Received: 19 February 2024 | Revised: 25 March 2024 | Accepted: 7 April 2024

DOI: 10.1111/jep.14001

REVIEW ARTICLE

Journal of Evaluation in Clinical Practice
International Journal of Public Health Policy and Health Services Research
WILEY

The effectiveness of evidence-based healthcare educational interventions on healthcare professionals' knowledge, skills, attitudes, professional practice and healthcare outcomes: Systematic review and meta-analysis

James Hill[1] | Nikki Gratton[2] | Amit Kulkarni[1,2] | Oliver Hamer[1] | Joanna Harrison[1] | Catherine Harris[1] | Jen Chesters[3] | Elaine Duddy[4] | Lindsey Collins[5] | Andrew Clegg[1]

[1]University of Central Lancashire, Preston, UK

[2]Royal College of Speech & Language Therapists, London, UK

[3]North Bristol NHS Trust, Bristol, UK

[4]University of Huddersfield, Huddersfield, UK

[5]University of Bradford, Bradford, UK

Correspondence
James Hill, University of Central Lancashire, Preston, Lancashire PR1 2HE, UK.
Email: Jehill1@uclan.ac.uk

Funding information
Royal College of Speech & Language Therapists; Institute for Health and Care Research Applied Research Collaboration North West Coast

Abstract

Objective: The primary aim of this systematic review is to assess the effectiveness of evidence-based healthcare (EBHC) educational interventions on healthcare professionals' knowledge, skills, attitudes, behaviour of EBHC, clinical process and care outcomes. A secondary aim of the review is to assess the effects of important pedagogical moderating factors for EBHC educational interventions.

Method: This systematic review used a forward and backward citation search strategy on the Web of Science platform (date of inception to 28 April 2023). Only randomised controlled trials (RCTs) and cluster RCTs which compared EBHC educational interventions for healthcare professionals were included. A random effects meta-analysis was undertaken for EBHC compared with an active and nonactive control for all outcomes.

Results: Sixty-one RCTs were identified which included a total of 5208 healthcare professionals. There was a large effect for EBHC educational interventions compared with waiting list/no treatment/sham control on knowledge (SMD, 2.69; 95% CI, 1.26–4.14, GRADE Low), skills (SMD, 0.88; 95% CI, 0.25–1.73, Very Low Certainty), attitude (SMD, 0.81; 95% CI, 0.16–1.47, Very Low Certainty) and behaviour of EBHC (SMD, 0.82; 95% CI, 0.25–1.40, Very Low Certainty). Over time the effect of EBHC educational interventions substantially decreased with no evidence of effect at 6 months for any outcome except behaviour (SMD,1.72; 95% CI, 0.74–2.71, Low Certainty). There was some evidence that blended learning, active learning and consistency in the individual delivering the intervention may be important positive moderating factors.

Registration: Protocol registered on PROSPERO CRD42022338152.

Conclusion: These findings suggest that EBHC educational interventions may have a large short-term effect on improving healthcare professionals' knowledge, skills, attitude and behaviour of EBHC. These effects may be longer-lasting regarding EBHC behaviour. In terms of pedagogy, blended learning, active learning, and consistency of the individual delivering the intervention may be important positive moderating factors.

KEYWORDS

evidence-based, evidence-based healthcare, healthcare professionals, meta-analysis, systematic review

1 | INTRODUCTION

The importance of evidence-based healthcare (EBHC) has continued to grow.[1] Central to efforts to improve the quality of care, EBHC is considered key to effective decision-making within healthcare systems that are under constant and increasing pressure.[2,3] In light of an ageing population grappling with persistent chronic conditions, the advent of expensive healthcare technologies, heightened expectations from both the public and professionals regarding service quality, and the constraints of limited funding, there exists a pressing need for healthcare professionals to possess expertise in EBHC.[3-6] While approaches to, and interpretations of, EBHC have evolved, two central components remain constant.[7] First, a multipillar model encompassing evidence from different sources, specifically external, scientific evidence, clinical expertise, and patient/service-user preferences. Second, a focus on the EBHC process, which typically involves five steps,[1,7,8] including finding knowledge gaps and formulating focused research questions, identifying the evidence, appraising the best available evidence, applying the evidence (evidence informed decision making), and evaluating practice (establishing effectiveness based on outcomes and processes).[9,10] Underpinning successful implementation of EBHC is the necessity for effective teaching strategies,[11,12] whether through face-to-face (e.g., lectures), online (e.g., remote seminars), blended learning (e.g., online educational and physical place-based sessions)[10,12,13] or self-directed learning (e.g., journal club, e-learning).[12,14]

Given concerns that the implementation of EBHC as part of patient care occurs irregularly, attention has focused on the most effective approach to educating health professionals in EBHC.[15] Although a recent umbrella review on educational interventions for EBHC identified multiple systematic reviews,[12] most had substantial methodological issues and were either out of date or selective in focus. Of the only four systematic reviews considered of high or moderate quality on the Measurement Tool to Assess Systematic Reviews (AMSTAR 2), four are over 10 years old[16-19] and the fifth only focused on the effectiveness of online delivery of EBHC.[14] Of the remaining six more recent systematic reviews, all six were classified to have critical methodological concerns.[19-24] Given the apparent inadequacies in previous systematic reviews on the most effective approach to educating health professionals in EBHC, we undertook a comprehensive and up-to-date SR.

2 | AIMS

The primary aim of this review is to assess the effectiveness of educational interventions compared with nonactive interventions (e.g., no education/placebo/sham intervention) on healthcare professionals' knowledge, skills, attitudes, and behaviour concerning EBHC, as well as on clinical processes and care outcomes. A secondary aim of the review is to assess important pedagogical moderating factors that may influence effectiveness of the intervention.

3 | METHODS

Our systematic review is reported in accordance with the PRISMA reporting standards[25] and was registered in PROSPERO before commencement (Registration number: CRD42022338152).

3.1 | Search strategy and study selection

This systematic review used a search strategy based upon citation analysis techniques, following the methods used in another review in this area.[26] The first stage of study selection involved rescreening 46 randomised controlled trials (RCTs) identified in a previous umbrella review on educational interventions for EBHC.[12]

All RCTs which met the inclusion criteria were then used as 'seed' studies for forward and backward citation retrieval on the Web of Science platform from date of inception to 28 April 2023 (All databases: SCI-EXPANDED; SSCI; AHCI; SPCI-S; CPCI-SSH; ESCI; BIOSIS Previews; KCI-Korean Journal Database; MEDLINE; Preprint Citation Index; SciELO Citation Index) (see Supporting Information File S1: Appendix 22 for search strategy details).

3.2 | Inclusion criteria

Only RCTs and cluster RCTs which compared educational interventions for EBHC to any active and nonactive comparator where included. RCTs were selected due to the methodological strength of this approach and the awareness of a large existing body of evidence

which utilised this study design.[12] The target population for the educational interventions for EBHC needed to be healthcare professionals (i.e., nurses, doctors, allied health workers, general practitioners, other primary care workers, pharmacists, midwives, health visitors, mental health workers, psychological professionals, psychiatrists, surgeons, paramedics, and students of any of these professions). Educational interventions for EBHC were defined as any mode of teaching which is aimed to improve any component of EBHC (i.e., defining a question, searching, and retrieving evidence, selection and screening, critical appraisal, synthesis, application, and dissemination of evidence). Despite the review having a specific focus on the outcomes concerning knowledge, skills, attitudes, and behaviour concerning EBHC, as well as clinical processes and care outcomes, no inclusion criteria were set based upon the outcomes reported.

3.3 | Study selection

Initial screening for developing the citation-based search strategy involved a single reviewer assessing manuscripts identified in the previous umbrella review, with decisions checked by a second reviewer (J. E. H., N. G., J. C., L. C.). Abstract and title of papers identified through forward and backward citation searching were then screened by a single reviewer and verified by a second reviewer using Rayyan (J. E. H., N. G., J. C., L. C., E. D.).[27] Full paper screening was undertaken by a single reviewer and verified by a second (J. E. H., N. G., J. C., L. C., E. D.). Disagreements were resolved by discussion or use of a third reviewer if consensus was not able to be achieved (J. E. H., N. G., J. C., L. C., E. D.).

3.4 | Data extraction (selection and coding)

Data extraction for each included RCT was carried out by a single reviewer using a prepiloted form (J. E. H., J. H., A. K., O. H.) (see Supporting Information File S1: Appendix 21 for blank data extraction form). The data items extracted were country; type of healthcare professionals; clinical setting; number of participants; pedagogical approach; educational contents; frequency; duration; total time of intervention in minutes; mode of delivery; control group description; outcomes; time of outcome collection; mean measurement of effect and a measure of variability (e.g., standard deviation). Where multiple tools were used to report a single outcome, the data extracted was either the primary outcome identified in the study or by the first outcome of that type reported within the article.

3.5 | Risk of bias (quality) assessment and rating the certainty of evidence

Study level risk of bias was assessed by a single reviewer using the Cochrane Collaboration risk of bias tool (RoB-1) (J. E. H., J. H., A. K., O. H.).[28] An additional criterion, use of validated tool for outcome assessment, was also assessed. Study level risk of bias was classified into three levels of Low risk of bias (The trial is judged to be at low risk of bias for all domains for this result), Some concerns (The trial is judged to raise some concerns in at least one domain for this result, but not to be at high risk of bias for any domain), High risk of bias (The trial is judged to be at high risk of bias in at least one domain for this result).[28] All statistically significant findings or multistudy meta-analyses were assessed using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach by two reviewers (J. H., C. H.).[29]

3.6 | Strategy for data synthesis

A narrative synthesis was undertaken to describe study characteristics. When describing the intervention, the term 'workshop' was used to indicate a single session delivery and the term 'course' was used to indicate multiple sessions. The primary comparison of effect was any teaching-based programmes of EBHC compared with no education, placebo, or sham intervention. Where provided, primary comparisons were categorised into three follow-up periods of end of intervention, short-term follow-up (≤6 months) and long-term follow-up (>6 months). Secondary analyses were undertaken comparing any teaching-based programmes of EBHC against any active comparator.

Evidence on the effectiveness of EBHC educational interventions was pooled through meta-analyses, using a random effects model due to preperceived heterogeneity.[28] As a range of measures were used to assess the same underlying construct, we estimated standardised mean difference (SMD) with 95% confidence intervals (CI) (95% CI).[28] Where comparisons were limited to a single study, the effect estimate, and 95% CI were converted to SMDs and presented on forest plots to allow some comparison. If standard deviation (SD) were not reported, other measures of variability (e.g., 95% CI or standard errors) were used to calculate an SD.[30] Heterogeneity was assessed through visual inspection of forest plots and the I^2 statistic.[28] Assessment of publication bias was undertaken using the Egger's test and visual inspection of a funnel plot for any comparison where there was greater than 10 studies.[31,32] All meta-analyses were performed using comprehensive meta-analysis software.[28,33-36]

Given the concerns around missing data (e.g., SD), we conducted an analysis on all outcomes using an additional vote counting approach.[28] This enabled the presentation of all study findings when there were inadequate data available for meta-analysis, which may reduce the impact of reporting bias.[37] A positive effect was counted if a benefit in the outcome was reported in the intervention group compared with the control group at the given point of time (end of treatment, short-term follow-up, and long-term follow-up). These findings were interpreted as evidence of directional effect (Is there any evidence of an effect?) rather than a specific estimation of effect.[28] Alongside this, the number of statistically significant ($p = <0.05$) differences between the intervention and control groups at these time periods were reported. The number of statistically

significant differences were interpreted as an indication of the probability of the improvement occurring by chance within these individual studies.

3.7 | Subgroup and sensitivity analysis

A subgroup analysis was undertaken for any outcome with more than 10 studies[31] for the following potential moderating factors: type of healthcare professionals, clinical setting, pedagogical approach, educational contents, frequency, duration, total time of intervention in minutes, and mode of delivery. A sensitivity analysis was undertaken to explore the effects of the inclusion of cluster RCTs.

4 | RESULTS

Forty-six RCTs were identified from the umbrella review by Bala et al.,[12] with 41 RCTs included after full paper screening. These were then used as seed papers for forward and backwards citation searching in the Web of Knowledge database, resulting in 1830 citations (see Figure 1 for PRISMA diagram). After title, abstract and full paper screening, a further 21 papers were identified, making a total of 61 RCTs (total sample 6257 healthcare professionals) which were included in this review.[38-101] The review included 37 individual participant RCTs, 21 cluster RCTs and three crossover RCTs.

4.1 | Study characteristics

The 61 RCTs took place across 24 countries (see Table 1 for Full Study Characteristics). Most studies took place in a single country, with only six RCTs being undertaken in multiple countries. Studies were largely conducted in eight countries: the USA ($n = 15$), UK ($n = 8$), Hong Kong ($n = 4$), Australia ($n = 3$), Netherlands ($n = 3$), Canada ($n = 3$), Taiwan ($n = 3$), and Iran ($n = 3$). Other studies were conducted in Norway ($n = 2$), Philippines ($n = 1$), Mexico ($n = 1$), Finland ($n = 2$), India, ($n = 1$), Germany ($n = 1$), Japan ($n = 1$), Malaysia ($n = 1$), Israel ($n = 1$), Ethiopia ($n = 1$) and Croatia ($n = 1$). The remaining six multicountry RCTs were undertaken in Argentina, Brazil, Democratic Republic of Congo, India, Philippines, South Africa and Thailand ($n = 1$), Australia and Malaysia ($n = 1$), Mexico and Thailand ($n = 1$), UK and Netherlands ($n = 1$), USA and Canada ($n = 1$) and USA and Lebanon ($n = 1$).

Studies took place across a range of clinical settings specifically, secondary care ($n = 26$), universities ($n = 20$), primary care ($n = 4$),

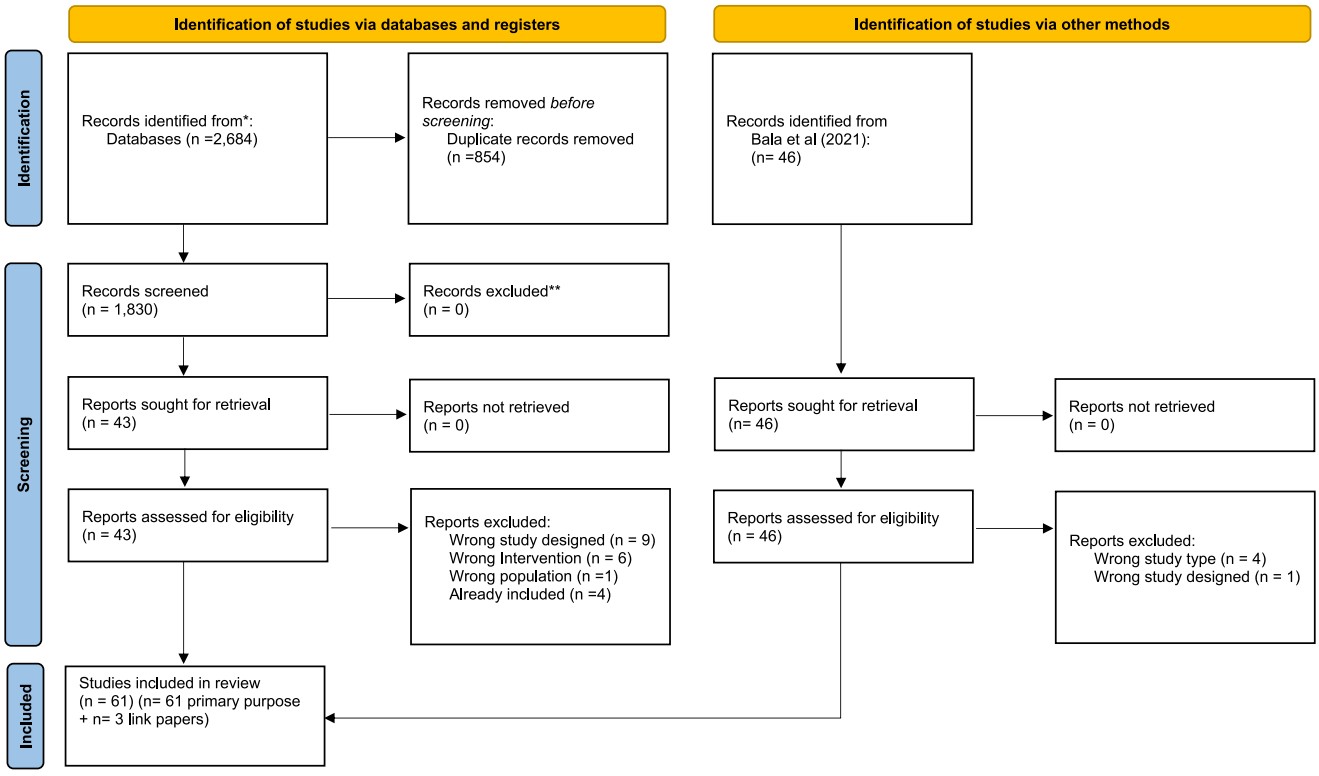

FIGURE 1 PRISMA flow diagram. *Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). **If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools. *From*: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi:10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/.

TABLE 1 Study characteristics.

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
Awedew and Abera[97]	Ethiopia	Standard RCT	Doctors	Qualified	University	52	N/R	N/R	N/R	2	Online course (synchronous)	Waiting-list control	KA
Basheer et al.[38]	India	Standard RCT	Doctors	Student	University	118	n/a	n/a	n/a	2	Face-to-face EBP workshop using the Simulated RCT to learn Critical Appraisal (SiRCA)	Face-to-face EBP Workshop (Didactic lectures with problem-based approaches and journal club discussion)	(Fresno test no separation of outcome) Self-perception of EBP Skills (unclear categories no data was able to be extracted)
Bergold et al.[39]	Germany	Standard RCT	Doctors	Qualified	Secondary care (hospital)	114	5	N/R	N/R	2	Online course (Asyn-chronous)	Waiting-list control	K, S (medium reported only)
Bradley et al.[40]	USA	Standard RCT	Doctors	Qualified	Secondary care (hospital)	10	N/R	N/R	N/R	2	Face-to-face workshop + one-to-one support (on literature searching)	Face-to-face workshop (on literature searching)	S
Bradley et al.[41]	Norway	Clustered RCT	Doctors	Student	University	175	5	3	15	2	Online course	Face-to-face EBP course	KAS
Brettle and Raynor[42]	UK	Standard RCT	Nurses	Student	University	77	1	N/R	N/R	2	Blended learning: Online Workshop (Asynchro-nous) + face to face Workshop (received by both groups)	Face-to-face EBP Workshop	S

(Continues)

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
Brouwers et al.[43]	Canada	Standard RCT	Multidisciplinary team	Qualified	Community network	87	1	N/R	N/R	3	Online EBP workshop + Practice examples	Received instructions on how to use the agreed 2-approach French or Online EBCH workshop (active control group)	S
Cabell et al.[44]	UK	Standard RCT	Doctors	Student	University	48	3	60	60	2	Face-to-face EBP workshop + practical activity and access to online databases	Face-to-face EBP workshop (sessions focused on literature searching)	B
Campbell et al.[45]	Australia	Clustered RCT	Multidisciplinary team	Qualified	Community	135	3	N/R	N/R	2	Face-to-face course + online evidence-based information resource + decision-making tools	Workshop on communica-tion skills	KAB
Chao et al.[98]	Taiwan	Standard RCT	Nurses	Qualified	Secondary care (hospital)	114	N/R	N/R	N/R	2	Online course (synchronous) + face-to-face (learner focused flipped classroom)	Face-to-face course (didactic instruction)	KAB
Cheng[46]	Hong Kong	Standard RCT	Multidisciplinary team	Qualified	Secondary care (hospital)	571	1	180	180	2	Face-to-face EBP workshop	Waiting-list control	K

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
Cheng et al.[99]	Taiwan	Standard RCT	Doctors	Student	Secondary care (hospital)	97	N/R	N/R	N/R	2	Face-to-face EBM course (evidence-based reward rounds & conference) + Online course (asyn-chronous)	Face-to-face course (didactic instruction)	KAB
Davis et al.[47]	UK	Standard RCT	Doctors	Qualified	Secondary care (hospital)	55	1	N/R	N/R	2	Online workshop (Asyn-chronous)	Face-to-face EBP workshop	KA
Davis et al.[48]	UK	Standard RCT	Doctors	Student	University	229	1	N/R	N/R	2	Online workshop (Asyn-chronous)	Face-to-face EBP workshop	KA
Dizon et al.[49,50]	Philippines	Standard RCT	Physiotherapists	Qualified	Secondary care and tertiary care	54	1	N/R	N/R	2	Face-to-face EBP workshop + online support	Waiting-list control	AB
D'Souza et al.[51]	India	Clustered RCT	Nurses	Qualified	University	51	n/a	n/a	1800	2 (with 3 clusters each)	Face-to-face course on EBP	Did not receive training on EBHC	KAB
Farokhzadian et al.[52]	Iran	Clustered RCT	Nurses	Qualified	Critical care units	60	3	480	1440	2	Face-to-face EBP training workshops	Did not receive training on EBHC	KSB
Forsetlund et al.[53]	Norway	Standard RCT	Doctors	Qualified	Primary care	148	1–5	N/R	N/R	2	Face-to-face course on EBP + additional access to online databases +	Did not receive training on EBHC	KAB

(Continues)

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
											information service		
Gulmezoglu et al.[54]	Mexico and Thailand	Clustered RCT	Multidisciplinary team	Qualified	Secondary care (hospital)	N/A	3	N/R	N/R	2	Face-to-face course on EBP	Did not receive training on EBHC	P
Hadley et al.[55]	UK	Clustered RCT	Doctors	Qualified	Secondary care (hospital)	237	N/A	N/A	N/A	2	Online course (Asyn-chronous)	Face-to-face EBP workshop	K
Hadvani et al.[56]	USA	Clustered RCT	Doctors	Student	Quartenary care children's hospital	127	60	N/R	N/R	2	Online course (Asynchro-nous): Self-paced, interactive, multimedia module on the application of EBM	Face-to-face EBP course (Didactic sessions)	KAB
Haidet et al.[57]	USA	Standard RCT	Doctors	Qualified	Secondary care (hospital)	82	1	60	60	2	Face-to-face EBP workshop (active session: Team-Learning)	Face-to-face EBP workshop (Didactic session)	K
Haynes et al.[58]	Canada	Standard RCT	Doctors	Both	Secondary care (hospital)	308	N/R	N/R	N/R	2	Face-to-face EBP workshop + Tutorial support	Face-to-face on EBP workshop (2 h only) and no feedback	ASB
Horiuchi et al.[59]	Japan	Standard RCT	Nurses and midwives	Qualified	Secondary care (hospital)	93	4	30	120	2	Online course (self-directed)	Face-to-face course on EBP	K
Hugenholtz et al.[60]	The Nether-lands	Clustered RCT	Occupational health	Qualified	Primary and	108	13	N/A	N/A	2	Face-to-face EBP workshop + case method	Did not receive	B

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
			physicians (OHPs)		secondary care						learning sessions	training on EBHC	
Ilic et al.[61,62] and Maloney et al.[63]	Australia and Malaysia	Clustered RCT	Doctors	Student	University	497	10	120	1200	2	Blended learning: Online video material + Face-to-face course on EBP	Face-to-face workshop on EBP and Received no training	KASB
Jalali-Nia et al.[64]	Iran	Standard RCT	Nurses	Student	University	41	11	N/R	N/R	2	Face-to-face course on EBP + Tutorial support	Face-to-face EBP course (lectures, questions, and answer)	EBP knowledge (28 questions) (separate scores not given just reported combined subject knowledge scores) Attitude to evidence-based and traditional education (separate scores not given)
Johnston et al.[65]	Hong Kong	Crossover RCT	Doctors	Student	University	129	4	120	480	2	Face-to-face course on EBP (using a problem based learning approach)	Face-to-face course on EBP	KAB
Kamin et al.[66]	USA	Standard RCT	Doctors	Student	University	27	N/R	N/R	N/R	2	Online course (Asyn-chronous)	Face-to-face course on EBP	K

(Continues)

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
Kim et al.[67]	USA	Standard RCT	Doctors	Student	University	50	2	360	720	2	Face-to-face EBM training workshops (2 workshops)	Journal club	SB
Kok et al.[68]	The Nether-lands	Clustered RCT	Doctors	Qualified	Community	132	5	360	1800	2	Face-to-face course	Did not receive training on EBHC	AB
Koota et al.[69]	Finland	Clustered RCT	Nurses	Qualified	University	80	N/R	N/R	N/R	2	Face-to-face EBM workshops	Self-directed learning module	KASB
Krueger[70]	USA	Standard RCT	Osteopath	Student	Secondary care (hospital)	77	1	60	360	2	Face-to-face course on EBP	Receive the usual curriculum	K
Kulier et al.[71]	UK and Nether-lands	Clustered RCT	Doctors	Qualified	Secondary care (hospital)	70	N/R	N/R	N/R	2	Blended learning: Online course (Asynchro-nous) + face-to-face tutorial support	Face-to-face EBP course (Didactic sessions)	K
Kulier et al.[72]	Argentina, Brazil, Demo-cratic Republic of Congo, India, Philip-pines, South Africa, and Thailand	Clustered RCT	Multidisciplinary team	Qualified	clinical training units	204	5	60	300	2	Blended learning: Online course (Asynchro-nous) + face-to-face tutorial support	Online course (Asyn-chronous)	KS

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
Laibhen-Parkes[73]	USA	Crossover RCT	Nurses	Qualified	Secondary care (hospital)	58	1	60	60	2	Online EBP Workshop	Two hour lecture on Munchau-sen's syndrome by proxy	KA
Lee et al.[74]	Hong Kong	Standard RCT	Doctors	Student	Secondary care (hospital)	155	5	40–60	240	2	Face-to-face course	Did not receive training on EBHC	S
Leung[75]	Hong Kong	Standard RCT	Doctors	Student	University	169	2	360	N/A	3	Face-to-face course on EBP (interactive sessions) + Info-Retriever group (face-to-face course clinical decision-making tool support)	Did not receive training Or Pocket card plus face-to-face workshop on EBP.	B
Levin et al.[76]	USA	Clustered RCT	Nurses	Student	Community	46	12	120	1440	2	Face-to-face course (didactic) + EBP Toolkit + mentoring intervention + environmental prompts	Lectures on adult physical assessment	AB
Linzer et al.[77]	USA	Standard RCT	Doctors	Qualified	Secondary care (hospital)	51	N/A	N/A	N/A	2	Face-to-face Journal club (led by a chief medical resident with invited subspecialists	Journal club run by chief medical resident with invited subspecialists	KB

(Continues)

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
Linzer[78]	USA	Standard RCT	Doctors	Qualified	Secondary care (hospital)	44	6	60	360	2	Face-to-face Journal club	Conference series on ambulatory medicine	KSB
Liou et al.[79]	Taiwan	Clustered RCT	Nurses	Student	University	209	N/R	N/R	N/R	2	Face-to-face course (enhance interactive learning)	Face-to-face EBP course (Didactic sessions)	KA
Long et al.[80]	USA, Lebanon	Standard RCT	Multidisciplinary team	Student	University	159	N/A	N/A	N/A	2	Face-to-face workshop on EBP plus Evidence-based practice tool	Did not receive training on EBHC	S
MacRae et al.[81]	Canada	Standard RCT	Doctors	Qualified	Secondary care (hospital)	86	8	N/R	N/R	2	Internet journal club group (Asynchro-nous: 8 months)	Control group received 8 clinical articles and had online access to major medical journals and were sent a monthly reminder to read the article.	S
Martinic et al.[100]	Croatia	Standard RCT	Multidisciplinary team	Student	University	589	N/R	N/R	N/R	2	Online course (asyn-chronous)	Web-based PRISMA checklist	K
McLeod et al.[82]	USA, Canada	Clustered RCT	Doctors	Qualified	Secondary care (hospital)	443	N/R	N/R	N/R	2	Online journal club group (Asyn-chronous)	Face-to-face journal club.	S

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
Moore[101]	USA	Standard RCT	Nurses	Qualified	Secondary care (hospital)	197	N/R	N/R	N/R	3	Online course (asyn-chronous)	PowerPoint learning module regarding pain management OR Receive no intervention	(Fresno test no separation of outcome) AB
Mukohara and Schwartz[83]	USA	Standard RCT	Doctors	Qualified	Primary care	136 (107 completed preinterven-tion survey)	12	N/A	N/A	2	Online learning via e-mail (journal club of research summaries)	Did not receive training on EBHC	ASB
Rostamnia et al.[84]	Iran	Crossover RCT	Nurses	Both	University	90	N/R	N/R	960	3	Face-to-face EBP course and an online course (Asyn-chronous)	Did not receive training on EBHC	S
Sanchez-Mendiola et al.[85]	Mexico	Standard RCT	Doctors	Students	University	289	14	120 min	1680	2	Face-to-face EBM course	Aviation Medicine course	KAS
Saunders et al.[86]	Finland	Standard RCT	Nurses	Qualified	Secondary care (hospital)	77	2	240	480	2	Blended learning: Face-to-Face workshop + online learning + mentoring intervention	Face-to-face workshop	K
Schaafsma et al.[87]	Nether-lands	Clustered RCT	Occupational health physicians (OHPs)	Qualified	Secondary care and Private enterprise	106	8	N/R	N/R	2	Face-to-face EBP course (stimuli for applying EBM performing a PubMed	Did not receive training on EBHC	Unclear and missing data on quality of advice on return-to-

(Continues)

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
											search and case-method learning sessions)		work interventions and S
Schilling et al.[88]	USA	Standard RCT	Doctors	Student	University	238	1	60	60	2	Online course (Asynchronous)	Did not receive training on EBHC	KSB
Shuval et al.[89]	Israel	Clustered RCT	Primary care doctors	Qualified	Primary care	101	3 workshops +6 individual visits	300 min per workshop	300–900 (workshop)	2	Face-to-face workshops and individual visits	Did not receive training on EBHC	KBP
Stark et al.[90]	USA	Standard RCT	Doctors	Student	Secondary care (hospital)	77	6	60	360	2	Face-to-face searching tutorial, answering clinical questions regarding hospitalised patients	Usual medical conference	S
Stevenson et al.[91]	UK	Clustered RCT	Physiotherapists	Qualified	Primary care	30	1	300	300	2	Face-to-face EBHC workshop	Clinical management of knee dysfunction and pathology (5 h of training)	K
Stevermer et al.[92]	USA	Standard RCT	Doctors	Student	Community-based and University	59	1	15	15	2	Face-to-face workshop	Did not receive training on EBHC	S
Taylor et al.[93]	UK	Standard RCT	Multidisciplinary team	Qualified	Primary, secondary and tertiary	145	1	180	180	2	Face-to-face EBP workshop	Did not receive	KSB

TABLE 1 (Continued)

References	Location	Type of random controlled trial	Type of healthcare professionals	Student/ Qualified	Clinical setting	Number of participants total at randomisation	Frequency of intervention	Duration of sessions minutes	Total time of intervention in minutes	Number of arms	Intervention group	Control/ control groups	Outcomes
					care (Across health authorities)							training on EBHC	
Villanueva et al.[94]	Australia	Standard RCT	Multidisciplinary team	Qualified	Tertiary care	52	Received once	N/A	N/A	2	Information sheet on improving research question	Used old request form for research request	S
Wenke et al.[95]	Australia	Clustered RCT +quali-tative	AHPs	Qualified	secondary	126	6	60	360	2	A structured journal club called "TREAT" (Tailoring Research Evidence and Theory)	Usual journal club format	KASB
Wyatt et al.[96]	UK	Clustered RCT	Obstetricians and midwives	Qualified	Secondary care (hospital)	N/A (25 units)	1	90–180	90–180	2	Face-to-face workshop (Single informal educational visit by a nationally respected obstetrician and author of Cochrane reviews to outline principles of EBHC)	Did not receive training on EBHC	B

Abbreviations: A, attitudes of evidence-based healthcare; B, behaviour of evidence-based healthcare; EBHC, evidence-based healthcare; K, knowledge of evidence-based healthcare; N/A, not applicable; N/R, not reported; S, skills of evidence-based healthcare; P, clinical practice; RCT, random controlled trial.

community (*n* = 4), tertiary care (*n* = 1), clinical training centre (*n* = 1) and unclear (*n* = 1). Four studies were conducted across two or more clinical settings these were primary, secondary, and tertiary care (*n* = 1), community and university (*n* = 1), primary and secondary care (*n* = 1) and secondary care and tertiary care (*n* = 1),

Although doctors (*n* = 31), nurses (*n* = 12) and multidisciplinary teams (*n* = 9) were the focus of most studies, other studies looked at physiotherapists (*n* = 2), occupational health physicians (*n* = 2), midwives (*n* = 2), osteopaths (*n* = 1), allied health professionals (*n* = 1), and obstetricians (*n* = 1). Of the 61 studies, 36 studies included only qualified healthcare professionals, 23 studies only included students (unqualified) and two studies included both qualified and student participants. Sample sizes ranged from 10 to 571 participants (total at randomisation).

4.2 | Pedagogical approach

The majority of studies used a face-to-face workshop (single session) (*n* = 18) or a face-to-face course (multiple session) (*n* = 16). The remaining studies used an online (*n* = 16), blended learning (*n* = 6), journal club (*n* = 4) or information sheet (*n* = 1) primary based approach.

Using the essential educational elements recommended by Khan and Coomarasamy (2006) the most common approaches of the included studies were learning using an interactive approach (*n* = 50), multifaceted strategies in teaching and learning (*n* = 44), learning incorporated into clinical practice (*n* = 43) and individual feedback with the opportunity for self-assessment (*n* = 37) (see Supporting Information File S1: Appendix 20 for full educational elements and course contents). Course contents commonly focused on accessing the literature (*n* = 45), critical appraisal (*n* = 40), critical thinking (*n* = 40), applying the results (*n* = 40) and asking questions (defining the research question) (*n* = 36).

The frequency of interventions ranged from 1 to 13 sessions and was not reported in 17 studies. The duration of each intervention session ranged from 30 to 480 min and was not reported in 32 studies. The total time of an intervention, from the information available, ranged from 15 to 1800 min.

Most studies had only two arms (*n* = 57), with 29 using a nonactive control. The nonactive control groups either did not receive any training on EBHC (*n* = 16), had sham non-EBHC educational training (*n* = 9) or were waiting-list controls (*n* = 4). There were 28 two-armed active control studies with active control groups using face-to-face EBP workshops (*n* = 10), face-to-face EBHC courses (*n* = 9), journal club-based interventions (*n* = 6), an online course (Asynchronous) (*n* = 1), web-based PRISMA checklist (*n* = 1), or a self-directed learning module (*n* = 1). Four studies had three arms comparing active and nonactive comparisons.

Knowledge (*n* = 35) (e.g,, recalling information regarding key factors for developing a research question and search strategies), skills (e.g., undertaking tasks such as search strategies and critical appraisal) and behaviour (e.g, how many literature searches were carried out and number of studies read this week) (*n* = 27), and attitudes toward (e.g., attitude toward research and evidence-based practice) (*n* = 23) EBHC were the most commonly reported outcomes. Two studies reported clinical process improvements. These process improvements were recorded by counting the number of processes which were undertaken in each group based upon recommendations from guidelines (e.g., use of statins and receiving of social support). Five studies did report outcomes on both knowledge and skills of EBHC but did not report appropriate information to be included in the review's meta-analysis or vote counting process (e.g., missing result findings, lack of separation of outcomes and lack of clarity of reporting). No studies reported patient level outcomes.

4.3 | Risk of bias

The four main areas of concern regarding risk of bias (high/unclear) were the lack of blinding of those who were delivering the intervention (*n* = 56), the lack of blinding of participants (*n* = 50), reporting bias (*n* = 44), and attrition bias (*n* = 44) (see Figure 2 for risk of bias for all included studies). Overall, all studies were judged to be at high risk of bias.

4.4 | Educational interventions for EBHC compared with waiting list/no intervention/sham control

A meta-analysis of educational interventions for EBHC compared with nonactive comparators (i.e. waiting list/no intervention/sham control) showed a large positive effect on knowledge (SMD, 2.69; 95% CI, 1.26–4.14, Low Certainty [The true effect might be markedly different from the estimated effect]) at the end of the intervention (see Table 2 for full results and Supporting Information File S1: Appendix 1 - 11 for all forest plots and corresponding studies). However, for skills (SMD, 0.88; 95% CI, 0.03–1.73, Very Low Certainty [The true effect is probably markedly different from the estimated effect]), attitude (SMD, 0.82; 95% CI, 0.16–1.47, Very Low Certainty) and behaviour of EBHC (SMD, 0.82; 95% CI, 0.25–1.40, Very Low Certainty) the effects were large but there was less certainty due to the lower estimates of the CI resulting in a small or negligible effect. The additional reasons for downgrading of the certainty of evidence within all estimates were due to substantial heterogeneity and high risk of bias (see File S2 for all GRADE tables). Unfortunately, there was a limited number of studies for all outcomes which made it inappropriate to examine the possible causes for heterogeneity.[28,102] Similarly, due to there being less than 10 studies for all comparisons a statistical assessment of publication bias and subgroup analyses were not performed. Using vote counting, most studies demonstrated a positive improvement for knowledge, skills, attitude, and behaviour of EBHC at the end of intervention (see Table 2 for full vote counting results).

Over time the effect of EBHC educational interventions decreased. With knowledge of EBHC showing a moderate positive effect (SMD,

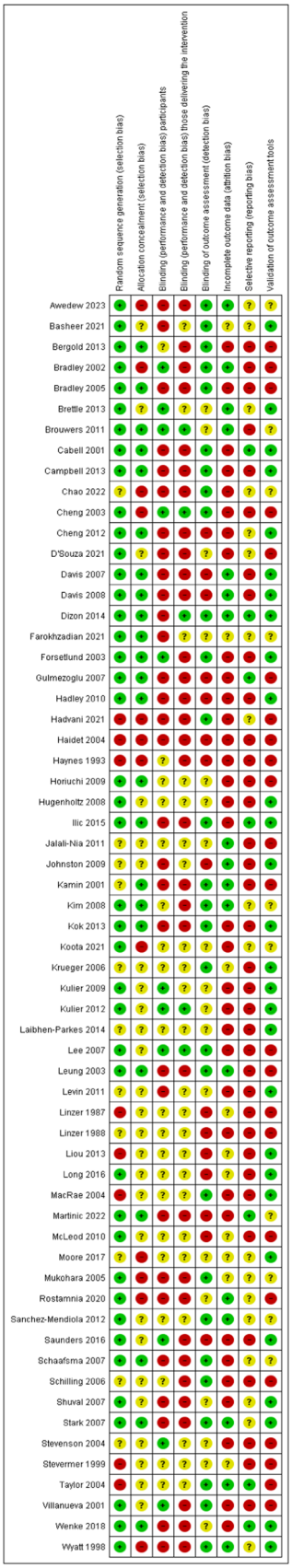

FIGURE 2 Risk of bias of all included studies.

0.40; 95% CI, 0.07–0.73, Very Low Certainty) at short-term follow-up (3–6 months dependent on study) and there was no evidence of effect for skills and attitude of EBHC at short-term follow-up (1–6 months). Similarly, there was no evidence of effect for knowledge, skills, and attitude of EBHC at long-term follow-up (7–12 months). However, there was a borderline statistically significant large effect of behaviour at short-term follow-up (3–6 months) (SMD, 0.75; 95% CI, 0.00–1.50, Very Low Certainty) and long-term follow-up (7–10 months) (SMD, 1.73; 95% CI, 0.74–2.71, Low Certainty).

A sensitivity analysis focusing on individual participant RCTs (excluding cluster RCTs) resulted in a statistical significant increase of knowledge of EBHC (SMD, 6.38; 95% CI, 2.91–9.84, three studies, $I^2 = 93.74\%$) and uncertainty as to the effects on skills (SMD, 0.52; 95% CI, −0.23 to 1.26 4 studies, $I^2 = 90.94\%$), attitudes (SMD, 0.55; 95% CI, −0.37; 1.47, 3 studies, $I^2 = 93.75\%$) and behaviour associated with EBHC (SMD,0.75 95% CI, 0.20–1.31, 3 studies, $I^2 = 78.59\%$) at the end of intervention.

4.5 | Active comparison

Active educational interventions compared differed considerably, limiting the opportunity to pool outcomes. Only six comparisons were evaluated by two or more studies, with 18 assessed by a single study (see Table 3 and Supporting Information File S1: Appendices 12–15). When assessed, all studies were found to be at high risk of bias (see Figure 2). Blended learning workshops/courses had a moderate to large effect in increasing knowledge of EBHC compared with a face-to-face workshop (SMD, 0.65; 95% CI, 0.32–0.97, Low Certainty) or an online course (Asynchronous) (SMD, 0.79; 95% CI, 0.50–1.09, Low Certainty) (see Table 3). When combined with tutorial support, blended learning resulted in a moderate effect in increasing knowledge of EBHC compared with a face-to-face workshop approach (SMD 0.58; 95% CI, 0.12–1.04, Very Low Certainty). A similar moderate benefit was found in developing EBHC skills following a blended learning workshop/course compared with an online course (Asynchronous) (SMD, 0.42; 95% CI, 0.14–0.71, Very Low Certainty). Furthermore, there was a large effect when comparing blended learning course to a face-to-face course on behaviour of EBHC (SMD, 0.83; 95% CI, 0.41–1.25, Low Certainty).

Active workshops led to large improvement in staff satisfaction concerning EBHC education interventions compared with a didactic workshop (SMD, 1.22; 95% CI, 0.92–1.51, Low Certainty). Large benefits were reported for behaviour of EBHC following a single specialist journal club compared with a multiple specialist journal club (SMD, 0.74; 95% CI, 0.30–1.18, Very Low Certainty). For education on systematic reviews, an online workshop (Asynchronous) resulted in a large improvement in knowledge of EBHC compared with providing only a web-based PRISMA checklist (SMD, 0.92; 95% CI, 0.70–1.15, Low Certainty). With low or very low certainty evidence underpinning the estimates, the actual effect may differ from those

TABLE 2 EBHC educational intervention Vs waiting list/no treatment.

Outcome	Number of studies included in the meta-analysis	Standard means difference	95% confidence interval	Prediction Interval	Meta-analysis estimates *p* =	I-squared. (I^2)	I-squared *p* =	Number of positive studies (Intervention vs. control)	Number of statistically significant studies (intervention vs. control)	Appendix number (supplement information one)
Knowledge of EBHC end of the intervention	6	2.69	1.26–4.14	−2.33 to 7.70	>0.001	96.3%	>0.001	10/10	9/10	1
Knowledge of EBHC (follow-up 6 months and less)	2	0.40	0.07–0.73	N/A	0.017	0%	0.52	3/3	1/1	2
Knowledge of EBHC (long-term follow-up 6 months plus)	1	0.19	−0.52 to 0.90	N/A	0.60	N/A	N/A	2/2	1/1	3
Skills of EBHC (end of intervention)	6	0.88	0.03–1.73	−2.22 to 3.98	0.044	79.6	>0.001	8/9	7/7	4
Skills of EBHC (follow-up 6 months and less)	1	0.16	−0.49 to 0.82	N/A	0.62	N/A	N/A	3/3	1/3	5
Skills of EBHC (long-term follow-up 6 months plus)	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/A
Attitude of EBHC (end of intervention)	7	0.82	0.16–1.47	−1.52 to 3.16	0.014	92.5%	>0.001	8/9	4/8	6
Attitude of EBHC (follow-up 6 months and less)	1	0.16	−0.39 to 0.71	N/A	0.57	N/A	N/A	1/2	N/R	7
Attitude of EBHC (long-term follow-up 6 months plus)	3	1.39	−0.41 to 3.19	−21.49 to 24.27	0.13	95.4%	>0.001	3/3	3/3	8
Behaviour of EBHC (end of intervention)	6	0.82	0.25–1.40	−1.20 to 2.85	0.005	88.0%	>0.001	9/10	6/8	9
Behaviour of EBHC (follow-up 6 months and less)	3	0.75	0.00–1.50	−8.40 to 9.89	0.049	86.6	0.001	4/4	3/3	10
Behaviour of EBHC (long-term follow-up 6 months plus)	3	1.73	0.74–2.71	−10.23 to 13.68	0.001	84.44	0.002	4/4	4/4	11

TABLE 2 (Continued)

Outcome	Number of studies included in the meta-analysis	Standard means difference	95% confidence interval	Prediction Interval	Meta-analysis estimates p =	I-squared. (I^2)	I-squared p =	Number of positive studies (Intervention vs. control)	Number of statistically significant studies (intervention vs. control)	Appendix number (supplement information one)
Practice improvement end of the intervention	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0/2	N/R	N/A
Practice improvement (follow-up 6 months and less)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0/1	N/R	N/A

Note: The number of positive studies and statistically significant difference number of studies is different due to the statistical comparison of the intervention group and the control group not being carried out at this given time point in the related studies.

Abbreviations: N/A, not applicable; N/R, not reported.

presented. One study stated it found a statistically significant improvement in skill of EBHC when comparing an online journal club to an emailed based journal club (estimate not reported). There was no evidence that an online course/workshop was more effective compared with a face-to-face course/workshop for knowledge, skills, attitudes of EBHC (Low Certainty).

5 | DISCUSSION

This systematic review and meta-analyses found supportive evidence that educational interventions for EBHC may have a large positive effect on knowledge, skills, attitude, and beliefs of EBHC at the end of the intervention (Low [The true effect might be markedly different from the estimated effect]/Very Low Certainty [The true effect is probably markedly different from the estimated effect]). These benefits tended to diminish over time (≤6 months), with no evidence of long-term effects (>6 months) (Very Low Certainty). Only the effects on behaviour persisted, and appear to strengthen, over the longer term (Very Low Certainty). Although the findings suggest that people may benefit from regular updates (e.g., 6 monthly), getting an understanding of how changes to behaviour are maintained would be helpful. Importantly, caution is necessary in interpreting these findings as the certainty in these estimates were judged to be low to very low. This uncertainty reflects both high risk of bias of the included studies and issues of heterogeneity. Unfortunately, due to the limited evidence base, it was not possible to explore causes and effects of heterogeneity further.[28,102] However, on visual inspection of the included RCTs there was notable variation in participants clinical discipline, frequency of intervention, duration of sessions and the pedagogical approach. These factors may be important moderating factors and require further exploration.

The pedagogical approach of the interventions varied in quality of reporting, method of delivery, course contents, number of sessions and duration of sessions across the included studies, there were some common aspects. Educational interventions for EBHC typically included a multifaceted interactive approach which were linked to clinical practice, provided individual feedback and opportunities for self-assessment. The most common topics covered were accessing the literature, critical appraisal, critical thinking and how to apply results to practice. The educational interventions for EBHC were mainly delivered face-to-face with some studies taking an online or blended approach. When compared directly, there was some evidence that blended learning may provide an enhanced delivery method for improving knowledge, skills and behaviour of EBHC compared with face-to-face or online (Low Certainty). When compared with online delivery, there was no evidence that face-to-face delivery provided an enhanced mode of delivery for knowledge, skills, or attitudes of EBHC (Low Certainty). It was shown that active delivery and consistency in individuals delivering the sessions may provide an enhancement in satisfaction of the EBHC educational intervention and behaviour of EBHC, respectively (Very Low Certainty). There was a dearth of evidence regarding the effects of

TABLE 3 EBHC educational intervention versus active comparison.

Comparison	Number of studies	Standard means difference	95% confidence interval	Prediction Interval	*p* =	I^2	*p* =	Number of positive studies (intervention vs. active intervention)	Number of statistically significant studies (intervention vs. control)	Appendix number (supplement information one)
Knowledge of EBHC at the end of the intervention										
Active workshop versus didactic workshop	2	1.00	−1.22 to 3.23	N/A	0.38	98.78%	>0.001	2/3	2/3	12
Blended learning + tutor support versus face-to-face workshop	1	0.583	0.12–1.04	N/A	0.013	N/A	N/A	1/1	1/1	12
Blended learning course versus face-to-face course	2	0.65	0.32–0.97	N/A	0.002	0%	0.41	2/2	2/2	12
Blended learning versus online course (asynchronous)	1	0.79	0.50–1.09	N/A	>0.001	N/A	N/A	1/1	1/1	12
Enhanced journal club versus standard journal club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	N/R	N/A
Problem based learning approach on EBHC versus face-to-face course on EBHC (standard approach)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/R	0/1	N/A
Face-to-face course versus self-directed module	1	0.26	−0.24 to 0.75	N/A	0.31	N/A	N/A	1/1	0/1	12
Online versus face-to-face course/workshop	6	−0.1	−0.37 to 0.16	−0.08 to 0.68	0.44	60%	0.028	2/6	0/5	12
Single specialist journal club versus multiple specialists journal club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	0/1	N/A
Flipped teaching model versus didactic instruction (face-to-face)	1	0	−0.37 to 0.37	N/A	N/A	N/A	N/A	0/1	0/1	12
Online workshop (asynchronous) versus Web-based PRISMA checklist	1	0.92	0.70–1.15	N/A	N/A	N/A	N/A	1/1	1/1	12
Skills of EBHC (end of intervention)										
Face-to-face EBHC workshop versus journal club	1	0.05	−0.52 to 0.60	N/A	0.87	N/A	N/A	1/1	0/1	13

TABLE 3 (Continued)

Comparison	Number of studies	Standard means difference	95% confidence interval	Prediction Interval	p =	I^2	p =	Number of positive studies (intervention vs. active intervention)	Number of statistically significant studies (intervention vs. control)	Appendix number (supplement information one)
Blended learning course or workshop versus face-to-face course or workshop	2	2.37	−2.69 to 7.42	N/A	0.36	98.8%	>0.001	1/2	1/1	13
Blended learning course versus online course (asynchronous)	1	0.42	0.14–0.71	N/A	0.003	N/A	N/A	1/1	1/1	13
Enhanced journal club versus standard journal club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	N/R	N/A
Face-to-face course versus self-directed module	1	0.60	−0.43 to 0.55	N/A	0.81	N/A	N/A	1/1	0/1	13
Online EBHC + practice examples versus online EBHC workshop	1	−0.20	−0.82 to 0.42	N/A	0.523	N/A	N/A	0/1	N/R	13
Online journal club versus emailed based journal club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	1/1	N/A
Online versus face-to-face course/workshop	2	−0.15	−0.34 to 0.03	N/A	0.10	0%	0.319	0/2	0/2	N/A
Tutorial support versus nontutorial support	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0/1	N/R	N/A
Attitudes of EBHC (end of intervention)										
Active workshop versus didactic workshop	2	0.23	−1.12 to 1.59	N/A	0.73	97.1%	>0.001	1/2	1/2	14
Blended learning course versus face-to-face course (1 month)	1	−0.025	−0.43 to 0.38	N/A	0.90	N/A	N/A	1/2	1/2	14
Enhanced journal club versus standard journal club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	N/R	N/A
Problem based learning approach on EBHC versus face-to-face course on EBHC (standard approach)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	0/1	N/A
Face-to-face course versus self-directed module	1	−0.018	−0.51 to 0.47	N/A	0.944	N/A	N/A	0/1	0/1	14
Online versus face-to-face course/workshop	1	0.082	−0.22 to 0.39	N/A	0.60	N/A	N/A	1/1	0/1	14

(Continues)

TABLE 3 (Continued)

Comparison	Number of studies	Standard means difference	95% confidence interval	Prediction Interval	*p* =	I^2	*p* =	Number of positive studies (intervention vs. active intervention)	Number of statistically significant studies (intervention vs. control)	Appendix number (supplement information one)
Tutorial support versus nontutorial support (10 months)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	0/1	N/A
Flipped teaching model versus didactic instruction (face-to-face)	1	0.11	−0.26 to 0.48	N/A	0.56	N/A	N/A	1/1	0/1	14
Behaviour of EBHC (end of intervention)										
Active session versus didactic session	1	−0.185	−0.54 to 0.172	N/A	0.310	N/A	N/A	0/1	0/1	15
Blended learning course versus face-to-face course	1	0.83	0.41–1.25	N/A	>0.001	N/A	N/A	2/2	2/2	N/A
Enhanced journal club versus standard journal club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0/1	N/R	N/A
Face-to-face course on EBHC (Problem based learning approach on) EBHC versus face-to-face course on EBHC (standard approach)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	0/1	N/A
Face-to-face course versus self-directed module	1	−0.19	−0.68 to 0.30	N/A	0.45	N/A	N/A	0/1	0/1	15
Single specialist journal club versus multiple specialists journal club	1	0.74	0.30–1.18	N/A	0.001	N/A	N/A	1/1	1/1	15
Tutorial support versus nontutorial support (2–10 months)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	0/1	N/A
Flipped teaching model versus didactic instruction (face-to-face)	1	−0.05	−0.42 to 0.32	N/A	0.78	N/A	N/A	0/1	0/1	N/A
Satisfaction of EBHC educational interventions (end of intervention)										
Active session versus didactic session (all sessions were face-to-face)	1	1.22	0.92–1.51	N/A	>0.001	N/A	N/A	2/2	1/1	15
Online versus face-to-face	1	0.41	−0.06 to 0.89	N/A	0.09	N/A	N/A	1/2	0/2	15

TABLE 3 (Continued)

Comparison	Number of studies	Standard means difference	95% confidence interval	Prediction Interval	p =	I^2	p =	Number of positive studies (intervention vs. active intervention)	Number of statistically significant studies (intervention vs. control)	Appendix number (supplement information one)
Online EBHC workshop + Practice examples versus Online EBHC workshop	1	0.33	−0.29 to 0.95	N/A	0.30	N/A	N/A	1/1	0/1	15
Online journal club versus emailed based journal club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1/1	N/R	N/A

Note: The number of positive studies and statistically significant difference number of studies is different due to the statistical comparison of the intervention group and the control group not being carried out at this given time point in the related studies.
Abbreviations: N/A, not applicable; N/R, not reported.

educational interventions for EBHC for both process improvement and patient outcomes.

5.1 | What does this review contribute to the existing evidence

The results of our review corroborate previous findings regarding educational interventions for EBHC having a positive effect on knowledge, skills,[21,23,24] and attitude,[21,24] with their narrative findings suggesting the effects were small.[21,23] Although another review contradicted the beneficial effects on behaviour found in our review, they included both before and after studies and RCTs.[23] When only considering the RCTs evidence, the findings from the other review are in line with ours. This is the first systematic review to identify that educational interventions for EBHC may only have a short-term (<6 months), effect on improving knowledge of, skills in, and attitude toward EBHC, although the effect on behaviour around implementing EBHC may be longer lasting.

Our findings appear to concur with those of previous systematic reviews in that blended learning[14] and active learning[22] may provide an enhanced method of delivery compared with alternative methods. Furthermore, our review aligns with the suggestion that there was no evidence of effect when comparing online compared with face-to-face delivery,[14] the lack of patient reported outcomes[19] and the need of standardisation of reporting.[21,23] This review did also identify that the individual delivering the intervention may be an important moderating factor.

5.2 | Strengths and limitations

To our knowledge, this is the first systematic review which has undertaken a meta-analysis on educational interventions for EBHC compared with nonactive comparisons (waiting list/no treatment/sham control). This review used a unique search strategy of forward and backward citation retrieval which identified an additional 20 new RCTs and three link papers from the original seed papers. Out of these 23 newly identified papers, 11 of the papers had publication dates which overlapped with the previous reviews which used traditional search strategies.[49,60,62,63,67,83,87,94-96,101] As demonstrated previously in assessments of this technique,[103-105] this method has the capability to outperform traditional term-based search strategies in specific circumstances. An assessment of bias was conducted for all the studies included, followed by a grading assessment for all primary outcomes.

This review also had multiple limitations which need to be considered when interpreting the findings in context to practice. These limitations were that the effect estimates presented in this review are based upon low to very low certainty evidence. Forward and backward citation searching have been previously indicated to be potentially influenced by positive publication bias.[28] It has been proposed that positive studies are more likely to be cited, which

would result in these studies being more easily identified using these techniques.[28] There were inconsistencies in reporting of interventions which makes it difficult to ensure that the classifications of the interventions are fully representative. Regrettably, owing to decreased team capacity, the prescribed screening and data extraction methods outlined in the review protocol could not be adhered to. Consequently, a single reviewer was tasked with conducting the data extraction and bias ascsessment, potentially introducing errors into the review process.[106] Nonadjustment of cluster RCTs may have led to overestimation of precision within the 95% CIs.[28] Due to the limited number of studies, no assessment of publication bias or heterogeneity was undertaken.[31,32]

6 | FUTURE RESEARCH

Due to the substantial inconsistency in reporting of interventions, future research should ensure it adopts a relevant reporting standard, such as the guideline for reporting evidence-based practice educational interventions and teaching (GREET).[107] Without this standardisation it will be difficult to explore key pedagogical moderating factors which may be causing the substantial observed heterogeneity within these effect estimates. Furthermore, future research should focus on active comparisons of standardised moderating factors of frequency of delivery, duration, course contents, and pedagogical approach. Due to the lack of reporting of practice change and patient outcomes, it is important that future research include outcomes at this level. Educational interventions for EBHC only had a lasting effect on behaviour longer than 6 months after the intervention. Future research examining this time point should take a mixed method approach to explore why this discontinuation of effect may be occurring.

7 | CONCLUSION

Educational interventions for EBHC appear to have a large, although short-term (<6 months), effect on improving knowledge of, skills in, and attitude toward EBHC. In contrast, their effects on behaviour around implementing EBHC may last longer. Blended learning, active learning and consistency in the individual delivering the intervention may be important positive moderating factors. Online and face-to-face delivery of educational interventions differed little in their effects. Future research should focus on RCTs, reported in accordance with recognised standards, examining practice and patient outcomes and, where relevant, compare active and nonactive interventions.

AUTHOR CONTRIBUTIONS

James Hill: Study design; literature search, title and abstract screening; full paper review and selection; data extraction and analysis; coauthorship of paper. **Nikki Gratton**: Study design; literature search, title and abstract screening; full paper review and selection; data extraction and analysis; coauthorship of paper. **Amit Kulkarni**: Study design; literature search; title and abstract screening; full paper review and selection; data extraction and analysis; coauthorship of paper. **Oliver Hamer**: Full paper review and selection; coauthorship of paper. **Joanna Harrison**: Full paper review and selection; coauthorship of paper. **Catherine Harris**: Study design; literature search; coauthorship of paper. **Jen Chesters**: Study design; literature search; title and abstract screening; coauthorship of paper. **Elaine Duddy**: Study design; literature search; title and abstract screening; coauthorship of paper. **Lindsey Collins**: Study design; literature search; title and abstract screening; coauthorship of paper. **Andrew Clegg**: Study design; literature search; coauthorship of paper.

ACKNOWLEDGEMENTS

James Hill, Oliver Hamer, Joanna Harrison, Catherine Harris and Andrew Clegg are part-funded by the National Institute for Health and Care Research Applied Research Collaboration North West Coast (NIHR ARC NWC). The views expressed are those of the authors and not necessarily those of the National Health Service, the NIHR, or the Department of Health and Social Care. Additional funding was received from the Royal College of Speech & Language Therapists.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this systematic review are available on request from James Hill Email: Jehill1@uclan.ac.uk.

ORCID

James Hill http://orcid.org/0000-0003-1430-6927
Joanna Harrison http://orcid.org/0000-0001-8963-7240
Catherine Harris http://orcid.org/0000-0001-7763-830X

REFERENCES

1. Dawes M. *Evidence-based Practice: A Primer for Health Care Professionals*. Elsevier/Churchill Livingstone; 2005.
2. Gillam S, Siriwardena AN. Evidence-based healthcare and quality improvement. *Qual Prim Care*. 2014;22(3):125-132.
3. Gray JM. *Evidence-Based Healthcare: How to Make Health Policy and Management Decisions*. Churchill Livingstone; 2002.
4. Rawlins M. In pursuit of quality: the National Institute for Clinical Excellence. *Lancet*. 1999;353(9158):1079-1082.
5. Woolf SH, Grol R, Hutchinson A, Eccles M, Grimshaw J. Clinical guidelines: potential benefits, limitations, and harms of clinical guidelines. *BMJ*. 1999;318(7182):527-530.
6. Goodwin NCN, Naylor C, Ross S, Duldig W. *Managing People with Long-Term Conditions: An Inquiry into the Quality of General Practice*. The King's Fund; 2010.
7. Jordan Z, Lockwood C, Munn Z, Aromataris E. The updated Joanna Briggs Institute model of evidence-based healthcare. *JBI Evid Implement*. 2019;17(1):58-71.
8. Immonen K, Tuomikoski A-M, Kääriäinen M, et al. Evidence-based healthcare competence of social and healthcare educators: a systematic review of mixed methods. *Nurse Educ Today*. 2022;108:105190.
9. Dawes M, Summerskill W, Glasziou P, et al. Sicily statement on evidence-based practice. *BMC Med Educ*. 2005;5:1-7.

10. Young T, Rohwer A, Volmink J, Clarke M. What are the effects of teaching evidence-based health care (EBHC)? Overview of systematic reviews. *PLoS One*. 2014;9(1):e86706.
11. Glasziou PP, Sawicki PT, Prasad K, Montori VM. Not a medical course, but a life course. *Acad Med*. 2011;86(11):e4.
12. Bala MM, Poklepović Peričić T, Zajac J, et al. What are the effects of teaching Evidence-Based Health Care (EBHC) at different levels of health professions education? An updated overview of systematic reviews. *PLoS One*. 2021;16(7):e0254191.
13. Pearson A, Wiechula R, Court A, et al. The JBI model of evidence-based healthcare. *Int J Evid Based Healthc*. 2005;3(8):207-215.
14. Rohwer A, Motaze NV, Rehfuess E, Young T. E-learning of evidence-based health care (EBHC) to increase EBHC competencies in healthcare professionals: a systematic review. *Campbell Syst Rev*. 2017;13:1-147.
15. Elaine L, Patricia L-W, Cliona OR, et al. Evidence-based practice education for healthcare professions: an expert view. BMJ Evidence-Based. *Medicine*. 2019;24(3):103.
16. Horsley T, O'Neill J, McGowan J, Perrier L, Kane G, Campbell C. Interventions to improve question formulation in professional practice and self-directed learning. *Cochrane Database Syst Rev*. 2010;5:Cd007335.
17. Horsley T, Hyde C, Santesso N, Parkes J, Milne R, Stewart R. Teaching critical appraisal skills in healthcare settings. *Cochrane Database Syst Rev*. 2011;2011(11):CD001270.
18. Hyde C, Parkes J, Deeks J, et al. Systematic review of effectiveness of teaching critical appraisal. In: *Database of Abstracts of Reviews of Effects (DARE): Quality-assessed Reviews [Internet]*. Centre for Reviews and Dissemination; 2000.
19. Fiander M, McGowan J, Grad R, et al. Interventions to increase the use of electronic health information by healthcare practitioners to improve clinical practice and patient outcomes. *Cochrane Database Syst Rev*. 2015;2015(3):CD004749.
20. Wu Y, Brettle A, Zhou C, Ou J, Wang Y, Wang S. Do educational interventions aimed at nurses to support the implementation of evidence-based practice improve patient outcomes? A systematic review. *Nurse Educ Today*. 2018;70:109-114.
21. Ramis M-A, Chang A, Conway A, Lim D, Munday J, Nissen L. Theory-based strategies for teaching evidence-based practice to undergraduate health students: a systematic review. *BMC Med Educ*. 2019;19(1):267.
22. Hines S, Ramsbotham J, Coyer F. Interventions for improving the research literacy of nurses: a systematic review. *JBI Database System Rev Implement Rep*. 2016;14(2):256-294.
23. Hecht L, Buhse S, Meyer G. Effectiveness of training in evidence-based medicine skills for healthcare professionals: a systematic review. *BMC Med Educ*. 2016;16:103.
24. Ahmadi S-F, Baradaran HR, Ahmadi E. Effectiveness of teaching evidence-based medicine to undergraduate medical students: a BEME systematic review. *Med Teach*. 2015;37(1):21-30.
25. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71.
26. Albarqouni L, Hoffmann T, Glasziou P. Evidence-based practice educational intervention studies: a systematic review of what is taught and how it is measured. *BMC Med Educ*. 2018;18(1):177.
27. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. 2016;5(1):210.
28. Higgins J, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA. *Cochrane Handbook for Systematic Reviews of Interventions Version 6.3*. Cochrane; 2022.
29. Brożek JL, Akl EA, Alonso-Coello P, et al. Grading quality of evidence and strength of recommendations in clinical practice guidelines. Part 1 of 3. An overview of the GRADE approach and grading quality of evidence about interventions. *Allergy*. 2009;64(5):669-677.
30. Drahota A, Beller E. RevMan calculator. 2023. https://training.cochrane.org/resource/revman-calculator
31. Higgins J, Green S. *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0*. Cochrane; 2011.
32. Dalton JE, Bolen SD, Mascha EJ. Publication bias: the elephant in the review. *Anesth Analg*. 2016;123(4):812-813.
33. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. *Introduction to Meta-Analysis*. 2nd ed. Wiley; 2021.
34. Borenstein M. *Common Mistakes in Meta-Analysis And How to Avoid Them*. Biostat, Inc; 2019.
35. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. A basic introduction to fixed-effect and random-effects models for meta-analysis. *Res Synth Methods*. 2010;1(2):97-111.
36. Hedges LV, Olkin I. *Statistical Methods for Meta-Analysis*. Academic Press; 1985.
37. Shah K, Egan G, Huan L, Kirkham J, Reid E, Tejani AM. Outcome reporting bias in Cochrane systematic reviews: a cross-sectional analysis. *BMJ Open*. 2020;10(3):e032497.
38. Basheer A, Iqbal N, Prabakaran S, Simiyon M, Anandan V. Simulated randomized controlled trial to learn critical appraisal (SiRCA): a randomized controlled study of effectiveness among undergraduate medical students. *Cureus*. 2021;13(11):e19946.
39. Bergold M, Strametz R, Weinbrenner S, et al. Evidenzbasierte Medizin online zum ärztlichen Berufsstart– eine randomisiert-kontrollierte Studie. *Z Evid Fortbild Qual Gesundhwes*. 2013;107(1):36-43.
40. Bradley DR, Rana GK, Martin PW, Schumacher RE. Real-time, evidence-based medicine instruction: a randomized controlled trial in a neonatal intensive care unit. *J Med Libr Assoc*. 2002;90(2):194-201.
41. Bradley P, Oterholt C, Herrin J, Nordheim L, Bjorndal A. Comparison of directed and self-directed learning in evidence-based medicine: a randomised controlled trial. *Med Educ*. 2005;39(10):1027-1035.
42. Brettle A, Raynor M. Developing information literacy skills in pre-registration nurses: an experimental study of teaching methods. *Nurse Educ Today*. 2013;33(2):103-109.
43. Brouwers MC, Makarski J, Durocher LD, Levinson AJ. E-learning interventions are comparable to user's manual in a randomized trial of training strategies for the AGREE II. *Implement Sci*. 2011;6:81.
44. Cabell CH, Schardt C, Sanders L, Corey GR, Keitz SA. Resident utilization of information technology. *J Gen Intern Med*. 2001;16(12):838-844.
45. Campbell L, Novak I, McIntyre S, Lord S. A KT intervention including the evidence alert system to improve clinician's evidence-based practice behavior--a cluster randomized controlled trial. *Implement Sci*. 2013;8:132.
46. Cheng GYT. Educational workshop improved information-seeking skills, knowledge, attitudes and the search outcome of hospital clinicians: a randomised controlled trial. *Health Inf Libr J*. 2003;20(suppl 1):22-33.
47. Davis J, Chryssafidou E, Zamora J, Davies D, Khan K, Coomarasamy A. Computer-based teaching is as good as face to face lecture-based teaching of evidence based medicine: a randomised controlled trial. *BMC Med Educ*. 2007;7:23.
48. Davis J, Crabb S, Rogers E, Zamora J, Khan K. Computer-based teaching is as good as face to face lecture-based teaching of evidence based medicine: a randomized controlled trial. *Med Teach*. 2008;30(3):302-307.
49. Dizon JM, Grimmer-Somers K, Kumar S. Effectiveness of the tailored EBP training program for Filipino physiotherapists: a randomised controlled trial. *BMC Med Educ*. 2011;11(1):14.
50. Dizon JMR, Grimmer-Somers K, Kumar S. Effectiveness of the tailored Evidence Based Practice training program for Filipino physical therapists: a randomized controlled trial. *BMC Med Educ*. 2014;14:147.

51. D'Souza P, George A, Nair S, Noronha J, Renjith V. Effectiveness of an evidence-based practice training program for nurse educators: a cluster-randomized controlled trial. *Worldviews Evid Based Nurs*. 2021;18(4):261-271.
52. Farokhzadian J, Jouparinejad S, Fatehi F, Falahati-Marvast F. Improving nurses' readiness for evidence-based practice in critical care units: results of an information literacy training program. *BMC Nurs*. 2021;20(1):79.
53. Forsetlund L, Bradley P, Forsen L, Nordheim L, Jamtvedt G, Bjørndal A. Randomised controlled trial of a theoretically grounded tailored intervention to diffuse evidence-based public health practice [ISRCTN23257060]. *BMC Med Educ*. 2003;3:2.
54. Gülmezoglu A, Langer A, Piaggio G, Lumbiganon P, Villar J, Grimshaw J. Cluster randomised trial of an active, multifaceted educational intervention based on the WHO Reproductive Health Library to improve obstetric practices. *BJOG-Int J Obstet Gy*. 2007;114(1):16-23.
55. Hadley J, Kulier R, Zamora J, et al. Effectiveness of an e-learning course in evidence-based medicine for foundation (internship) training. *J R Soc Med*. 2010;103(7):288-294.
56. Hadvani T, Dutta A, Choy E, et al. Effectiveness of modalities to teach evidence based medicine to pediatric clerkship students: a randomized controlled trial. *Acad Pediatr*. 2021;21(2):375-383.
57. Haidet P, Morgan RO, O'Malley K, Moran BJ, Richards BF. A controlled trial of active versus passive learning strategies in a large group setting. *Adv Health Sci Educ*. 2004;9(1):15-27.
58. Haynes RB, Johnston ME, McKibbon KA, Walker CJ, Willan AR. A program to enhance clinical use of MEDLINE. A randomized controlled trial. *Online J Curr Clin Trials*. 1993;Doc No 56:1-16. https://pubmed.ncbi.nlm.nih.gov/8306006/
59. Horiuchi S, Yaju Y, Koyo M, Sakyo Y, Nakayama K. Evaluation of a web-based graduate continuing nursing education program in Japan: a randomized controlled trial. *Nurse Educ Today*. 2009;29(2):140-149.
60. Hugenholtz NIR, Schaafsma FG, Nieuwenhuijsen K, van Dijk FJH. Effect of an EBM course in combination with case method learning sessions: an RCT on professional performance, job satisfaction, and self-efficacy of occupational physicians. *Int Arch Occup Environ Health*. 2008;82(1):107-115.
61. Ilic D, Nordin RB, Glasziou P, Tilson JK, Villanueva E. A randomised controlled trial of a blended learning education intervention for teaching evidence-based medicine. *BMC Med Educ*. 2015;15:39.
62. Ilic D, Hart W, Fiddes P, Misso M, Villanueva E. Adopting a blended learning approach to teaching evidence based medicine: a mixed methods study. *BMC Med Educ*. 2013;13(1):169.
63. Maloney S, Nicklen P, Rivers G, et al. A cost-effectiveness analysis of blended versus face-to-face delivery of evidence-based medicine to medical students. *J Med Internet Res*. 2015;17(7):e182.
64. Jalali-Nia SF, Salsali M, Dehghan-Nayeri N, Ebadi A. Effect of evidence-based education on Iranian nursing students' knowledge and attitude. *Nurs Health Sci*. 2011;13(2):221-227.
65. Johnston JM, Schooling CM, Leung GM. A randomised-controlled trial of two educational modes for undergraduate evidence-based medicine learning in Asia. *BMC Med Educ*. 2009;9:63.
66. Kamin C, Glicken A, Hall M, Quarantillo B, Merenstein G. Evaluation of electronic discussion groups as a teaching/learning strategy in an evidence-based medicine course: a pilot study. *Educ Health Change Learn Pract*. 2001;14(1):21-32.
67. Kim S, Willett LR, Murphy DJ, O'Rourke K, Sharma R, Shea JA. Impact of an evidence-based medicine curriculum on resident use of electronic resources: a randomized controlled study. *J Gen Intern Med*. 2008;23(11):1804-1808.
68. Kok R, Hoving JL, Smits PBA, Ketelaar SM, van Dijk FJH, Verbeek JH. A clinically integrated post-graduate training programme in evidence-based medicine versus 'no intervention' for improving disability evaluations: a cluster randomised clinical trial. *PLoS One*. 2013;8(3):e57256.
69. Koota E, Kääriäinen M, Kyngäs H, Lääperi M, Melender HL. Effectiveness of evidence-based practice (EBP) education on emergency nurses' ebp attitudes, knowledge, self-efficacy, skills, and behavior: a randomized controlled trial. *Worldviews Evid Based Nurs*. 2021;18(1):23-32.
70. Krueger PM. Teaching critical appraisal: a pilot randomized controlled outcomes trial in undergraduate osteopathic medical education. *J Am Osteopath Assoc*. 2006;106(11):658-662.
71. Kulier R, Coppus SF, Zamora J, et al. The effectiveness of a clinically integrated e-learning course in evidence-based medicine: a cluster randomised controlled trial. *BMC Med Educ*. 2009;9:21.
72. Kulier R, Gülmezoglu AM, Zamora J, et al. Effectiveness of a clinically integrated e-learning course in evidence-based medicine for reproductive health training: a randomized trial. *JAMA*. 2012;308(21):2218-2225.
73. Laibhen-Parkes N. *Web-Based evidence based practice educational intervention to improve EBP competence among BSN-prepared pediatric bedside nurses: a mixed methods pilot study*. Mercer University; 2014.
74. Lee A, Joynt GM, Ho AMH, Gin T, Hazlett CB. Effect of an integrated teaching intervention on clinical decision analysis: a randomized, controlled study of undergraduate medical students. *Med Teach*. 2007;29(2-3):231-236.
75. Leung GM. Randomised controlled trial of clinical decision support tools to improve learning of evidence based medicine in medical students. *BMJ*. 2003;327(7423):1090.
76. Levin RF, Fineout-Overholt E, Melnyk BM, Barnes M, Vetter MJ. Fostering evidence-based practice to improve nurse and cost outcomes in a community health setting: a pilot test of the advancing research and clinical practice through close collaboration model. *Nurs Adm Q*. 2011;35(1):21-33.
77. Linzer M, DeLong ER, Hupart KH. A comparison of two formats for teaching critical reading skills in a medical journal club. *J Med Educ*. 1987;62(8):690-692.
78. Linzer M. Impact of a medical journal club on house-staff reading habits, knowledge, and critical appraisal skills. A randomized control trial. *JAMA*. 1988;260(17):2537-2541.
79. Liou S-R, Cheng C-Y, Tsai H-M, Chang C-H. Innovative strategies for teaching nursing research in Taiwan. *Nurs Res*. 2013;62(5):335-343.
80. Long JD, Gannaway P, Ford C, et al. Effectiveness of a technology-based intervention to teach evidence-based practice: the EBR Tool. *Worldviews Evid Based Nurs*. 2016;13(1):59-65.
81. Macrae HM, Regehr G, McKenzie M, et al. Teaching practicing surgeons critical appraisal skills with an Internet-based journal club: a randomized, controlled trial. *Surgery*. 2004;136(3):641-646.
82. McLeod RS, MacRae HM, McKenzie ME, Victor CJ, Brasel KJ. A moderated journal club is more effective than an Internet journal club in teaching critical appraisal skills: results of a multicenter randomized controlled trial. *J Am Coll Surg*. 2010;211(6):769-776.
83. Mukohara K, Schwartz MD. Electronic delivery of research summaries for academic generalist doctors: a randomised trial of an educational intervention. *Med Educ*. 2005;39(4):402-409.
84. Rostamnia L, Ghanbari V, Shabani F, Farahani A, Dehghan-Nayeri N. Evidence-based practice for cardiac intensive care unit nurses: an educational intervention study. *J Contin Educ Nurs*. 2020;51(4):167-173.
85. Sánchez-Mendiola M, Kieffer-Escobar LF, Marín-Beltrán S, Downing SM, Schwartz A. Teaching of evidence-based medicine to medical students in Mexico: a randomized controlled trial. *BMC Med Educ*. 2012;12:107.
86. Saunders H, Vehviläinen-Julkunen K, Stevens KR. Effectiveness of an education intervention to strengthen nurses' readiness for evidence-based practice: a single-blind randomized controlled study. *Appl Nurs Res*. 2016;31:175-185.

87. Schaafsma F, Hugenholtz N, de Boer A, Smits P, Hulshof C, van Dijk FJ. Enhancing evidence-based advice of occupational health physicians. *Scand J Work Environ Health*. 2007;33(5):368-378.
88. Schilling K, Wiecha J, Polineni D, Khalil S. An interactive web-based curriculum on evidence-based medicine: design and effectiveness. *Fam Med*. 2006;38(2):126-132.
89. Shuval K, Berkovits E, Netzer D, et al. Evaluating the impact of an evidence-based medicine educational intervention on primary care doctors' attitudes, knowledge and clinical behaviour: a controlled trial and before and after study. *J Eval Clin Pract*. 2007;13(4):581-598.
90. Stark R, Helenius IM, Schimming LM, Takahara N, Kronish I, Korenstein D. Real-time EBM: from bed board to keyboard and back. *J Gen Intern Med*. 2007;22(12):1656-1660.
91. Stevenson K, Lewis M, Hay E. Do physiotherapists' attitudes towards evidence-based practice change as a result of an evidence-based educational programme? *J Eval Clin Pract*. 2004;10(2):207-217.
92. Stevermer JJ, Chambliss ML, Hoekzema GS. Distilling the literature: a randomized, controlled trial testing an intervention to improve selection of medical articles for reading. *Acad Med*. 1999;74(1):70-72.
93. Taylor RS, Reeves BC, Ewings PE, Taylor RJ. Critical appraisal skills training for health care professionals: a randomized controlled trial [ISRCTN46272378]. *BMC Med Educ*. 2004;4(1):30.
94. Villanueva EV, Burrows EA, Fennessy PA, Rajendran M, Anderson JN. Improving question formulation for use in evidence appraisal in a tertiary care setting: a randomised controlled trial [ISRCTN66375463]. *BMC Med Inform Decis Mak*. 2001;1:4.
95. Wenke RJ, Thomas R, Hughes I, Mickan S. The effectiveness and feasibility of TREAT (Tailoring Research Evidence and Theory) journal clubs in allied health: a randomised controlled trial. *BMC Med Educ*. 2018;18(1):104.
96. Wyatt JC, Paterson-Brown S, Johanson R, Altman DG, Bradburn MJ, Fisk NM. Randomised trial of educational visits to enhance use of systematic reviews in 25 obstetric units. *BMJ*. 1998;317(7165):1041-1046.
97. Awedew AF, Abera EG. Effectiveness of clinical integrated short course training of evidence based medicine for postgraduate medical specialty students in Ethiopia in 2022: a randomized control trial. *PLoS One*. 2023;18(1):e0277886.
98. Chao WY, Huang LC, Hung HC, et al. Effectiveness of digital flipped learning evidence-based practice on nurses' knowledge, attitude, and practice: a quasi-experimental trial. *Healthcare*. 2022;10(7):1257.
99. Cheng HM, Guo FR, Hsu TF, et al. Two strategies to intensify evidence-based medicine education of undergraduate students: a randomised controlled trial. *Ann Acad Med Singapore*. 2012;41(1):4-11.
100. Krnic Martinic M, Čivljak M, Marušić A, et al. Web-based educational intervention to improve knowledge of systematic reviews among health science professionals: randomized controlled trial. *J Med Internet Res*. 2022;24(8):e37000.
101. Moore L. Effectiveness of an online educational module in improving evidence-based practice skills of practicing registered nurses. *Worldviews Evid Based Nurs*. 2017;14(5):358-366.
102. Cuijpers P, Griffin JW, Furukawa TA. The lack of statistical power of subgroup analyses in meta-analyses: a cautionary note. *Epidemiolo Psychiatr Sci*. 2021;30:e78.
103. Hinde S, Spackman E. Bidirectional citation searching to completion: an exploration of literature searching methods. *Pharmacoeconomics*. 2015;33(1):5-11.
104. Linder SK, Kamath GR, Pratt GF, Saraykar SS, Volk RJ. Citation searches are more sensitive than keyword searches to identify studies using specific measurement instruments. *J Clin Epidemiol*. 2015;68(4):412-417.
105. Cooper C, Lovell R, Husk K, Booth A, Garside R. Supplementary search methods were more effective and offered better value than bibliographic database searching: a case study from public health and environmental enhancement. *Res Synth Methods*. 2018;9(2):195-223.
106. Buscemi N, Hartling L, Vandermeer B, Tjosvold L, Klassen TP. Single data extraction generated more errors than double data extraction in systematic reviews. *J Clin Epidemiol*. 2006;59(7):697-703.
107. Phillips AC, Lewis LK, McEvoy MP, et al. Development and validation of the guideline for reporting evidence-based practice educational interventions and teaching (GREET). *BMC Med Educ*. 2016;16(1):237.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Hill J, Gratton N, Kulkarni A, et al. The effectiveness of evidence-based healthcare educational interventions on healthcare professionals' knowledge, skills, attitudes, professional practice and healthcare outcomes: systematic review and meta-analysis. *J Eval Clin Pract*. 2024;1-27. doi:10.1111/jep.14001