BMJ Open

Bright light therapy and circadian rhythm regulation for delirium prevention in hospitalised adults: a systematic review and meta-analysis

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To cite: Saleh Moussa R, Edwards LM, Chang S, *et al*. Bright light therapy and circadian rhythm regulation for delirium prevention in hospitalised adults: a systematic review and meta-analysis. *BMJ Open* 2026;**16**:e116709. doi:10.1136/bmjopen-2026-116709

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2026-116709).

Received 18 January 2026
Accepted 10 September 2026

Check for updates

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ABSTRACT

Objective To evaluate the effects of bright light therapy (BLT) on circadian regulation and delirium incidence in hospitalised adults.

Design Systematic review and meta-analysis.

Data sources Scopus, MEDLINE, EMBASE, CINAHL and PsycINFO were searched from database inception to October 2025.

Eligibility criteria for selecting studies Randomised controlled trials, controlled clinical trials and pilot studies evaluating BLT for delirium prevention in hospitalised adults published in English were included.

Data extraction and synthesis Risk of Bias was assessed using the Risk of Bias tool for randomised trials (version 2) or Risk Of Bias In Non-randomised Studies of Interventions. Publication bias was explored using visual inspection of funnel plots. Data were narratively synthesised to summarise BLT protocolisation, adherence and impact on circadian rhythm and delirium incidence. Random-effects meta-analysis was performed to estimate pooled risk ratios (RRs) for delirium incidence. Certainty of evidence was assessed using GRADE.

Results Eight studies (participants n=1190) were included. Risk of bias for delirium incidence varied, with several studies judged to have some concerns or high risk of bias. Adherence, cessation and adverse events were inconsistently measured and reported across studies. Three studies assessed circadian outcomes: two reported increased circadian cycle lengths following BLT, while one found no between-group differences. Most studies applied morning BLT at intensities ≥5000 lux for 60–120 min over 3–4 days. Meta-analysis demonstrated an uncertain effect of BLT on delirium incidence (RR 0.64, 95% CI 0.38 to 1.07; p=0.09), with moderate heterogeneity (I^2=52.06%). The certainty of evidence was very low because of risk of bias, inconsistency, imprecision and potential publication bias.

Conclusions Current evidence remains uncertain regarding the effect of BLT on delirium incidence in hospitalised adults. Further high-quality studies are needed to determine effectiveness, identify optimal intervention characteristics and clarify the role of sleep-related mechanisms in delirium prevention.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This systematic review used a broad, comprehensive search strategy across five major databases, enhancing wide coverage of relevant controlled trials, improving methodological robustness.
⇒ Study selection, data extraction and risk of bias assessment were conducted using predefined methods, enhancing the rigour and reproducibility of the review process. A narrative synthesis that systematically examined protocolisation of BLT parameters for delirium prevention, applying rigorous assessment of potential sources of bias across included studies.
⇒ Limited number of studies with circadian rhythm assessments constrained mechanistic insights.
⇒ Variability in BLT protocols across included studies affected comparability and synthesis.

PROSPERO registration number CRD42020193040.

BACKGROUND

Delirium is an acute neurocognitive condition that is associated with serious health and social outcomes.[1 2] It is a clinical condition involving an acute change in cognition, arousal and attention[3] that is observed in one in four hospitalised older people[4] and over two-thirds of intensive care unit (ICU) admissions.[5] A single episode of delirium in hospital is associated with accelerated cognitive and functional decline, longer stay, institutionalisation (ie, placement into residential aged care), an increased risk of dementia and early mortality.[6] The financial burden is also significant due to the substantial additional healthcare utilisation required to manage it, placing strain on healthcare resources. A recent systematic review found the per-case cost of delirium to range from

US$806 to US$24 509 (2019 US dollars).[7] Using Kinchin *et al*'s per-case estimates,[7] the annual financial burden of delirium could be estimated to be between US$1.61 and US$49.02 billion of healthcare expenditure.

There are no effective treatments for delirium[8]; however, there is strong evidence that non-pharmacological, multicomponent interventions targeting modifiable risk factors such as sleep-wake cycle disturbances, vision and hearing, immobility, dehydration and nutrition, orientation and cognition reduce incident delirium by one-third.[9–12] Despite their effectiveness and significant cost-savings to the health system,[13] complete adherence to these delirium prevention protocols can be challenging, especially for older adults with underlying chronic health issues, frailty, fatigue and functional decline.[14] Furthermore, high patient to nurse ratios, limited staff time and competing clinical priorities can affect both the delivery and sustainability of these interventions.[15 16] As a result, adoption of these interventions into routine clinical practice continues to be inconsistent, contributing to avoidable cases of delirium and patient suffering.[16–19]

Sleep-wake cycle disturbances, including insomnia, sleep fragmentation, daytime sleepiness and disturbed circadian rhythms, are consistently identified as a common clinical feature of delirium in both diagnostic criteria and clinical studies.[20–24] Meta-analyses show that pre-existing or perioperative sleep-wake cycle disturbances significantly increase the risk of developing delirium, especially postoperative delirium, with ORs ranging from 2.90 (95% CI 2.28 to 3.69, p≤0.001)[25] to 3.73 (95% CI 2.34 to 5.96; p=0.05).[26] Melatonin is a hormone that plays a major role in sleep, helping to regulate circadian rhythms in response to light exposure during the day and darkness at night.[27 28] Bright light therapy (BLT), which mimics natural exposure to daylight, has emerged as a potential non-pharmacological, single-component intervention for restoring and maintaining circadian rhythm, demonstrating efficacy in many different patient cohorts including people with dementia, seasonal affective disorder and cancer.[29–31]

Currently, there is no evidence or consensus on how BLT should be applied and at what settings for the prevention of delirium in hospitalised adults. For circadian rhythm disturbances, clinical studies suggest that BLT should be administered in the morning, soon after waking, with avoidance of evening bright light[32–34]; the light source should be positioned in front of the user at eye level, ensuring that the light enters the eyes while the person is awake and facing the device.[34 35] Standard BLT protocols typically involve exposure to ~10 000 lux for approximately 30 min to improve circadian, sleep and cognitive outcomes, although lower intensities (2500–5000 lux) applied for longer durations (60–120 min) may also yield comparable effects.[34 36 37] This pattern suggests an intensity-duration trade-off, whereby different combinations of light intensity and exposure time (eg, 10 000 lux for 30 minutes vs 2500 lux for 2 hours) may deliver similar overall light exposure and circadian effects, consistent with a dose-response relationship.[33 38 39] Further research should examine whether BLT prevents delirium in hospitalised adults, define optimal protocols and assess if its effects are linked to circadian rhythm regulation.

Research into delirium prevention is essential to reduce its impact. Moreover, prevention of delirium offers the potential to prevent future cases of dementia, currently an incurable condition that is responsible for over 1.6 million deaths each year.[40 41] Thus, the objective of this study was to systematically review international data on BLT as a delirium prevention intervention for hospitalised adults, building on previous findings[29] by examining protocolisation, adherence and safety, impact on circadian rhythm and delirium incidence.

METHODS

A systematic review and meta-analysis, reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[42] The review was registered in the PROSPERO database (CRD42020193040). The databases Scopus (Elsevier), MEDLINE (Ovid), EMBASE (Ovid), CINAHL (EBSCO) and PsycINFO (Ovid) were originally searched in October 2020, with no date limitation. The search strategy was split into two core concepts using a combination of words related to 'delirium' and 'bright light therapy' (see online supplemental file 1 for full Search Strategy). The database search using the original search strategy was re-run in March 2024 to retrieve any new records published since 2020 (search 2) and again in October 2025 to retrieve new records published from 2024 to current (search 3). Finally, the references of included studies were manually searched for any additional studies eligible for inclusion.

Selection criteria

Using the PICOS framework (Population, Intervention, Control, Outcomes, Study design),[43] one reviewer searched for randomised controlled trials (RCTs), non-RCTs and pilot RCTs (PICOS) that evaluated the effectiveness of BLT in preventing delirium (PICOS) in hospitalised adults (>18 years; PICOS). Any type of BLT (eg, portable, fixed or other forms of lighting control) was included if it was delivered with the intention of preventing delirium. Although delirium is more common in older adults (>65 years), we did not apply an age restriction to the population criteria. This ensured that our search captured all studies evaluating BLT for delirium prevention, allowing us to examine which populations have been targeted and whether intervention effects differ across age groups. Hospitalised adults were those admitted to any hospital setting (eg, ICU, palliative care, oncology wards) without delirium at intervention commencement.

No limit was set on the comparator (PICOS). Studies were included if they assessed delirium incidence, severity and/or duration and reported intervention effects using validated outcome measures for delirium (PICOS).

Studies that did not evaluate BLT as an independent prevention method for delirium were excluded.

Data extraction and quality assessment

The 2020 search results were imported into Endnote V.X7 software (Thomson Reuters, New York, New York, USA) and duplicates were removed. Title and abstract screening were carried out in Endnote V.X7 by two independent investigators (RSM and MG) according to predetermined inclusion and exclusion criteria. Investigators recorded inclusion and exclusion reasons in Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA) and discrepancies were resolved through discussion. Study reports that passed the initial screening process were progressed to full-text screen where investigators systematically reviewed each for eligibility and documented reasons for exclusion. Discrepancies were resolved by consensus and, when necessary, with a third investigator (MA).

In 2024 and 2025, another investigator (LME) re-ran the original search strategy, imported search results into Endnote V.X7 software and removed duplicates. All results published between 2021 and 2024 (search 2) and 2024 and 2025 (search 3) were exported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) where the inclusion/exclusion criteria were applied to the title and abstract screen. Two investigators (LME, KC and RSM) independently reviewed individual articles to check eligibility and documented reasons for exclusion. Discrepancies were again identified by consensus and resolved through discussion with a third reviewer (RSM). All articles that were excluded at full text screen are available in online supplemental file 2.

Three authors (LME, MG and KC) extracted data using a piloted Microsoft Excel V.15.28 spreadsheet, which captured the first author's last name, publication year, study design, setting, intervention and control characteristics, participant characteristics and outcome measures and findings. Data extraction was cross-checked by LME and RSM, and any discrepancies were resolved by discussion and consensus among the review team.

Risk of bias was assessed at the outcome level for delirium incidence using the revised Cochrane Risk of Bias tool for randomised trials (version 2; RoB-2).[44] The RoB-2 evaluates bias across five domains: (1) bias arising from the randomisation process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in measurement of the outcome and (5) bias in selection of the reported result. Each domain was judged as low risk, some concerns or high risk of bias.

For non-RCTs, the Risk Of Bias In Non-randomised Studies of Interventions (ROBINS-I) tool was applied. This tool evaluates bias across seven domains: (1) bias due to confounding; (2) bias in selection of participants; (3) bias in classification of interventions; (4) bias due to deviations from intended interventions; (5) bias due to missing data; (6) bias in measurement of outcomes and (7) bias in selection of the reported result. These domains consider sources of bias arising before, during and after the implementation of the intervention, with particular attention to confounding, participant selection and baseline imbalances inherent to non-randomised study designs. Outcome-specific judgements were judged as low, moderate, serious or critical risk of bias. Two investigators independently evaluated each study (RSM, MG 2020 data; LME and KC 2021–2025 data), with discrepancies resolved by discussion.

Blinding of participants and personnel delivering the intervention is inherently difficult for visible interventions such as BLT. This was considered within the relevant risk of bias domains and instead greater emphasis was placed on whether outcome assessors or research personnel were blinded, as this was deemed more relevant for minimising bias in outcome assessment.

Publication bias and small-study effects were explored using funnel plots generated in Stata V.19 software (Stata). Contour-enhanced funnel plots were used to visually assess symmetry of study effects and their distribution across regions of statistical significance.

Certainty of evidence for each outcome was assessed using theGrading of Recommendations Assessment, Development and Evaluation (GRADE) approach,[45] considering the domains of risk of bias, inconsistency, indirectness, imprecision and publication bias. As all included studies were controlled trials, evidence was initially rated as high and downgraded based on these domains. This assessment was conducted post hoc, as it was not specified in the PROSPERO protocol.

Data synthesis and meta-analysis

Tables and text were generated to report study and intervention characteristics and outcomes pertaining to BLT protocolisation, adherence and safety, impact on circadian rhythm and delirium incidence. Extracted data were narratively synthesised to provide a comprehensive and integrated overview of the evidence pertaining to each outcome.

Meta-analyses were performed in Stata V.19 software (Stata)[46] to examine the effects of BLT compared with controls on changes to circadian regulation and the incidence of delirium. Our analysis required a minimum of two studies that reported each outcome. A pooled risk ratio (RR) with 95% CIs was calculated. Statistical significance was determined with a p value of<0.05. A random effects meta-analysis, performed using the Restricted Maximum Likelihood (REML) estimator, was used to account for clinical and methodological heterogeneity among the various BLT interventions, clinical settings and patient populations.

Heterogeneity was assessed by visual inspection of the forest plots and I^2 statistics. The variance between studies was measured using the tau-square (Tau^2). The level of heterogeneity was classified as I^2=0%–24%: low; I^2=25%–49%: moderate; I^2=50%–74%: substantial and

I^2=75%–100%: considerable heterogeneity. To assess the robustness of the pooled effect estimates, we conducted a leave-one-out sensitivity analysis. In this approach, the meta-analysis was repeated iteratively, each time omitting one study from the dataset. This allowed us to evaluate the influence of individual studies on the overall pooled effect size and its statistical significance, and to identify whether the findings were disproportionately driven by any single trial.

To further explore how BLT protocols may impact outcomes, exploratory sensitivity analyses were undertaken based on intervention features identified during the review process as per the intervention subgroup analyses outlined in the review protocol. Models were restricted to studies delivering BLT within recommended therapeutic ranges for circadian regulation, including face-directed light exposure of ≥2500 lux and morning administration, delivered within intensity-duration established protocols (eg, 10 000 lux for 30 minutes or 2500 lux for 120 min). Due to the small number of studies, formal subgroup analyses and meta-regression were not performed because such approaches would be underpowered and potentially unreliable. Consequently, these sensitivity analyses should be interpreted as exploratory and hypothesis-generating.

Patient and public involvement

This study involved two consumers (people with lived experience), who joined the research team after study conception, as invited coauthors. They actively contributed to shaping the research questions and outcome measures by reviewing all protocol drafts prior to the development of the search strategy, ensuring alignment with consumer priorities, experiences and preferences. Recruitment of consumer representatives was based on their prior involvement in related projects within the Improving Palliative, Aged and Chronic Care through Clinical Research and Translation (IMPACCT) research centre, leveraging their expertise and familiarity with the research context. No formal assessment of the burden of the intervention and time commitment was undertaken; however, these consumers will continue to be engaged in a subsequent phase II study that will evaluate the feasibility and tolerability of BLT for delirium prevention. Furthermore, they will play a key role in the dissemination of study findings to ensure accessibility and relevance to the broader patient and public community.

RESULTS

Across the three searches conducted in 2020, 2024 and 2025, a total of 1150 records were identified. Following title and abstract screening, 44 records underwent full-text review. Four studies were included from the 2020 search, four additional studies were identified in the 2024 search, and no new eligible studies were found in the 2025 search. In total, eight studies met the eligibility criteria and were included in this review (figure 1).

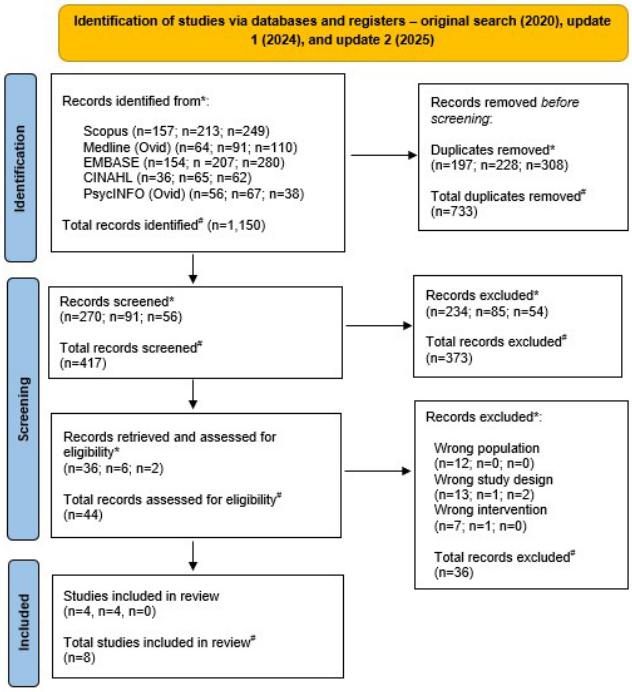


Figure 1 PRISMA diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Study characteristics

Of the eight studies conducted between 2007 and 2023, two were from the USA,[47 48] two from Japan[49 50] and one each from China,[51] the Netherlands,[52] Thailand[53] and Türkiye[54] (table 1). Five studies were RCTs,[48 49 51–53] one non-randomised control trial,[54] one randomised 'experimental intervention study'[50] and one feasibility RCT.[47] Of the eight included studies, six were conducted in an ICU,[48–50 52–54] one in an emergency department (ED)[47] and one in an unspecified hospital setting.[51]

Incident delirium was an outcome in seven studies.[47–50 52–54] Five studies used the Confusion Assessment Method (CAM) or CAM-ICU[47 48 52–54] to measure incident delirium and two used the Japanese version of the NEECHAM Confusion Scale.[49 50] The remaining study[51] assessed delirium severity over time, using the CAM severity scale. In this study,[51] authors reported the mean change in CAM severity scores between groups over time rather than delirium incidence.

Five studies[47 48 52–54] used more than one assessment as part of delirium evaluation, incorporating delirium-specific tools alongside measures of level of sedation or consciousness, such as the Richmond Agitation-Sedation Scale (as a required component of the CAM-ICU),[48 54] the Glasgow Coma Scale (also a component of the CAM-ICU),[54] the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition,[53] Delirium Observation Screening scale[52] and by chart review.[47]

Table 1 Study characteristics

Characteristic	Number (%)	Reference
Country of origin		
Japan	2 (25)	49 50
USA	2 (25)	47 48
China	1 (12.5)	51
Netherlands	1 (12.5)	52
Thailand	1 (12.5)	53
Republic of Türkiye	1 (12.5)	54
Study design		
Randomised controlled trial (RCT)	5 (62.5)	48 49 51–53
Non-RCT	1 (12.5)	54
A randomised 'experimental interventional study'	1 (12.5)	50
Feasibility RCT	1 (12.5)	47
Target population		
Adults (>18 years)	4 (50)	48 49 51 52
Middle to older adults (>50 years)	2 (25)	50 53
Older adults (>65 years)	2 (25)	47 54
Hospital setting (health area)		
Surgical Intensive Care Unit (SICU)	3 (37.5)	49 50 53
SICU and Medical Intensive Care Unit	2 (25)	48 52
Intensive care unit	1 (12.5)	54
Emergency department	1 (12.5)	47
Hospital setting not clear	1 (12.5)	51
Outcomes		
Delirium incidence	7 (87.5)	47–50 52–54
Adherence to treatment protocol	6 (75)	47–49 51–53
Duration of delirium	3 (37.5)	48 52 53
Adverse event (headaches and/or photophobia)	2 (25)	51 53
Changes to rest-activity levels	2 (25)	49 50
Changes to circadian rhythm	1 (12.5)	52
Delirium severity	1 (12.5)	49
Delirium risk	1 (12.5)	53
Delirium assessment		
Confusion Assessment Method (CAM) or CAM-ICU	5 (62.5)	47 48 52–54
Japanese version of the NEECHAM Confusion Scale	2 (25)	49 50
CAM delirium severity scoring	1 (12.5)	51

Six studies measured adherence to BLT protocols[47–49 51–53] and two measured adverse events (headaches and/or photophobia).[51 53] Only one study measured the effect of BLT on circadian rhythms, specifically endogenous biological processes, by examining the patterns of melatonin and cortisol levels.[52] Two other studies assessed the effects of BLT on rest-activity cycles via actigraphy (a small wristwatch-like device that continuously records movement).[49 50]

Intervention and control characteristics

Each study used a different BLT device with variations in both the timing and duration of application (ie, dose) (table 2). Seven BLT devices were portable and were placed in front of participants' faces.[47–51 53 54] The remaining study used a ceiling-mounted device which 'was at the level of the participant's head'.[52] The location of the portable BLT devices ranged from 50 cm[51] to 140 cm[53] from the participant's face. Three studies[47 49 50] did not report the distance from the participants but noted that the device was either next to their bed[49 52] or in front of their face.[50]

Notably, there was marked heterogeneity in the technical specifications and application of BLT devices across studies. Intensity-duration ranged from 1700 lux for two and a half hours[52] to 14 000 lux for 30 min,[51] with a median intensity-duration of approximately 5000 lux for 60–120 min.[47 49 50 53] Two studies reported the BLT colour[48 52] and two reported the temperature[47 52] of BLT applied. Most studies did not report BLT colour[47 49–51 53 54] or temperature.[48–51 53 54]

BLT intervention characteristics, dose, participant protocol and comparator

BLT was applied once daily in seven studies.[47–51 53 54] Of which, five applied BLT in the morning (between 7:00 and 11:30),[48–51 53] one applied BLT in the afternoon (12:00 to 14:00)[54] and one applied BLT between 6:00 and 22:00.[47] Only one study applied BLT twice,[52] once between 9:00 to 11:30 and again between 13:30 and 16:00. Four studies delivered BLT for a set number of days, ranging from 3,[53] 4[49 50] and up to 28 days[51]; three studies exposed participants to BLT for the length of their hospital admission[47 48 52] and one study did not report treatment duration.[54]

Some studies reported other BLT protocol requirements: three studies reported that participants could close their eyes during treatment[48 49 52]; two required participants to lie horizontally during BLT exposure[50 53]; one allowed participants to move freely during treatment[48]; another reported that participants could

Table 2 BLT intervention characteristics, dose, participant protocol and comparator

	BLT device characteristics			BLT dose				
Author, year	Name of device	Location of device	Brightness (lux) Temperature (K) Colour	Number and length (minutes) of treatment	Time of administration	Intervention duration (days)	Other protocols	Comparator
Keene *et al* 2023[47]	Full-spectrum lightbox	On a table next to the participant's bed	5000 lux 6500K Colour=NR	Once daily (excluding weekends) for 120 min	Between 10:00 and 18:00	Until participant left ED (mean duration 3.6)	BLT was not administered on Saturdays or Sundays.	Standard lighting (Lux NR)
Çavuşoğlu and Yılmaz, 2022[54]	Daylight lamp	60–80 cm away from the participant's face with light angled at 60°	10 000 lux K=NR Colour=NR	Once daily for 120 min	12:00–14:00	NR	The intervention group implemented nursing interventions to prevent delirium. Sound level was controlled by reducing the volume of alarms, by speaking in a low voice during the delivery or having conversations in a different environment rather than around the participant. The indoor humidity level was between 30% and 60% in line with WHO recommendations. Participants were warned not to look directly at the lamp. They were allowed to use glasses or hearing aids if they had, and a large written clock and calendar were hung somewhere they could easily see.	Routine care in the ICU, including orientation techniques (Lux NR)
Zou *et al*, 2022[51]	Light source	50 cm from participant's face	14 000 lux K=NR Colour=NR	Once daily for 30 min	9:00–9:30	28	NR	Dim light with a brightness of 50 lux.

Continued

Table 2 Continued

Author, year	BLT device characteristics			BLT dose			Other protocols	Comparator
	Name of device	Location of device	Brightness (lux) Temperature (K) Colour	Number and length (minutes) of treatment	Time of administration	Intervention duration (days)		
Zhang *et al*, 2021[48]	Carex Day-Light Classic Plus BLT Sun Lamp	30–45 cm from the head of the bed	10 000 lux K=NR Glare-free white light	Once daily for 30 min	7:00–7:30	Until participant left ICU (mean duration 3; range 2–5.5)	Participants can freely change their position in bed or adjust the bedframe angle to dull the direct brightness of the BLT.	Usual care and exposed to standard light brightness of 150 lux in the ICU
Potharajaroen *et al*, 2018[53]	BLT	140 cm from the participant's face	5000 lux K=NR Colour=NR	Once daily for 120 min	9:00–11:00	3	Participants were positioned at a 30°–40° position during BLT.	Usual care and exposed to a light source of 500 lux
Simons *et al*, 2016[52]	Ceiling mounted lighting system	Level with the participant's head	1700 lux 4300K (that achieves a brightness of 800–1000 lux) Bluish white light	Twice daily for 150 min (each treatment)	9:00–11:30 and 13:30–16:00	Until participant left ICU (mean duration 5; range 3–9)	NR	Usual care with standard light settings of 300 lux (and 3000K), up to 1000 lux for procedures.
Ono *et al*, 2011[49]	BLT	In front of the participant's face	5000 lux K=NR Colour=NR	Once daily for 60 min	8:00–9:00	4	Participants can spend their time freely with their eyes closed or by watching television.	Usual care with normal light conditions. There were variations in interior lighting intensity based on the weather, season and bed position, but these variations were within 1000 lux.

Continued

Table 2 Continued

Author, year	BLT device characteristics			BLT dose			Other protocols	Comparator
	Name of device	Location of device	Brightness (lux) Temperature (K) Colour	Number and length (minutes) of treatment	Time of administration	Intervention duration (days)		
Taguchi *et al*, 2007[50]	BLT	100 cm immediately before the participant's eyes	5000 lux K=NR Colour=NR	Once daily for 120 min	7:30–9:30	4 (mean duration 2.8)	Light at night was turned off in the ICU between 09:00 and 22:00 to 6:00 the next morning. Body position during BLT was the supine or semi-Fowler in most participants, but the height of the entire bed was adjusted to allow the participants to watch television in the Fowler position or sitting position if they wished to do so. Nurses helped participants rinse their mouth or brush teeth and clean their faces at about 7:00 before commencement of BLT.	Usual care with natural lighting environment (Lux NR)

BLT, bright light therapy; ED, emergency department; ICU, intensive care unit; K, temperature; NR, not reported.

watch television.[49] Environmental factors (known as Zeitgebers) are external cues that can disrupt circadian rhythms. Two studies[50 54] controlled for various environmental factors. One study controlled for light at night, sound and humidity in the BLT group, as well as offering delirium-risk prevention (eg, cognitive stimulation)[54]; while the other study controlled for light at night only.[50] Two studies reported room configuration, with one allocating participants to single-occupancy rooms[54] and another to four-bed occupancy rooms.[50]

Six control groups received usual care with 'standard lighting'.[47–50 52 54] Three of which did not report standard lighting brightness,[47 50 54] one reported standard lighting brightness of 150 lux,[48] another at 300 lux[52] and one reported that normal light conditions varied in intensity based on the weather, season and bed position, but these variations were within 1000 lux.[49] The remaining two studies controlled the lighting brightness for the control group exposing participants to 50 lux in one study[51] and 500 lux in the other.[53] Finally, one study reported controls could be exposed to 1000 lux during procedures.[52] Across these studies, it was unclear what controls were doing during this exposure (eg, eyes open/closed, distance to light source) and for how long they were exposed to this intensity.

Intervention limitations

Across the included studies, some limitations in BLT and participant protocols were noted: one study did not administer BLT on weekends (Saturday or Sunday) resulting in treatment gaps[47]; one study allowed participants to move freely during BLT to 'dull the effects'[48]; one study had a ceiling mounted device meaning the light source was not emitted directly into participants' eyes[52]; and three studies reported that participants could close their eyes during treatment[48 49 52] (table 2). One study explicitly reported that they did not control for environmental zeitgebers,[48] and it was unclear in the remaining five studies.[47 49 51–53] Moreover, room configuration was unclear in six studies.[47–49 51–53]

Risk of bias assessment

Risk of bias was assessed at the outcome level for delirium incidence using the RoB-2 for randomised studies[47–50 52 53] and the ROBINS-I for non-randomised studies[54] (figure 2). Zou *et al* did not report the overall incidence of delirium, instead reporting changes in delirium severity scores over time and is therefore not included.[51]

Bias arising from the randomisation process

Most studies used random allocation procedures; however, two studies were judged to be at high risk of bias

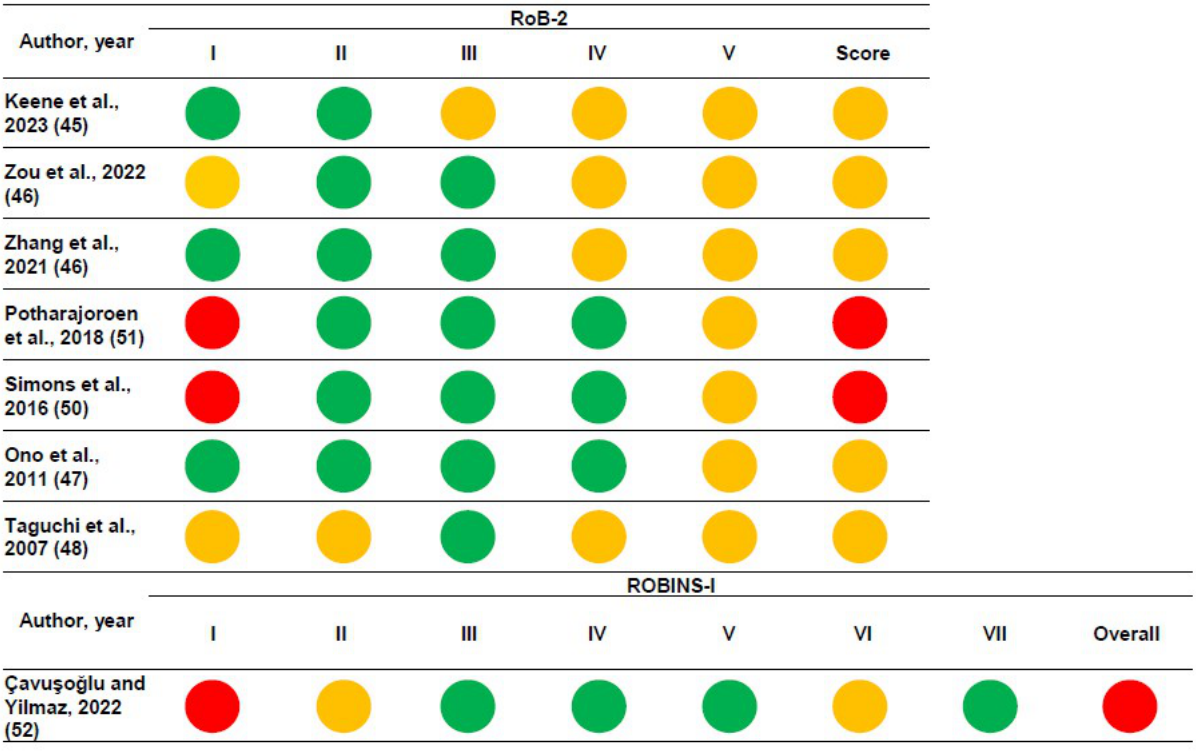


Figure legend: Colours - Red = High/serious risk; Yellow = Some concerns/moderate risk; Green = Low risk ;
RoB-2 domains: I – bias arising from the randomisation process; II – bias due to deviations from intended interventions; III – bias due to missing outcome data; IV – bias in measurement of the outcome; V – bias in selection of the reported result
ROBINS I domains: I – bias due to confounding; II – bias in selection of participants; III – bias in classification of interventions; IV – bias due to deviations from intended interventions; V – bias due to missing data; VI – bias in measurement of outcomes; VII – bias in selection of the reported result.

Figure 2 Outcome-level risk of bias assessment for delirium incidence using RoB-2 and ROBINS-I. ROBINS-I, Risk Of Bias In Non-randomised Studies of Interventions; RoB-2, revised Cochrane Risk of Bias tool for randomised trials, version 2.

due to non-random allocation methods[53] or important baseline imbalances between intervention groups.[52] One additional study had some concerns because insufficient information was provided regarding the sequence generation or allocation concealment.[50]

Bias due to deviations from intended interventions

Blinding of participants and personnel was not reported in any study, which is expected given the visible nature of BLT interventions. However, no studies reported substantial protocol deviations that were likely to have influenced delirium outcomes, resulting in low risk of bias in this domain.

Bias due to missing outcome data

No study had missing outcome data. Consequently, this domain was rated as low risk.

Bias in measurement of the outcome

Delirium incidence was assessed using validated diagnostic tools across studies.[47–50 52 53] Three studies were considered to have lower risk of bias due to blinding of outcome assessors and/or research staff.[49 52 53] The remaining studies did not report assessor blinding, resulting in some concerns regarding outcome measurement.[47 48 50]

Bias in selection of the reported result

Selection of the reported result was the domain associated with the greatest uncertainty. Most studies lacked prospective protocols or sufficient reporting to determine whether analyses were pre-specified, resulting in some concerns across this domain.[47–50 52 53]

ROBINS-I study

One non-randomised study[54] was assessed using the ROBINS-I and judged to be at serious risk of bias overall. Key concerns relate to confounding, participant selection and outcome measurement. The serious rating was driven by sequential group allocation, recruitment of study groups during different seasons, baseline group differences and unblinded outcome assessment.[54]

Publication bias

Visual inspection of the contour-enhanced funnel plot suggested some asymmetry, with studies distributed unevenly around the pooled effect estimate (figure 3). Smaller studies appeared more widely scattered and were predominantly located on one side of the funnel, whereas larger, more precise studies clustered closer to the centre. Most studies fell within regions of non-significance ($p > 0.10$), with fewer studies in areas corresponding to higher statistical significance. However, given the small number of included studies and their methodological heterogeneity, interpretation of funnel plot asymmetry is limited.

Participant characteristics

Across the studies, a total of 1190 participants were enrolled, with males representing 42.3%[53] to 100%[49 50] of

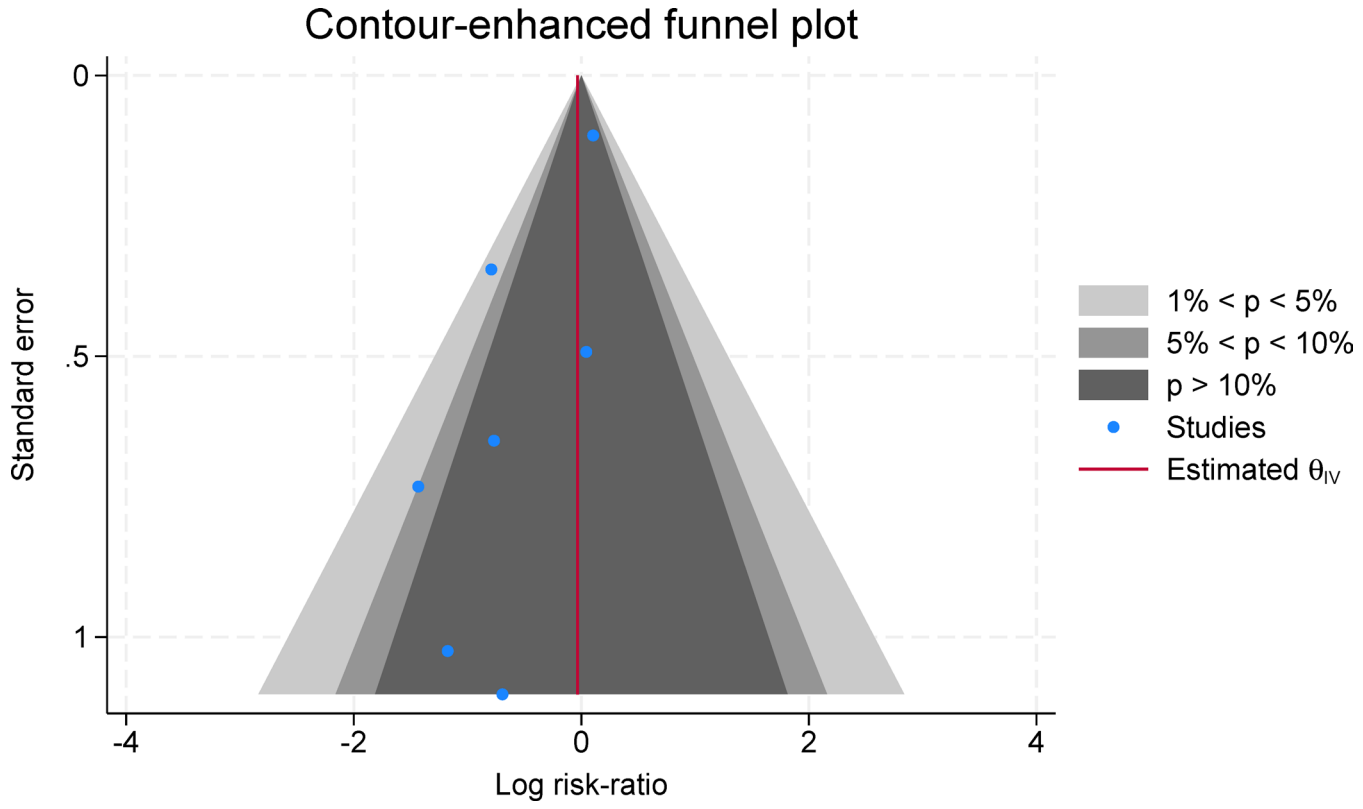


Figure 3 Meta funnel plot graph.

the samples (table 3). The mean age of participants across studies ranged from 57.6[50] to 83.0[47] years. Three studies involved participants with a mean age <65 years,[48–50] whereas the remaining five studies predominantly enrolled older adults (≥65 years).[47 51–54] Across studies, participants generally had significant acute or chronic illnesses, including cognitive impairment,[47] Alzheimer's dementia,[51] postoperative recovery[49 50 53] and critical illness requiring ICU care.[48 52 54] While two studies used strict exclusion criteria to control for psychiatric, neurological or sensory comorbidities,[51 54] others reflected more clinically heterogeneous and thus representative patient populations.[47 48 52]

Four studies reported that participants were prescribed sedative medications,[48–50 52] one of which reported that some participants were sedated during BLT treatment.[48] It was unclear in the remaining three whether participants were sedated during BLT treatment.[49 50 52] The remaining four studies did not specify whether participants were prescribed sedatives or not during the study period.[47 51 53 54] Three studies reported that a proportion of participants were medically ventilated during the trial,[48 52 54] with ventilated participants comprising 29.0%[48] to 65.0%[52] of the BLT groups.

Intervention adherence and safety reporting

Six studies[47–51 53] reported adherence rates to the BLT treatment protocols, all of which concluded that BLT was a feasible intervention and that the majority (66.7%–100%) of BLT participants were able to complete the required treatment protocols (table 3). Intervention cessation rates varied between 1.6%[53] and 33.3%[47] of BLT participants. Two studies reported reasons for BLT cessation, including participants finding the BLT 'too bright' or 'distracting when they wished to do something else, like sleep or read'[47] and 'could not tolerate the brightness'.[49] Keene *et al* also reported that BLT was better tolerated when the ceiling light remained on.[47] Two studies[48 52] reported that headaches and/or photophobia would be monitored as adverse events, but none were reported by participants or staff. Two other studies did not specify in their methods that adverse events would be captured[51 53]; however, one reported no treatment-emergent adverse events or worsening of pretreatment status[53] and the other noted that no participants experienced adverse reactions after BLT exposure.[51]

Changes in circadian rhythms and rest-activity cycles

One study reviewed the effects of BLT versus standard lighting on circadian rhythm regulation[52] (table 3). In this study, analysis of circadian rhythm markers showed a significantly longer circadian cycle in the BLT group (24.1±3.2 hours) compared with the control group (21.9±1.5 hours). Continuous activity monitoring revealed no between-group differences in hourly counts of movement until the night of day 3. From the night of day 4 onwards, the BLT group demonstrated significantly lower activity counts at 2:00, 4:00, 6:00 and 7:00 on day 4 and at 4:00 and 7:00 on day 5, suggesting a shift in nocturnal activity patterns consistent with circadian rhythm adjustment.

Two studies reviewed the effects of BLT on daily rhythms using rest-activity cycles.[49 50] Of which, one study found that there was a significant lengthening of daily rhythms in the BLT group compared with controls (24.1±3.2 vs 21.9±1.5)[49]; suggesting that BLT can adjust the postoperative rest-activity cycle. The remaining study reported no significant changes in rest-activity cycles between groups.[50]

Delirium incidence

Delirium incidence among BLT participants ranged from 6.5%[53] to 38.0%[52] compared with 17.5%[48] to 86.7%[54] among controls (table 3). Three studies reported that BLT significantly reduced delirium compared with controls,[51 53 54] three reported non-significant reductions[47 50 52] and the remaining two found no difference in incident delirium between groups.[48 49]

Meta-analysis

Seven studies were included in the meta-analysis examining the incidence of delirium as an outcome.[47–50 52–54] Zou *et al* was excluded as they did not report the overall incidence of delirium, instead reporting changes in CAM severity scores over time.[51]

The overall pooled analysis indicated an uncertain effect of BLT on delirium incidence (RR 0.64, 95% CI 0.38 to 1.07; p=0.09), with moderate between-study heterogeneity (I^2=52.06%; figure 4A). Leave-one-out sensitivity analysis demonstrated that the overall findings were generally stable (RRs ranging from 0.51 to 0.73). However, the magnitude and statistical significance of the pooled estimate were sensitive to inclusion of Simons *et al*,[52] with its exclusion resulting in a statistically significant effect (RR 0.51 (95% CI 0.32 to 0.80, p=0.003) (figure 4B). As the largest study included in the meta-analysis, Simons *et al*[52] contributed substantial weight to the pooled estimate, indicating that the overall result was sensitive to inclusion of this study.

A sensitivity analysis restricted to studies delivering higher-intensity BLT (≥2500 lux), consistent with commonly applied therapeutic parameters, excluded Simons *et al*, which used a ceiling-mounted 'dynamic lighting' system with lower brightness intensity (1700 lux) and indirect light exposure.[52] In this analysis, pooled estimates indicated a statistically significant reduction in delirium (RR 0.51; 95% CI 0.32 to 0.80; p<0.001), with low observed heterogeneity (I^2≤0.01%; figure 4C). A further sensitivity analysis restricted to studies applying BLT in the morning, aligned with circadian-based therapeutic principles, excluded both Çavuşoğlu and Akman Yılmaz and Simons *et al*, who delivered BLT after 12:00.[52 54] In this model, the pooled estimate suggested a reduction in delirium that did not reach statistical significance (95% CI 0.27 to 1.05; p=0.07) with low between-study heterogeneity (I^2=13.79%; figure 4D).

Table 3 Study results

Author, year	Results		
	Setting, sample size and characteristics (sex and age*, years)	Delirium	Other outcomes
Keene *et al*, 2023[47]	ED N=155 (n=33 BLT, n=35 music and BLT vs n=32 control group) Male: 39.4% (BLT group), 34.3% (BLT+ music group), and 31.2% (control group) Age, median (IQR): 83 (11) BLT, 83 (8) BLT+music, and 84 (12) control group.	Delirium incidence: BLT three (9.1%); music+BLT eight (22.9%); control seven (21.9%); p=0.125.	Adherence: 11 (33.3%) of BLT participants, and 7 (20.0%) in the BLT+music group requested intervention discontinuation due to BLT being too bright and/or distracting when they wished to do something else, like sleep or read. BLT was more tolerable when the ceiling light was on.
Çavuşoğlu and Yilmaz, 2022[54]	ICU N=60 (n=30 BLT vs n=30 control group) Male: 66.7% (BLT group) and 60.0% (control group) Age: 76.7±8.0 (BLT group) and 74.7±8.5 (control group).	Delirium incidence: BLT eight (26.7%); control 26 (86.7%); p=0.03.	Environmental factors: significant relationship found between humidity level and delirium (data and p value NR). Reducing the sound level decreased the risk of delirium (data and p value NR). The effect of temperature level on delirium could not be examined.
Zou *et al*, 2022[51]	Hospital N=69 (n=35 BLT vs n=34 control group) Male: 47.1% (BLT group) and 44.4% (control group) Age: 75.9±9.5 (BLT group) and 73.0±9.3 (control group).	Delirium incidence: NR CAM severity scores over time: BLT significantly suppressed average delirium severity (p=<0.01). After 4 weeks of BLT, the CAM severity score decreased from 29.82±3.79 to 17.65±3.47	Adherence: During the 4 weeks of treatment, 8 (11.6%) participants discontinued the study. Adverse events: No participants experienced adverse reactions after BLT exposure.
Zhang *et al*, 2021[48]	Surgical and medical ICU N=78 (n=38 BLT vs n=40 control group) Male: 55.3% (BLT group) and 60.0% (control group) Age, median (IQR) 63.5 (46.5–75.0) BLT and 64.0 (48.0–75.0) control group.	Delirium incidence: BLT seven (18.0%); control seven (17.5%); p=0.999.	Adherence: 97.4%. One participant requested to turn the light off 10 min into their scheduled 30-minute BLT session on their second to last day in the ICU. Adverse events: No adverse events from either the patients or ICU care team were reported.
Potharajaroen *et al*, 2018[53]	Surgical ICU N=61 (n=30 BLT vs n=31 control group) Male: 50.0% (BLT group) and 38.7% (control group) Age: 68.1±9.5 (BLT group) and 68.3±13.1 (control group).	Delirium incidence: BLT two (6.5%); control 11 (35.5%); p=0.005.	Adherence: 60 (98.4%) participants completed the 3-day study treatment; one (1.6%) participant discontinued the study. Adverse events: No new treatment-emergent adverse events or adverse effects that worsened the pretreatment status were reported.
Simons *et al*, 2016[52]	Medical and Surgical ICU N=734 (n=361 BLT vs n=373 control group) Male: 58.0% (BLT group) and 59.0% (control group) Age: 66.3±12.8 (BLT group) and 64.4±13.7 (control group).	Delirium incidence: BLT 137 (38.0%); control 123 (33.0%); p=0.16.	Adherence: 100% Adverse events: Dynamic lighting was well tolerated by patients and staff, with no adverse events reported. Changes in daily rhythms: No differences between BLT and control groups in average hourly excretion of 6-sulfatoxymelatonin; cortisol excretion during night-time or morning periods or 24-hour total excretion of these markers.

Continued

Table 3 Continued

Author, year	Results Setting, sample size and characteristics (sex and age*, years)	Delirium	Other outcomes
Ono *et al*, 2011[49]	Surgical ICU N=22 (n=10 BLT vs n=12 control group) Male: 100% Age: 63.4±9.7 (BLT group) and 63.8±7.8 (control group).	Delirium incidence: BLT one (10.0%); control five (42.0%); authors noted no significant difference between groups (p value NR).	Adherence: Two (20%) participants complained that they could not tolerate the brightness of the BLT and dropped out. Circadian rhythm markers: Frequency analysis found circadian spectrum cycle was 24.1±3.2 hours for the intervention group vs 21.9±1.5 hours for the control group. Authors reported this difference was significant (p value NR). As a result of continuously counting the movements in level-mode, there was no difference in the hourly counts until the night of day 3. However, from the night of day 4 onwards, the count was lower in the study group and significant differences were observed at 2:00, 4:00, 6:00 and 7:00 during the night-time of day 4 and at 4:00 and 7:00 during the night-time of day 5.
Taguchi *et al*, 2007[50]	Surgical ICU N=11 (n=6 BLT vs n=5 control group) Male: 100% Age: 57.2±14.1 (BLT group) and 59.2±14.1 (control group).	Delirium incidence: BLT one (16.0%); control two (40.0%); p=0.47.	Changes in daily rhythms: no significant difference was noted in the activity level between the two groups.

*Age is reported as mean±SD unless otherwise stated.
BLT, bright light therapy; CAM, Confusion Assessment Method; ED, emergency department; ICU, intensive care unit; NR, not reported.

Certainty of evidence

The certainty of evidence for delirium outcomes, assessed using GRADE, was rated as very low due to risk of bias, inconsistency across studies, imprecision related to small sample sizes and limited number of studies and potential publication bias (table 4).

DISCUSSION

This systematic review and meta-analysis synthesised evidence on the use of BLT for delirium prevention in hospitalised populations and, to our knowledge, is the first synthesis of this intervention in this context. The eight included studies involved diverse patient populations, intervention protocols and outcome measures. Although three individual studies reported reductions in delirium incidence, the pooled analysis demonstrated an uncertain effect of BLT on delirium incidence, with moderate heterogeneity, and the overall certainty of evidence was rated very low. Consequently, the current evidence base is insufficient to draw conclusions regarding the effectiveness of BLT for delirium prevention in hospitalised adults.

Exploratory sensitivity analyses indicated that differences in intervention characteristics, particularly light intensity and timing, may contribute to variability in observed effects. In particular, studies utilising daily morning application (7:30–11:00), administering 5000 lux for 120 min or 10 000 lux for 30–60 min, directly emitted towards the face at distances of approximately 30–140 cm, over 3–4 consecutive days, demonstrated more favourable outcomes. These protocols broadly align with established therapeutic parameters for BLT.[32–34 38 39]

These findings suggest that both the intensity and timing of BLT are likely important considerations in BLT protocol design. The importance of these parameters is biologically plausible, as high-intensity, face-directed light exposure is required to stimulate retinal pathways involved in circadian entrainment, while morning administration is critical for suppressing melatonin secretion and reinforcing circadian alignment.[32–34] However, these findings should be interpreted with caution, as the sensitivity

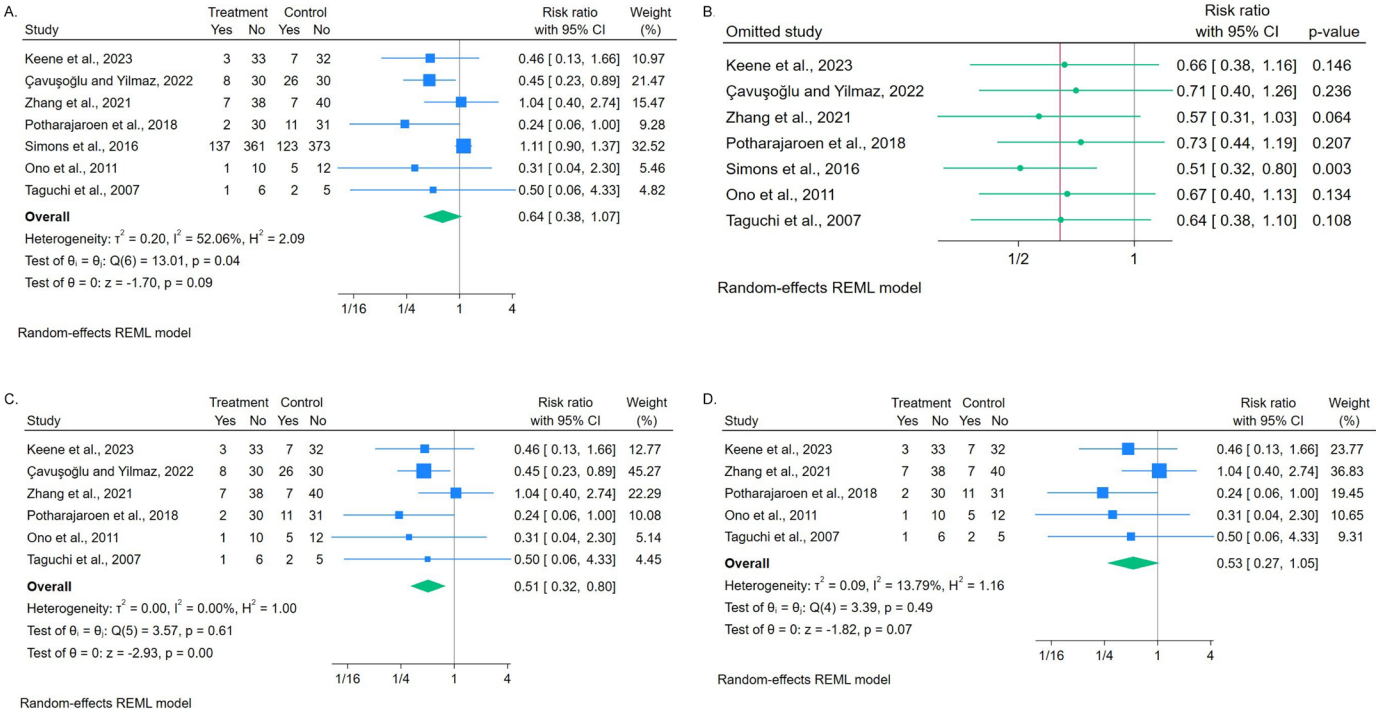


Figure 4 Meta forest plots. (A) The effect of bright light therapy on the incidence of delirium; (B) Sensitivity analysis–leave-one-out; (C) The effect of bright light therapy with a light intensity of 2500 lux or more on the incidence of delirium; (D) The effect of morning application of bright light therapy on the incidence of delirium. REML, Restricted Maximum Likelihood.

analyses were exploratory and based on a limited number of studies. As such, these results cannot establish causal relationships but may help guide protocol development for future research.

BLT appeared feasible under controlled trial conditions, with several studies reporting high adherence and no adverse events. However, adverse event monitoring and adherence reporting were inconsistently defined and measured, with limited detail regarding how tolerability was assessed. In addition, several studies reported that participants had their eyes closed during BLT exposure, which may substantially reduce retinal light exposure and therefore compromise intervention fidelity. Consequently, recorded exposure intensity and duration may not reflect the effective therapeutic dose, raising concerns that adherence may be overestimated. While BLT appears feasible in some acute care contexts, conclusions regarding tolerability, safety and effective treatment exposure remain uncertain.

The certainty of evidence was rated as very low using the GRADE framework, primarily due to study risk of bias, inconsistency, imprecision and potential publication bias. Outcome-level risk of bias assessment for delirium incidence identified concerns relating to the randomisation process, measurement of the outcome and selection of reported results, with several studies judged to have some concerns or high risk of bias. In addition, incomplete reporting of intervention delivery and co-interventions and concomitant medication use limited confidence in the findings. Inconsistent reporting and use of sedatives is clinically relevant, given the established association between sedative exposure (particularly benzodiazepines) and increased risk of delirium.[55 56] Failure to adequately account for these factors may have influenced observed estimates of the effect of BLT on delirium incidence.

Funnel plot analysis suggested some asymmetry; however, this may reflect a combination of small-study effects, clinical heterogeneity and potential publication bias. Given the limited number of studies (<10), formal interpretation is unreliable and should be considered exploratory.

Nevertheless, these findings are notable in the context of existing delirium prevention strategies. While multicomponent non-pharmacological interventions are effective, their implementation in routine clinical practice is often challenging due to resource constraints, staff burden and environmental limitations.[16] Factors such as nocturnal disruptions, shared rooms and limited access to mobility resources or family support further complicate delivery.[14 57 58] Above all, underlying conditions, frailty, pain and/or fatigue can make it difficult for hospitalised older adults to engage in prevention activities.[14 58 59] In this context, BLT may represent a complementary approach that could be integrated into existing care pathways. Its relatively low cost and ease of implementation make it an attractive option[29 60]; however, its effectiveness and value relative to established multicomponent interventions

Table 4 Certainty of evidence for delirium incidence (GRADE)

Outcome	No. of studies (participants)	Factors that may decrease certainty of evidence					Overall certainty of evidence	Key messages
		Limitations	Inconsistency	Indirectness	Imprecision	Reporting bias		
Delirium incidence	7 studies (n=1121)	Serious (unclear/ randomisation issues, deviations from intervention, blinding limitations)	Serious (heterogeneity in BLT protocols and populations)	Not serious	Very serious (small sample sizes, wide confidence intervals)	Suspected	⊕◯◯◯ Very low	Considerable variation in BLT intensity, duration and adherence

BLT, bright light therapy; GRADE, Grading of Recommendations Assessment, Development and Evaluation.

remain unclear, particularly in the absence of formal cost-effectiveness evaluations.

Circadian disruption is a recognised contributor to delirium in critically ill hospitalised adults,[61 62] and BLT is hypothesised to exert effect through restoration of circadian alignment.[63 64] Although improvements in circadian rhythm alignment were observed in one study[52] and enhanced daily rhythms (via rest-activity cycles) in another,[49] only one demonstrated statistically significant effects.[49] The evidence supporting this proposed BLT mechanism of action remains inconclusive. Future studies should incorporate objective measures of circadian rhythm and sleep to determine whether changes in these pathways mediate clinical effects. Without such data, the proposed mechanism of action remains largely speculative.

Limitations

This review identified several limitations related to both the included studies and the review process. Many trials omitted to report or account for key clinical and contextual factors that may influence delirium risk and intervention effectiveness. These included sedation exposure, polypharmacy, ventilation status, co-interventions and participant alertness (eg, eyes open) during BLT delivery. Reporting on participant activity, sleep-related factors (including sleep hygiene interventions and sleep outcomes), and environmental conditions such as background light exposure, light at night, noise and room configuration was also limited. These factors are closely linked to circadian dysregulation and delirium risk,[60 65–67] and their inconsistent measurement introduces potential confounding, limiting the ability to isolate the effects of BLT.

In addition, several studies included participants with pre-existing cognitive impairment or dementia, which may complicate delirium assessment due to overlapping clinical features.[68 69] However, these populations remain highly relevant, as they are at increased risk of delirium and represent a key target group for prevention interventions[70]; excluding them would limit clinical relevance and raise ethical concerns regarding equitable representation.[68 69] Together, these limitations restrict understanding of how BLT should be optimally applied and hinder interpretation of its true therapeutic effect.

The small number of studies included and substantial heterogeneity in study designs and BLT protocols mean the meta-analytic findings should be interpreted as hypothesis-generating rather than confirmatory. Furthermore, most studies were conducted in intensive care settings, restricting the generalisability of findings to broader hospital populations.

Additional methodological limitations should be considered; assessment of publication bias was limited by the small number of included studies and heterogeneity, reducing the reliability of funnel plot interpretation. Restriction to English-language publications may have introduced language bias, as potentially relevant

non-English studies could have been excluded during the title and abstract screening.

Future trials should employ adequately powered, randomised designs that standardise BLT protocols, including the precise reporting of brightness intensity, duration, timing and spectral characteristics. Ensuring adequate retinal light exposure (eg, eyes open during intervention) will be essential to maintain intervention fidelity. Studies should also incorporate consistent outcome measures for delirium and circadian alignment, systematically monitor adverse events using a recommended framework for non-pharmacological interventions,[71] and comprehensively report co-interventions and environmental conditions. Multisite studies across diverse care settings would further strengthen the evidence base and help identify protocols most likely to be effective in routine clinical practice.

Conclusions

This review provides insight into the potential role of BLT as a non-pharmacological intervention for delirium prevention in hospitalised populations. The current evidence remains uncertain regarding the effectiveness of BLT to reduce delirium incidence, with very low certainty of evidence influenced by risk of bias, heterogeneity in intervention protocols and outcome measures, and imprecision arising from small sample sizes. Although several studies reported favourable adherence and tolerability, these outcomes were inconsistently measured and reported. Further high-quality research is required to determine whether BLT reduces delirium incidence, identify optimal intervention characteristics, and clarify the role of circadian and sleep-related mechanisms.

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Contributors RSM and LME contributed equally to this work and are joint first authors. RSM is the guarantor for this manuscript. RSM and MA initiated the project. Project administration was managed by LME and RSM. The methodology was developed by RSM and LME, with validation by LME. Data extraction was performed by LME, RSM, KC and MG. Data curation, formal analysis and visualisation were undertaken by LME. The original draft of the manuscript was prepared by LME and refined by RSM, AH, SC, IK, GC, IG, IAD, VY and MA. Supervision was provided by RSM, SC and MA. All authors contributed to the manuscript and have read and approved the final version.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data sharing not applicable as no datasets generated and/or analysed for this study. All data generated or analysed during this study are included in this published article. Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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