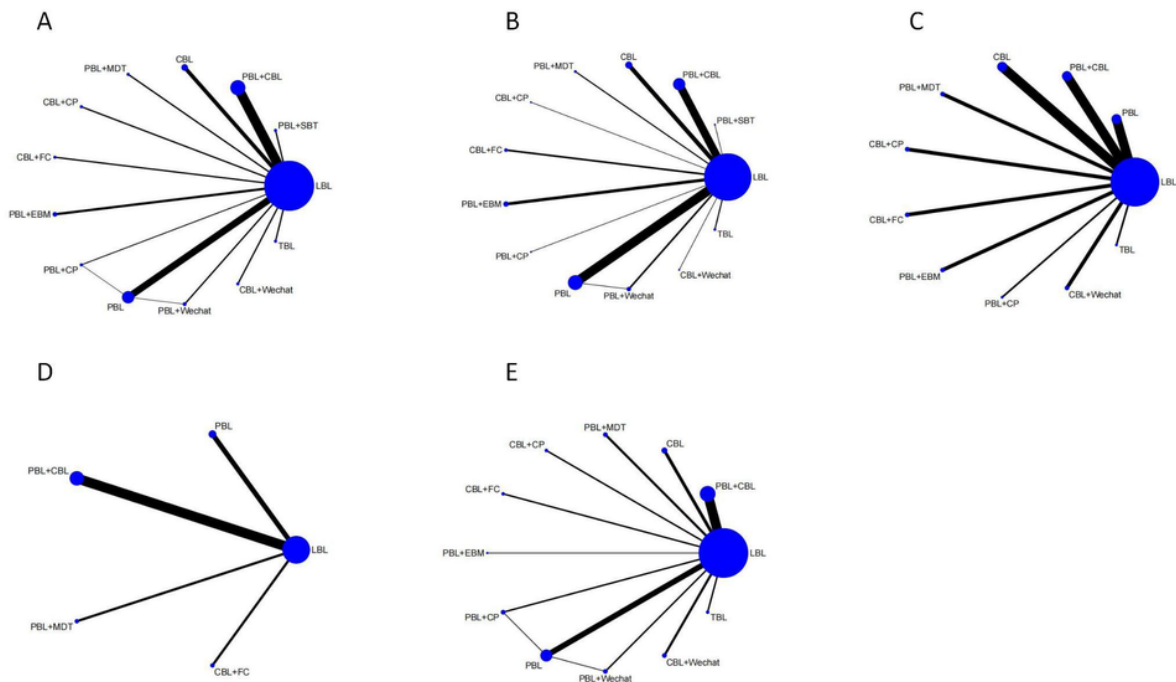


Figure 2

The evidence network of all papers about different treatments. (A) Theoretical test scores; (B) Practical test scores; (C) Medical record test scores; (D) Score of autonomous learning ability; (E) Number of dissatisfied people. The thickness of the line segment represented the number of studies, and node sizes indicated the total sample sizes for treatments.

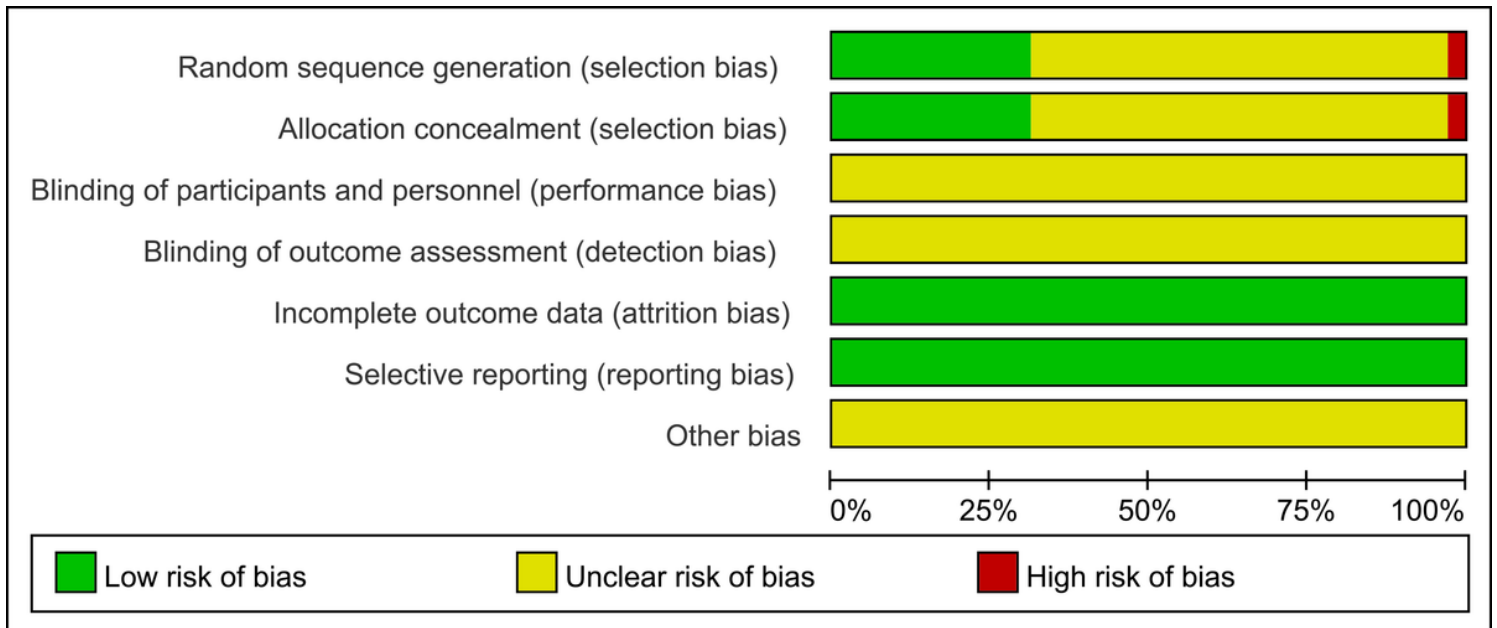


Figure 3

Risk of bias assessment included in the study.

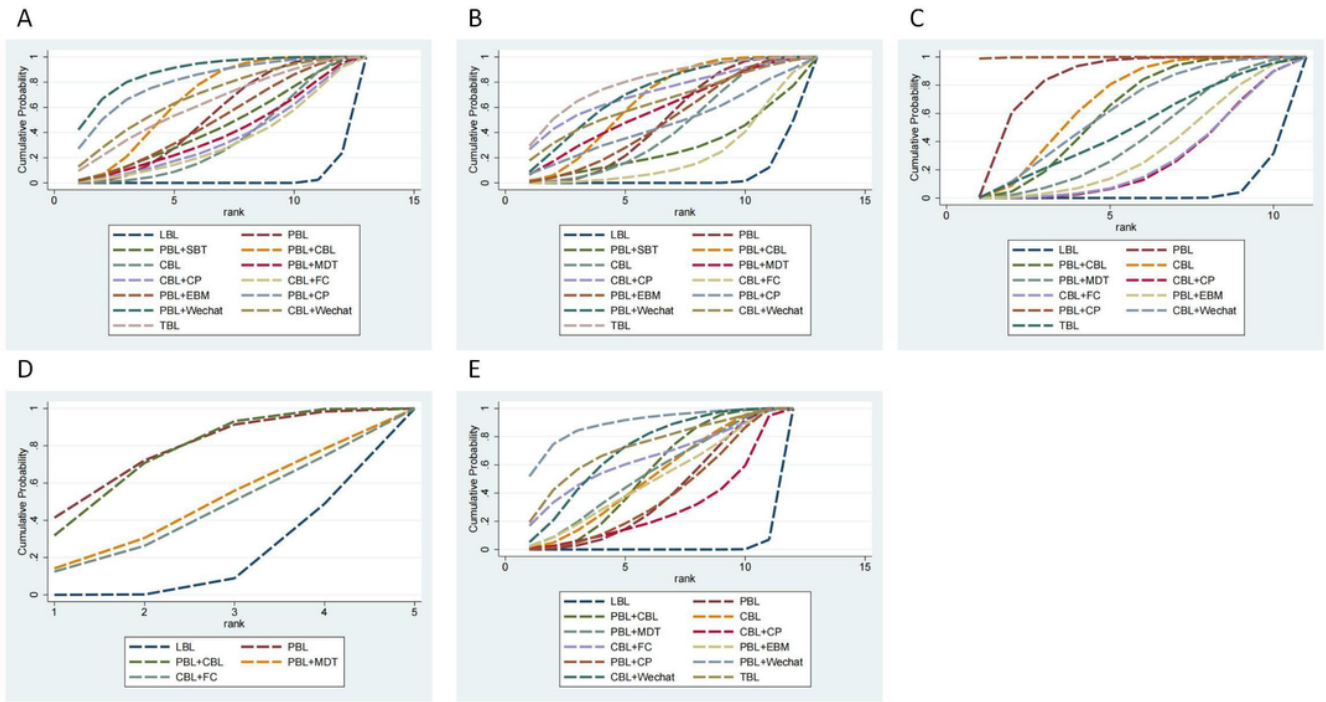


Figure 4

Rank of the cumulative probabilities for basic parameters. (A) Theoretical test score; (B) Practical test score; (C) Medical record test score; (D) Score of autonomous learning ability; (E) Number of dissatisfied people

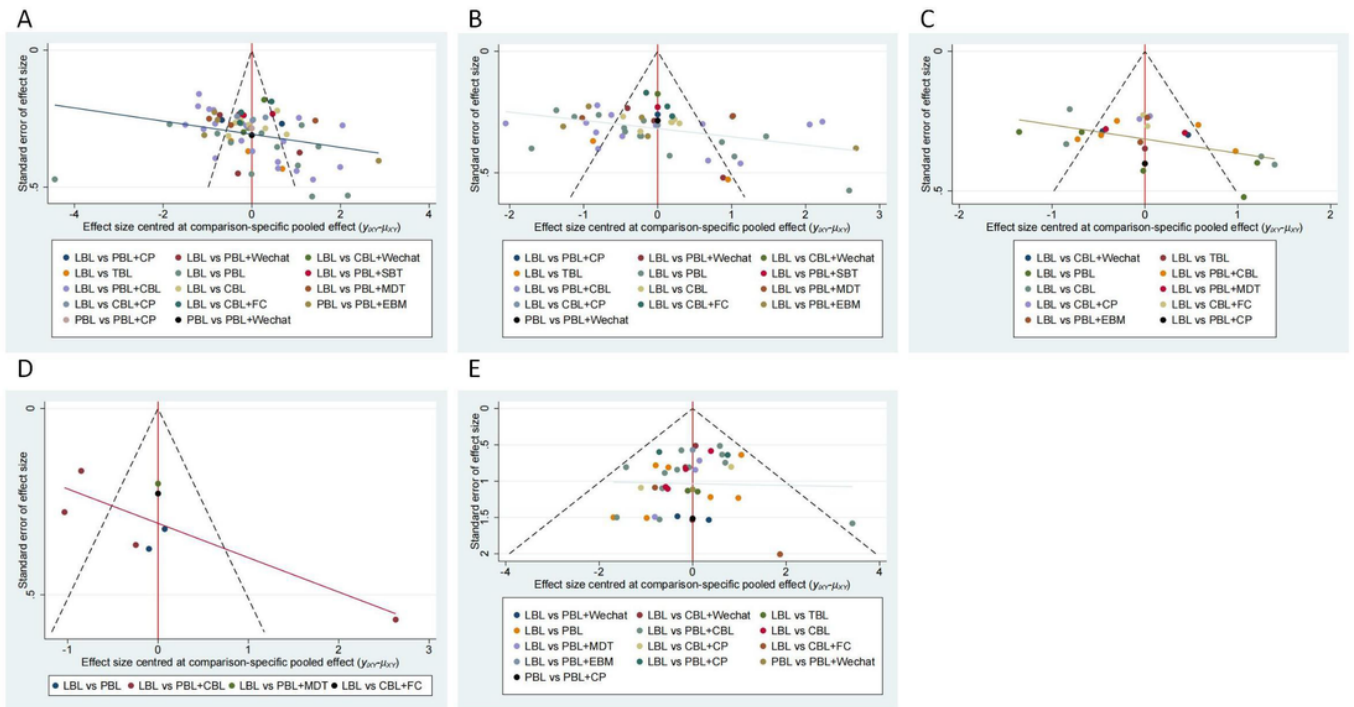


Figure 5

Funnel plot. (A) Theoretical test score; (B) Practical test score; (C) Medical record test score; (D) Score of autonomous learning ability; (E) Number of dissatisfied people

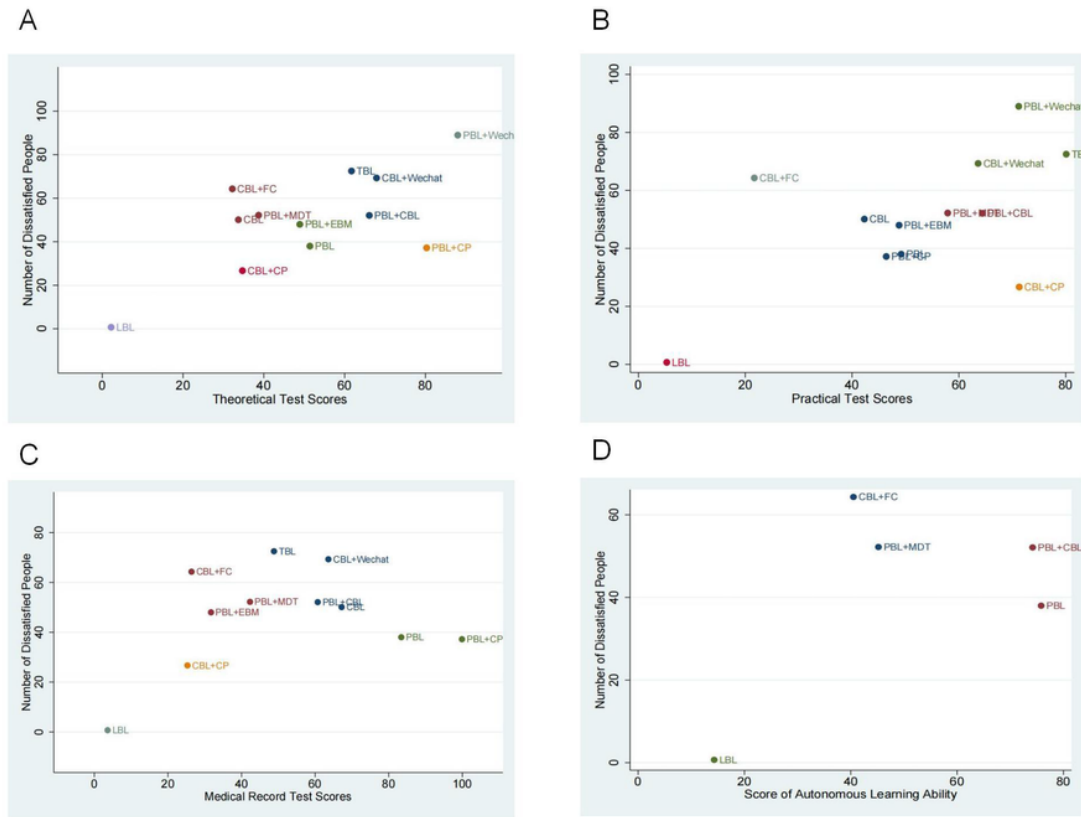


Figure 6

Cluster analysis plot of efficacy and degree of satisfaction. (A) Theoretical test score; (B) Practical test score; (C) Medical record test score; (D) Score of autonomous learning ability

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