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Scotland

NHS SCOTLAND

Effect of Openable Windows on the Health and Wellbeing of Building Users in Acute Healthcare Settings

Systematic Literature Review

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NHS Scotland Assure

Contents

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1. Introduction

Background

1.1. A systematic literature review was commissioned by NHS Scotland Assure's Property, Sustainability, and Capital Planning team to examine the effect of openable windows on the health and wellbeing of building users in acute healthcare settings and explore the perceptions and experiences of this population in this regard. The review was executed as part of a recent scoping review on window and door design. Although scoping reviews are generally broad, a more targeted strategy was used to provide an overview of specific window and door design features of interest, including openable windows. The findings of this systematic literature review identified and synthesised the best evidence currently available regarding openable windows to support Subject Matter Experts (SMEs) in the development of technical guidance, including that for windows,[1, 2] circulation spaces,[3] ventilation,[4, 5] and Healthcare Associated Infection Systems for Controlling Risk in the Built Environment (HAI-SCRIBE).[6, 7] To date, there are no existing or ongoing systematic literature reviews in this topic area.

Aim and review questions

Aim

1.2. This systematic literature review identified and synthesised the best evidence examining the effect of openable windows on the health and wellbeing of building users in acute healthcare settings and exploring the perceptions and experiences of this population in this regard. The review used an interdisciplinary approach and considered quantitative, qualitative, and mixed methods research. Although focused on acute healthcare settings, relevant evidence from other non-acute healthcare settings were included if generalisable and transferable, except for studies investigating infection prevention and control outcomes, which were restricted to acute healthcare settings. Outcomes assessed covered physical and mental health and wellbeing outcomes, staff-related outcomes, and environmental outcomes known to influence building user health and wellbeing, following approaches used in other reviews.[8-10]

Review questions

1.3. RQ1. **What is the best evidence examining the effect of openable windows on the health and wellbeing of building users in acute healthcare settings and exploring the perception and experiences of this population in this regard?**

2. Methods

2.1. This systematic literature review was conducted per the Standard Operating Procedure: Healthcare Scientist Technical Team Literature Review Process[11] and the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.[12, 13] The list below represents the key processes. Refer to Appendix A for detailed methods.

- **Eligibility criteria** – An inclusion and exclusion criteria was developed to guide all aspects of the review, this included detailing the population(s), exposure(s)/ intervention(s) and comparator(s), outcome(s), setting(s), study type(s), and other criteria.
- **Search strategy** – The search strategy for this systematic literature review is detailed in Appendix B. It was executed in February 2025 as part of a recent scoping review on window and door design.
- **Report selection** – Title/ abstract screening and full text screening was conducted independently by two reviewers, where a third reviewer resolved any conflicts. The PRISMA flow diagram documenting this process is presented in Appendix C.
- **Critical appraisal** – Each of the included studies were critically appraised to assess their methodological quality using a series of checklists.
- **Data extraction** – Data was extracted from the selected studies and included author(s), year of publication, source of origin, country of origin, aims/ purpose, methodology/ methods, study design, setting, population/ sample, exposure(s)/ intervention(s), comparator(s), measure(s), outcome(s), key finding(s), and limitations.
- **Data synthesis** – The synthesis was informed by the Joanna Briggs Institute (JBI) methodology for mixed-methods reviews.[14] Findings were reported by outcome, as per similar approaches used in other reviews,[8-10] including ‘Physical health and wellbeing outcomes’, ‘Mental health and wellbeing outcomes’, ‘Staff-specific outcomes’, and ‘Environmental outcomes’.
- **Confidence assessment** – A summary of each finding was produced, accompanied by an assessment of the confidence in the evidence supporting that finding. The confidence assessments were based on five key criteria, each of which was assigned one of four potential levels of concern. An overall confidence level was then assigned to the findings using the results of the five key criteria. Each finding was assigned one of the four overall confidence levels.[11] Further information is detailed in Table 2.1.

Table 2.1 - Confidence assessment assignment criteria

Confidence assessment	Criteria and levels
Five criteria for developing confidence assessments	• The type of evidence and its limitations – Evaluates the quality and reliability of the evidence, including any methodological limitations/ risk-of-bias and type of study design or report • Relevance – Assesses how applicable the evidence is to the review question, considering the context and scope • Adequacy of the data – Determines whether the evidence is sufficient in terms of quantity and depth to support the review finding • Coherence – Examines how clear and cogent the fit is between the evidence and the review finding itself, including consistency across different evidence sources (contradictions within the evidence are explicitly addressed and factored into this criterion) • Potential publication bias – Evaluates whether the findings could be skewed due to selective publication practices
Four levels of concern for each criteria	• No or very minor concerns – Unlikely to reduce confidence in the review finding • Minor concerns – May reduce confidence • Moderate concerns – Likely to reduce confidence • Serious concerns – Very likely to reduce confidence in the review finding
Four overall finding confidence levels	• High confidence - Strong, consistent evidence from multiple high-quality reports; little or no doubt about the reliability of the finding • Moderate confidence – Some uncertainty due to variability in quality, quantity, or consistency of evidence; the finding is likely reliable, but concerns are present • Low confidence – Substantial uncertainty; the evidence is limited or inconsistent, raising doubts about the reliability of the finding • Very low confidence – High uncertainty; serious limitations in the evidence suggest the finding may not be reliable

3. Results

Report inclusion

3.1. After screening and critical appraisal five studies were included in this review. The study characteristics and findings table are detailed in Appendix E.

3.2. The outcomes from the screening process were recorded in the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram in Appendix C. Three thousand four hundred and eighty-four reports were identified from database searches (Medline, n = 546; Embase, n = 853; PsycInfo, n = 79; CINAHL, n = 273; Scopus, n = 942; Web of Science, n = 791). One thousand eight hundred and thirty reports were duplicates and excluded. A first screening (titles and abstracts) was conducted on the remaining 1,654 reports, and 1,462 were excluded. Second screening (full texts) of the remaining 192 reports was conducted, with 187 excluded. Appendix D contains the excluded reports.

3.3. Forty-two reports were identified from other methods searches, including databases for grey literature (n = 3) and backwards and forward citation searching (n = 39). Full texts of the reports were retrieved and assessed. All were excluded.

3.4. A total of five studies were included, two of which originated (that is, the location of the first author) from the USA. The other reports were from South Korea (n = 1), Germany (n = 1), and China (n = 1).

3.5. Three of the included five studies had quantitative observational methodology/ methods. Of which, all had cross-sectional analytical study designs. One report had quantitative experimental methodology/ methods and a quasi-experimental study design. One report had qualitative methodology/ methods and study design.

Methodological quality

3.6. Critical appraisal assessments are detailed in Appendix F. Of the five studies that were critically appraised, three studies had ‘Very minor methodological concerns’ (quasi-experimental, n = 1;[15] cross-sectional analytical, n = 1;[16] qualitative, n = 1)[17], one cross-sectional analytical study had ‘Minor methodological concerns’,[18] and another had ‘Moderate methodological concerns’.[19] No studies were excluded.

Evidence synthesis/ themes

3.7. There were four pre-specified themes, as per similar approaches used in other reviews,[8-10] including 'Physical health and wellbeing outcomes', 'Mental health and wellbeing outcomes', 'Staff-specific outcomes', and 'Environmental outcomes'. However, no studies assessed 'Staff-specific outcomes'. For 'Physical health and wellbeing outcomes', there was only one sub-theme: 'Nosocomial infection rates'. For 'Mental health and wellbeing outcomes' and 'Environmental outcomes' there were two corresponding sub-themes, including 'Thermal comfort and other comfort related factors' and 'Preferences', and 'Air exchange rates' and 'Built environment microbiome', respectively. Where available, statistics including confidence intervals and probability values (p-values) are detailed.

3.8. This review identified five findings; their study characteristics are provided in Appendix E. Confidence assessment tables for these are detailed in Appendix G. All findings were assessed as 'Very low confidence'. This was due to 'Serious concerns' regarding adequacy of data, including data volume (that is, all findings were only supported by a single study), data richness (that is, data saturation), and publication bias.

Physical health and wellbeing outcomes

3.9. One study examined the effect of openable windows on the physical health and wellbeing of building users in acute healthcare settings.

Nosocomial infection rates

3.10. One study[18] examined the effect of openable windows on nosocomial infection rates in patients in acute healthcare settings. The quantitative observational, cross-sectional analytical study by Stiller et al.[18] examined the effect of different healthcare built environment design features, including openable windows, on nosocomial infection rates in patients in intensive care units in Germany, using the Krankenhause-Infektions-Surveillance-System (KISS), between March and June 2015. Findings indicated that patient rooms with openable windows had a significantly lower likelihood of device-associated lower respiratory tract infections, compared to patient rooms with non-openable windows (odds ratio = 0.73, 95% confidence interval 0.58 to 0.90, $p < 0.01$). There was no association between the availability of an air conditioning system in patient rooms and device-associated infection rates.

3.11. The finding of this sub-theme was that openable windows in acute healthcare settings reduced nosocomial infection rates in patients. This was assessed as 'Very low confidence', details of the evidence grading assessment for finding 1 can be found in Appendix G.

Mental health and wellbeing outcomes

3.12. Two studies examined the effect of openable windows on the mental health and wellbeing of building users in acute healthcare settings.

Thermal comfort and other comfort-related factors

3.13. One study[19] explored the perceptions and experiences of patients and visitors regarding openable windows in acute healthcare settings and its links to thermal comfort and other comfort-related factors. The quantitative observational, cross-sectional analytical study by Xiao et al.[19] examined both pregnant women and their families' reasons together regarding opening/ closing windows in a maternity ward in Ningbo, China, in March 2019. Findings show the most frequently reported factors for window opening and closing were 'a little hot' (55.10%) and 'cold' (50.34%), respectively. The most frequently reported reasons for window opening were 'stuffy' (65.99%), 'hot' (59.18%), and 'low indoor air quality' (57.14%). The most frequently reported reasons for window closing were 'outdoor noise' (59.18%), 'cold' (55.10%), and 'windy' (53.74%).

3.14. The finding of this sub-theme was that patient's and visitor's reasons for window opening/ closing were linked to thermal comfort and other comfort-related factors, including indoor air quality and noise, in acute healthcare settings. This was assessed as 'Very low confidence', details of the evidence grading assessment for finding 2 can be found in Appendix G.

Preferences

3.15. One study[17] explored resident's preferences regarding openable windows in non-acute healthcare settings. The qualitative study by Bae and Asojo[17] explored the perceptions of residents on their living environment in long term care facilities in Midwest USA, with reference to the theory of supportive design. Findings suggested that residents hoped to have an openable window to let in fresh air. An openable window was related to the element of perceived control in the theory of supportive design.

3.16. The finding of this sub-theme was that residents preferred to have openable windows, albeit in non-acute healthcare settings. This was assessed as 'Very low confidence', details of the evidence grading assessment for finding 3 can be found in Appendix G.

Environmental outcomes

3.17. Two studies examined the effect of openable windows on the environmental outcomes related to the health and wellbeing of building users in healthcare settings.

Air exchange rates

3.18. One study[15] the quantitative, quasi-experimental report by Srikanth et al.[15] investigated the effects of low-cost interventions, including window opening/ closing, on summer air exchange rates in resident rooms in two long term care facilities in Sedro-Woolley and Mount Vernon, Washington, USA. Both facilities had heating, ventilation, and air conditioning (HVAC) systems in the hallways, but the system in Sedro-Woolley facility was not operational during testing. Both bedrooms had openable windows and baseboard heating. Bedrooms in Sedro-Woolley facility had a bathroom exhaust fan, whereas bedrooms in Mount Vernon had infiltration from the hallway HVAC system.

3.19. The scenarios tested were combinations of doors open/ closed, windows open/ closed, and window fan on/ off. The authors state that, regardless of whether the door is opened or closed, opening a window significantly increased the mean air exchange rate in residents' rooms compared to a closed window.

3.20. The finding of this sub-theme was that compared to a closed window, an open window significantly increases air exchange rates in residents' rooms in non-acute healthcare settings. This was assessed as 'Very low confidence', details of the evidence grading assessment for finding 4 can be found in Appendix G.

Built environment microbiome

3.21. One study[16] investigated the effects of openable windows on environmental microbiome.[16] The quantitative, cross-sectional analytical study by Kembel et al.[16] examined the effect of mechanical and natural ventilation on the structure and diversity of microbiome in patient rooms in an acute hospital in Milwaukie, Oregon, USA, in February 2010.

3.22. The study found that building attributes, specifically the source of ventilation air, airflow rates, relative humidity and temperature, were correlated with the diversity and composition of indoor bacterial communities. The phylogenetic diversity of airborne bacterial communities was lower indoors than outdoors, and mechanically-ventilated rooms contained less diverse microbial communities than did window-ventilated rooms. The indoor environment contained bacterial communities with many taxa that are absent or rare outdoors, including taxa closely related to potential human pathogens.

3.23. With respect to potentially pathogenic bacteria, the study found that irrespective of ventilation source (mechanical versus window), the relative abundance of potentially pathogenic bacteria taxa (that is, with a 97% or greater sequence similarity to known human pathogens) significantly decreased with increasing airflow rates ($p = 0.04$), air changes per hour ($p = 0.004$), and relative humidity ($p = 0.02$).

3.24. Based on these findings, the authors interpreted their data to suggest that reducing direct contact with the outdoor environment may not always be an optimal design strategy for bacterial pathogen management. The finding of this sub-theme was that increasing indoor airflow rates, air changes per hour, and relative humidity reduced potentially pathogenic bacteria in healthcare settings. This was assessed as ‘Very low confidence’, details of the evidence grading assessment for finding 5 can be found in Appendix G.

4. Discussion

Implications for practice

4.1. This systematic literature review identified and synthesised the best evidence on the effect of openable windows on the health and wellbeing of building users in acute healthcare settings. As well as exploring the perceptions and experiences of this population in this regard. Within this review, scientific principles related to five criteria were applied: (1) type of evidence and methodological limitations, (2) relevance, (3) adequacy, (4) coherence, and (5) publication bias. This review identified five studies, which resulted in five findings. All findings being assessed as 'Very low confidence'. This was due to 'Serious concerns' regarding adequacy of data, including data volume (that is, all findings were only supported by a single study) and data richness (that is, data saturation), and publication bias. This review presents a transparent, scientifically derived evidence base. Importantly, Subject Matter Experts (SMEs) may use this evidence, together with their own expertise, contextual knowledge and professional judgement, to inform any use within their own decision-making and guidance development processes.

Implications for research

4.2. Evidence from this review indicated that there was a lack of high-quality evidence examining the effect of openable windows on the health and wellbeing of building users in acute healthcare settings. Of the five studies, three focussed on service users, one of which additionally surveyed visitors. No studies focused on staff members.

4.3. Only one study focussed on the theme of physical health and wellbeing outcomes. Two studies focussed on the theme of mental health and wellbeing outcomes, with a further two focused on environmental outcomes.

4.4. Only one study had quantitative experimental methodology/ methods, with a quasi-experimental study design. Similarly, only one study had qualitative methodology/ methods and study design.

4.5. Future high-quality research should be conducted to elucidate this topic area, including all building users and a wide range of health and wellbeing outcomes, methodology/ methods, and study designs.

Review limitations

4.6. This review had several limitations. For instance, this systematic literature review was nested within a recent scoping review on window and door design. Specifically, this review was executed using the included studies identified within the scoping review. As a result, although the search strategy was deemed to be sufficient for use within this review, it included search terms that were not relevant to the aim and review question. The main exclusion reasons at second screening were largely established within the scoping review and, as such, they may not be the main reason for exclusion within this review, but these studies would have nevertheless remained excluded.

4.7. Although this review searched seven databases, three key journals, and conducted backwards and forward citation searches, it is possible that some relevant studies were not identified. The eligibility criteria required studies to be published in peer reviewed journals, meaning that relevant unpublished or non-peer-reviewed work was not included. Whilst the search strategy was extensive, the possibility of publication bias cannot be entirely excluded. Given that only peer-reviewed studies were eligible and a small number of studies were ultimately identified, there remains a chance that additional studies, particularly grey literature or studies with different or null/ negative findings, may exist outside the peer-reviewed domain and were therefore not captured. This does not imply that the included studies are biased or that contradictory evidence should have been found. Rather, it acknowledges a standard limitation of reviews restricted to published academic literature.

4.8. Other limitations are that this review excluded studies that were not written in the English language due to resource constraints. Physical mock-up/ in-situ, in-vitro (laboratory testing), and computer/ numerical simulation studies were excluded due to the absence of a relevant critical appraisal checklist. Finally, processes surrounding report selection, critical appraisal, data extraction, synthesis, and confidence assessments may have been influenced by human error and subjective opinion. Although best-practice methodological frameworks were used to guide the conduct of this review, subjective assessments within these processes are inherent and unavoidable.

5. Conclusion

5.1. This systematic literature review identified and synthesised the best evidence on the effect of openable windows on the health and wellbeing of building users in acute healthcare settings and explored the perceptions and experiences of this population in this regard. Five studies were identified, resulting in five review findings, listed below:

- openable windows reduced nosocomial infection rates in patients in acute healthcare settings
- pregnant women and their families' reasons for window opening/ closing were linked to thermal comfort and other comfort-related factors, including indoor air quality and noise, in acute healthcare settings
- openable windows were preferred among residents in non-acute healthcare settings
- compared to a closed window, an open window significantly increases air exchange rates in residents' rooms in non-acute healthcare settings
- irrespective of ventilation source (mechanical or window based), higher airflow rates, air changes per hour, and relative humidity were associated with a lower relative abundance of potentially pathogenic bacterial taxa in healthcare settings. Mechanically-ventilated rooms contained less diverse microbial communities than did window-ventilated rooms

5.2. In relation to the final review finding concerning environmental microbiology, the authors of the included study interpreted their data to suggest that reducing direct contact with the outdoor environment may not always be an optimal design strategy for bacterial pathogen management.

5.3. Overall, the review findings indicate that openable windows point towards their benefits in acute healthcare facilities. Nevertheless, the available evidence remains very limited. Only a small number of studies met the eligibility criteria: three included service users, one of which included visitors, and none recruited staff. Only one study examined physical health and wellbeing outcomes. Meanwhile, two examined mental health and wellbeing with a further two focused on environmental outcomes. Only one study used quantitative experimental methodology/ methods and only one other used qualitative methodology/ methods. These limitations resulted in 'Very low confidence' across all findings.

5.4. This review provides a transparent, scientifically derived evidence base that Subject Matter Experts (SMEs) can draw upon, together with their expertise and contextual knowledge, to inform their professional judgement. Further high-quality research, including a broader range of building users, outcomes, study designs, and methodological approaches, is needed to clarify and strengthen the evidence-base in this area.

6. References

The five studies included within the review are numbers 15-19.

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19. Xiao M, Deng W, Ma H, et al. Influence of subjective factors on window use in maternity hospitals in spring. Sustainability (Switzerland) 2024; 16.

Appendix A Detailed methods

Preliminary search

A.1 Preliminary searches were undertaken to determine whether any relevant systematic literature review had been conducted, examining physical and mental health and wellbeing, staff-specific, and environmental outcomes. Due to the lack of a consensus academic, policy, or practice-based definition, ‘building users’ were defined as individuals requiring access to a building, including staff, service users, and visitors. Service users were defined as any person(s) for which the specific service was created, including patients and residents (that is, of residential care settings). Searches were conducted in Scopus, Web of Science, Google Scholar, and International Prospective Register of Systematic Reviews (PROSPERO), and the Open Science Framework (OSF) using the search terms ‘window’, ‘open’, and ‘review’. No existing or ongoing systematic literature reviews were identified.

Search strategy

A.2 The search strategy for this systematic literature review is detailed in Appendix B. It was executed in February 2025 as part of a recent scoping review on window and door design. Although search strategies for scoping reviews are generally broad, a more targeted strategy was used to provide an overview of specific window and door design features of interest, including openable windows.

A.3 An initial limited search was conducted in Scopus and Google Scholar to identify pertinent studies focussing on window and door design and to gather search terms useful in developing the search strategy. This list of search terms, further refined by the Subject Matter Experts (SMEs) and through consultation with NHS Scotland’s Building Design and Construction (BDaC) group, guided the development of the search strategy. To avoid unduly narrowing the search and excluding relevant studies, the search strategy did not attempt to specify search terms for outcomes. The finalised search strategy included all identified keywords and index terms and was tailored to suit each included database and evidence source.

A.4 To ensure comprehensive coverage and best practice, were the review to extend beyond a year, the search process would have been revisited prior to the final synthesis to capture any new studies that emerged during the course of the review. Considering that no existing or ongoing systematic literature reviews were identified, the search strategy from the recent scoping review was deemed to be sufficient for use within this systematic literature review.

A.5 Searches were conducted in general academic electronic bibliographic databases, including Scopus (Elsevier) and Web of Science (Clarivate), biomedical and health sciences databases, including Embase (Ovid), Medline (Ovid), CINAHL (EBSCOhost), and PsycInfo (Ovid), and databases for grey literature, including Google Scholar, where only the first 50 to 100 reports were screened. Key journals were also searched, including the Health Environments Research and Design (HERD) Journal, the International Journal for Quality in Health Care, and Building and Environment. In addition to database and key journal searches, backwards and forward citation searching was conducted to identify additional reports. Although the protocol included an option to contact authors for additional details or clarifications, this was not required.

Eligibility criteria

Inclusion criteria

A.6 Population(s): Building users of health and care settings, including staff, service users, and visitors. Staff are any person(s) employed within the healthcare built environment, including, but not limited to, healthcare professionals, such as doctors and nurses, administrative staff, cleaning staff, and external contractors. Service users are any person(s) for which the specific service was created, including patients and residents (that is, of residential care settings). Visitors include family members or friends. The population were not restricted by sex, age, or other socio-demographic characteristics or presence or absence of a specific disease or condition.

A.7 Exposure(s)/ intervention(s) and comparator(s): Openable/ open and non-openable/ closed windows.

A.8 Outcome(s): Quantitative and qualitative indicators of health and wellbeing, including, but not limited to, physical and mental health and wellbeing, staff-specific, and environmental outcomes:

- physical health and wellbeing outcomes could include mortality, recovery, length of stay, falls, musculoskeletal injury, sleep, influence on circadian rhythms, and those relating to infection
- mental health and wellbeing outcomes could include quality of life, satisfaction, comfort, pain, stress, anxiety, and depression, and outcomes associated with a specific mental condition or illness.
- staff-specific outcomes could include work-related performance, productivity, concentration, work satisfaction, burnout, and errors with medications and other products or equipment

- environmental outcomes could include those for fire safety, noise, wind permeability, weather-tightness, watertightness, temperature, usability, and accessibility

A.9 Setting(s): Acute healthcare settings and other non-acute healthcare settings, including, but not limited to, intensive care units, inpatient and outpatient facilities, and nursing homes. Other settings were included if they report relevant generalisable and transferable insights into the effect of openable windows on the health and wellbeing of building users in acute healthcare settings.

A.10 Study type(s): Published peer-reviewed empirical research, including all relevant quantitative, qualitative, and mixed methods study designs.

A.11 Other criteria: Written in the English language. Published from 1980 onwards.

Exclusion criteria

A.12 Systematic and narrative reviews. However, these were used for backwards and forward citation searching. Dissertations, theses, conference proceedings, including abstracts and papers, and other unpublished and non-peer-reviewed empirical research.

A.13 Outcomes such as deliberate self-harm, vandalism, absconding due to the unique complexity of these issues.

A.14 Studies that focussed on natural or mechanical ventilation without specifying the effect of openable windows.

A.15 There were no limitations on country of publication. Despite this, were findings not to have applications within the context of western countries, that given study could be excluded. There were no such cases within this review.

A.16 Physical mock-up/ in-situ, in-vitro (laboratory testing), and computer/ numerical simulation studies were excluded due to the absence of a relevant critical appraisal checklist.

Report selection

A.17 Reports identified through the search strategy from the selected databases were exported to EndNote Version 21. The lead author was responsible for this initial step and the subsequent removal of duplicate entries. Once deduplication was complete, references from EndNote were transferred to an Excel spreadsheet, which served as the primary tool for recording screening decisions.

A.18 The review process involved two stages of screening. Initially, a first screening was conducted, involving reading the titles and abstracts of all reports to assess their relevance.

This was followed by a second screening, where the full texts of potentially eligible reports were examined in detail. Both screening stages were performed by two reviewers working independently. Any disagreements arising between the reviewers during any stage of the selection process was addressed through discussion. A third reviewer was called upon to resolve these conflicts if a consensus could not be reached.

A.19 The search results and the report inclusion process was reported in full using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram.[12, 13]

Critical appraisal

A.20 The critical appraisal checklists used to assess the methodological quality of studies included: modified versions of Joanna Briggs Institute (JBI) checklists for cross-sectional analytical and quasi-experimental studies and the Critical Appraisal Skills Programme (CASP) checklist for qualitative studies. Further details can be found in the Healthcare Scientist Technical Team Literature Review Process.[11]

Data extraction, synthesis and confidence assessment

A.21 Two authors were involved in the data extraction process, where the lead author extracted the data and a supporting author checked the entirety. Data extracted from the selected studies included author(s), year of publication, source of origin, country of origin, aims/ purpose, methodology/ methods, study design, setting, population/ sample, exposure(s)/ intervention(s), comparator(s), measure(s), outcome(s), key finding(s), and limitations. There were no modifications to the data extraction form as detailed in the protocol.

A.22 Data synthesis was informed by the JBI methodology for mixed-methods reviews.[14] Specifically, any quantitative data extracted from included studies was qualitised, that is integrated by transformation into qualitative data, utilising a standard convergent approach to data synthesis. A narrative synthesis was conducted for each summary finding. Findings were reported by outcome, as per similar approaches used in other reviews,[8-10] including ‘Physical health and wellbeing outcomes’, ‘Mental health and wellbeing outcomes’, ‘Staff-specific outcomes’, and ‘Environmental outcomes’. For any other findings that did not succinctly fit within these categories, a new category would have been created to accommodate these. However, there were no such cases within this review.

A.23 A summary of each review finding was produced, accompanied by an assessment of the confidence in the evidence supporting that finding. It is important to note that evidence within healthcare built environment research generally differs from other more established fields of clinical research. Due to the complex nature of healthcare built environment research, there are often architectural limits, operational practices, and ethical

considerations that make the conduct of high-quality studies, like randomised controlled trials (RCTs), unviable. For example, RCTs use strict randomisation and controlled conditions to reduce bias. However, studies within healthcare built environment research mostly takes place in complex, real-world settings where variables cannot be fully and ethically controlled. Nevertheless, these studies yet still offer meaningful and useful insights through quasi-experimental, observational, qualitative, mock-up, laboratory, and modelling studies. Despite this, the level of evidence is generally low, at least within traditional evidence hierarchies. Notwithstanding these limitations, assessing the confidence in evidence within healthcare built environment research is essential, where these assessments examine whether findings are supported by a high-quality, robust, and reliable evidence base and help to determine implications for practice and future research.

A.24 Each finding was assessed and assigned one of four confidence levels:

- high confidence – Strong, consistent evidence from multiple high-quality reports; little or no doubt about the reliability of the finding
- moderate confidence – Some uncertainty due to variability in quality, quantity, or consistency of evidence; the finding is likely reliable, but concerns are present
- low confidence – Substantial uncertainty; the evidence is limited or inconsistent, raising doubts about the reliability of the finding
- very low confidence – High uncertainty; serious limitations in the evidence suggest the finding may not be reliable

A.25 The confidence assessments were based on five key criteria:

- the type of evidence and its limitations – Evaluates the quality and reliability of the evidence, including any methodological limitations/ risk-of-bias and type of study design or report
- relevance – Assesses how applicable the evidence is to the review question, considering the context and scope
- adequacy of the data – Determines whether the evidence is sufficient in terms of quantity and depth to support the review finding
- coherence – Examines how clear and cogent the fit is between the evidence and the review finding itself, including consistency across different evidence sources (contradictions within the evidence are explicitly addressed and factored into this criterion)
- potential publication bias – Evaluates whether the findings could be skewed due to selective publication practices

A.26 Each criterion was assessed and assigned one of four potential levels of concern:

- no or very minor concerns – Unlikely to reduce confidence in the review finding
- minor concerns – May reduce confidence
- moderate concerns – Likely to reduce confidence
- serious concerns – Very likely to reduce confidence in the review finding

A.27 Crucially, confidence assessments provide an overall level of confidence in a finding (that is, a summary of the evidence), not the individual studies themselves. Further details can be found in the Healthcare Scientist Technical Team Literature Review Process.[11]

Appendix B Search terms and strategies

Table B.1 – Search terms

Search terms (1) – related to health and care settings	Search terms (2) – related to design	Search terms (3) – related to windows and doors	Search terms (4) – related to window or door design features
• hospital • health facility • healthcare facility • health care facility • acute facility • acute care facility • intensive care facility • critical care facility • intensive treatment facility • residential facility • care facility • nursing facility • health environment • healthcare environment • health care environment • acute environment	• design • construction • renovation • refurbishing • architecture • ergonomic • human factors	• window • door • door set • door way • entry • exit • entrance • building opening	• placement • position • location • layout • configuration • orientation • frame • assembly • ironmongery • size • shape • height • width • depth • thickness • weight • material • finish • feature • component • mechanism • operation • projection • barrier • façade • open

Search terms (1) – related to health and care settings	Search terms (2) – related to design	Search terms (3) – related to windows and doors	Search terms (4) – related to window or door design features
• acute care environment • intensive care environment • critical care environment • intensive treatment environment • residential environment • care environment • nursing environment • health institution • healthcare institution • health care institution • acute institution • acute care institution • intensive care institution • critical care institution • intensive treatment institution			• close • glass • glazing • curtain • lock • lockset • latch • catch • handle • hinged • sliding • spacer • louvre • grill • grille • vent • ventilation • circulation • airflow • air flow • crossflow • air gap • seal • view • outlook • light • lighting • daylight • sunlight

Search terms (1) – related to health and care settings	Search terms (2) – related to design	Search terms (3) – related to windows and doors	Search terms (4) – related to window or door design features
• residential institution • care institution • nursing institution • health unit • healthcare unit • health care unit • acute unit • acute care unit • intensive care unit • critical care unit • intensive treatment unit • residential unit • care unit • nursing unit • health department • healthcare department • health care department • acute department			• solar • pane • sill • cill • blind • shade • sash • bar • shutter • fastener • stay • restrictor • restraint • reflectivity • illumination • wall-ratio • wall ratio • leaf • leaves • light duty • medium duty • heavy duty • severe duty • high security duty • high-security duty • x-ray grade • penny farthing • penny-farthing • automatic

Search terms (1) – related to health and care settings	Search terms (2) – related to design	Search terms (3) – related to windows and doors	Search terms (4) – related to window or door design features
• acute care department • intensive care department • critical care department • intensive treatment department • residential department • care department • nursing department • health ward • healthcare ward • health care ward • acute ward • acute care ward • intensive care ward • critical care ward • intensive treatment ward • residential ward • nursing ward			• swing • doorplate • door plate • knob • undercut • under-cut • vision panel • buffer strip

Search terms (1) – related to health and care settings	Search terms (2) – related to design	Search terms (3) – related to windows and doors	Search terms (4) – related to window or door design features
• care ward • care home • nursing home			

Table B.1 - Database search strategies

Database/ Search date	Search string	Limits	Hits
Ovid MEDLINE(R) ALL <1946 to February 11, 2025>	1 health facility environment/ or hospitals/ or hospital units/ or exp intensive care unit/ or residential facilities/ or (hospital? or ((health or healthcare or health care or acute or acute care or intensive care or critical care or intensive treatment or residential) adj1 (facility or facilities or environment? or institution? or unit? or department? or ward?)) or ((care or nursing) adj1 (facility or facilities or environment? or institution? or unit? or department? or ward? or home?)) or ICU or CCU or ITU).ti,ab,kf. 1917005 2 evidenced based facility design/ or "hospital design and construction"/ or "facility design and construction"/ or architectural accessibility/ or built environment/ or "interior design and furnishings"/ or architecture/ or ergonomics/ or universal design/ or (design* or construct* or renovat* or refurbish* or architectur* or ergonomic* or human factor?).ti,ab,kf. 3439833 3 (window? or door* or door set? or door way? or entry or entries or entrance? or exit? or building opening?).ti,ab,kf. 384721 4 (placement? or position* or layout? or configur* or orient* or frame? or assembl* or	Not applicable	546

Database/ Search date	Search string	Limits	Hits
	ironmongery or size? or shape? or height? or width? or depth? or thickness* or weight* or material? or finish or finishes or finishing or feature? or component? or aspect? or mechanism? or operat* or project* or barrier? or facade? or open? or opening or opened or openable or close? or closing or closable or glass or glazing or curtain? or lock* or latch* or catch or catches or handle? or hing* or slid* or spacer? or louvre? or louver? or grill or grills or grille or grilles or vent* or circulat* or airflow? or air flow? or cross flow? or crossflow? or cross-flow? or air gap? or seal* or rating? or view? or outlook? or light? or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill? or blind? or shade? or shading or sash or sashes or bar or bars or shutter? or fasten* or stay? or restrictor? or restraint? or reflect* or illumin* or wall-ratio? or wall ratio? or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) adj1 duty) or x-ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate? or door plate? or knob? or undercut? or under-cut? or vision panel? or buffer strip?).ti,ab,kf. 15758066 5 1 and 2 and ((window? or door* or door set? or door way? or entry or entries or entrance? or exit? or building opening?) adj3 (placement? or position* or layout? or configur* or orient* or frame? or assembl* or ironmongery or size? or shape? or height? or width? or depth? or thickness* or weight* or material? or finish or finishes or finishing or feature? or component? or aspect? or mechanism? or operat* or project* or barrier? or facade? or open? or opening or opened or openable or		

Database/ Search date	Search string	Limits	Hits
	close? or closing or closable or glass or glazing or curtain? or lock* or latch* or catch or catches or handle? or hing* or slid* or spacer? or louvre? or louver? or grill or grills or grille or grilles or vent* or circulat* or airflow? or air flow? or cross flow? or crossflow? or cross-flow? or air gap? or seal* or rating? or view? or outlook? or light? or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill? or blind? or shade? or shading or sash or sashes or bar or bars or shutter? or fasten* or stay? or restrictor? or restraint? or reflect* or illumin* or wall-ratio? or wall ratio? or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) adj1 duty) or x-ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate? or door plate? or knob? or undercut? or under-cut? or vision panel? or buffer strip?)).ti,ab,kf. 586 6 limit 5 to (english language and yr="1980 -Current") 546		
Embase <1974 to 2025 February 10>	1 health care facility/ or hospital/ or hospital building/ or nursing home/ or exp intensive care unit/ or residential home/ or (hospital? or ((health or healthcare or health care or acute or acute care or intensive care or critical care or intensive treatment or residential) adj1 (facility or facilities or environment? or institution? or unit? or department? or ward?)) or ((care or nursing) adj1 (facility or facilities or environment? or institution? or unit? or department? or ward? or home?)) or ICU or CCU or ITU).ti,ab,kf. 3072602 2 hospital design/ or "construction work and architectural phenomena"/ or built environment/ or furniture/ or exp architecture/ or ergonomics/	Not applicable	853

Database/ Search date	Search string	Limits	Hits
	or (design* or construct* or renovat* or refurbish* or architectur* or ergonomic* or human factor?).ti,ab,kf. 4131083 3 (window? or door* or door set? or door way? or entry or entries or entrance? or exit? or building opening?).ti,ab,kf. 502587 4 (placement? or position* or layout? or configur* or orient* or frame? or assembl* or ironmongery or size? or shape? or height? or width? or depth? or thickness* or weight* or material? or finish or finishes or finishing or feature? or component? or aspect? or mechanism? or operat* or project* or barrier? or facade? or open? or opening or opened or openable or close? or closing or closable or glass or glazing or curtain? or lock* or latch* or catch or catches or handle? or hing* or slid* or spacer? or louvre? or louver? or grill or grills or grille or grilles or vent* or circulat* or airflow? or air flow? or cross flow? or crossflow? or cross-flow? or air gap? or seal* or rating? or view? or outlook? or light? or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill? or blind? or shade? or shading or sash or sashes or bar or bars or shutter? or fasten* or stay? or restrictor? or restraint? or reflect* or illumin* or wall-ratio? or wall ratio? or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) adj1 duty) or x-ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate? or door plate? or knob? or undercut? or under-cut? or vision panel? or buffer strip?).ti,ab,kf. 19296743 5 1 and 2 and ((window? or door* or door set? or door way? or entry or entries or		

Database/ Search date	Search string	Limits	Hits
	entrance? or exit? or building opening?) adj3 (placement? or position* or layout? or configur* or orient* or frame? or assembl* or ironmongery or size? or shape? or height? or width? or depth? or thickness* or weight* or material? or finish or finishes or finishing or feature? or component? or aspect? or mechanism? or operat* or project* or barrier? or facade? or open? or opening or opened or openable or close? or closing or closable or glass or glazing or curtain? or lock* or latch* or catch or catches or handle? or hing* or slid* or spacer? or louvre? or louver? or grill or grills or grille or grilles or vent* or circulat* or airflow? or air flow? or cross flow? or crossflow? or cross-flow? or air gap? or seal* or rating? or view? or outlook? or light? or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill? or blind? or shade? or shading or sash or sashes or bar or bars or shutter? or fasten* or stay? or restrictor? or restraint? or reflect* or illumin* or wall-ratio? or wall ratio? or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) adj1 duty) or x-ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate? or door plate? or knob? or undercut? or under-cut? or vision panel? or buffer strip?)).ti,ab,kf. 912 6 limit 5 to (english language and yr="1980 -Current") 853		
APA PsycInfo <1806 to February 2025 Week 1>	1 Hospitals/ or Hospital Environment/ or Nursing Homes/ or exp Intensive Care/ or Residential Care Institutions/ or (hospital? or ((health or healthcare or health care or acute or acute care or intensive care or critical care or intensive treatment or residential) adj1 (facility or	Not applicable	79

Database/ Search date	Search string	Limits	Hits
	facilities or environment? or institution? or unit? or department? or ward?)) or ((care or nursing) adj1 (facility or facilities or environment? or institution? or unit? or department? or ward? or home?)) or ICU or CCU or ITU).ti,ab,id. 213918 2 Human Factors Engineering/ or Built Environment/ or exp Architecture/ or (design* or construct* or renovat* or refurbish* or architectur* or ergonomic* or human factor?).ti,ab,id. 886684 3 (window? or door* or door set? or door way? or entry or entries or entrance? or exit? or building opening?).ti,ab,id. 75646 4 (placement? or position* or layout? or configur* or orient* or frame? or assembl* or ironmongery or size? or shape? or height? or width? or depth? or thickness* or weight* or material? or finish or finishes or finishing or feature? or component? or aspect? or mechanism? or operat* or project* or barrier? or facade? or open? or opening or opened or openable or close? or closing or closable or glass or glazing or curtain? or lock* or latch* or catch or catches or handle? or hing* or slid* or spacer? or louvre? or louver? or grill or grills or grille or grilles or vent* or circulat* or airflow? or air flow? or cross flow? or crossflow? or cross-flow? or air gap? or seal* or rating? or view? or outlook? or light? or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill? or blind? or shade? or shading or sash or sashes or bar or bars or shutter? or fasten* or stay? or restrictor? or restraint? or reflect* or illumin* or wall-ratio? or wall ratio? or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) adj1 duty) or x-		

Database/ Search date	Search string	Limits	Hits
	ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate? or door plate? or knob? or undercut? or under-cut? or vision panel? or buffer strip?).ti,ab,id. 2856018 5 1 and 2 and ((window? or door* or door set? or door way? or entry or entries or entrance? or exit? or building opening?) adj3 (placement? or position* or layout? or configur* or orient* or frame? or assembl* or ironmongery or size? or shape? or height? or width? or depth? or thickness* or weight* or material? or finish or finishes or finishing or feature? or component? or aspect? or mechanism? or operat* or project* or barrier? or facade? or open? or opening or opened or openable or close? or closing or closable or glass or glazing or curtain? or lock* or latch* or catch or catches or handle? or hing* or slid* or spacer? or louvre? or louver? or grill or grills or grille or grilles or vent* or circulat* or airflow? or air flow? or cross flow? or crossflow? or cross-flow? or air gap? or seal* or rating? or view? or outlook? or light? or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill? or blind? or shade? or shading or sash or sashes or bar or bars or shutter? or fasten* or stay? or restrictor? or restraint? or reflect* or illumin* or wall-ratio? or wall ratio? or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) adj1 duty) or x-ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate? or door plate? or knob? or undercut? or under-cut? or vision panel? or buffer strip?)).ti,ab,id. 87		

Database/ Search date	Search string	Limits	Hits
	6 limit 5 to (english language and yr="1980 -Current") 79		
CINAHL search 11/02/2025	S5 S1 AND S2 AND S3 (with limiters) 273 S4 S1 AND S2 AND S3 286 S3 (TI (window* or door* or door set or door sets or door way or door ways or entry or entries or entrance* or exit or exits or building opening or building openings) or AB (window* or door* or door set or door sets or door way or door ways or entry or entries or entrance* or exit or exits or building opening or building openings)) N3 (TI (placement* or position* or layout* or configur* or orient* or frame* or assembl* or ironmongery or size* or shape* or height* or width* or depth* or thickness* or weight* or material* or finish or finishes or finishing or feature* or component* or aspect* or mechanism* or operat* or project* or barrier* or facade* or open or opens or opening or opened or openable or close or closes or closed or closing or closable or glass or glazing or curtain* or lock* or latch* or catch or catches or handle* or hing* or slid* or spacer* or louvre* or louver* or grill or grills or grille or grilles or vent* or circulat* or airflow* or air flow* or cross flow* or crossflow* or cross-flow* or air gap* or seal* or rating* or view or views or outlook* or light or lights or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill or cills or blind or blinds or shade* or shading or sash or sashes or bar or bars or shutter* or fasten* or stay or stays or restrictor* or restraint* or reflect* or illumin* or wall-ratio* or wall ratio* or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) N1 duty) or x-ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate* or	Limiters - Publication Date: 19800101-20251231; English Language	273

Database/ Search date	Search string	Limits	Hits
	door plate* or knob* or undercut* or under-cut* or vision panel* or buffer strip*) or AB (placement* or position* or layout* or configur* or orient* or frame* or assembl* or ironmongery or size* or shape* or height* or width* or depth* or thickness* or weight* or material* or finish or finishes or finishing or feature* or component* or aspect* or mechanism* or operat* or project* or barrier* or facade* or open or opens or opening or opened or openable or close or closes or closed or closing or closable or glass or glazing or curtain* or lock* or latch* or catch or catches or handle* or hing* or slid* or spacer* or louvre* or louver* or grill or grills or grille or grilles or vent* or circulat* or airflow* or air flow* or cross flow* or crossflow* or cross-flow* or air gap* or seal* or rating* or view or views or outlook* or light or lights or lighting or daylight* or sunlight or solar or pane or panes or sill or sills or cill or cills or blind or blinds or shade* or shading or sash or sashes or bar or bars or shutter* or fasten* or stay or stays or restrictor* or restraint* or reflect* or illumin* or wall-ratio* or wall ratio* or leaf or leaves or ((light or medium or heavy or severe or high security or high-security) N1 duty) or x-ray grade or penny farthing or penny-farthing or automatic* or swing* or doorplate* or door plate* or knob* or undercut* or under-cut* or vision panel* or buffer strip*)) 8,315 S2 (MH "Architecture+") or (MH "Built Environment") or (MH "Ergonomics") or TI (design* or construct* or renovat* or refurbish* or architectur* or ergonomic* or human factor or human factors) or AB (design* or construct* or renovat* or refurbish* or architectur* or ergonomic* or human factor or human factors) 730,952		

Database/ Search date	Search string	Limits	Hits
	S1 (MH "Hospitals") or (MH "Health Facility Departments") or (MH "Health Facility Environment") or (MH "Hospital Units") or (MH "Intensive Care Units+") or (MH "Residential Facilities") or (MH "Nursing Homes") or TI ((hospital or hospitals) or ((health or healthcare or health care or acute or acute care or intensive care or critical care or intensive treatment or residential) N1 (facility or facilities or environment or environments or institution or institutions or unit or units or department or departments or ward or wards)) or ((care or nursing) N1 (facility or facilities or environment or environments or institution or institutions or unit or units or department or departments or ward or wards or home or homes)) or ICU or CCU or ITU) or AB ((hospital or hospitals) or ((health or healthcare or health care or acute or acute care or intensive care or critical care or intensive treatment or residential) N1 (facility or facilities or environment or environments or institution or institutions or unit or units or department or departments or ward or wards)) or ((care or nursing) N1 (facility or facilities or environment or environments or institution or institutions or unit or units or department or departments or ward or wards or home or homes)) or ICU or CCU or ITU) 728,964		
Scopus search 11/02/25	TITLE-ABS-KEY (((hospital OR hospitals) OR ((health OR healthcare OR "health care" OR acute OR "acute care" OR "intensive care" OR "critical care" OR "intensive treatment" OR residential) W/1 (facility OR facilities OR environment OR environments OR institution OR institutions OR unit OR units OR department OR departments OR ward OR wards)) OR ((	Not applicable	942

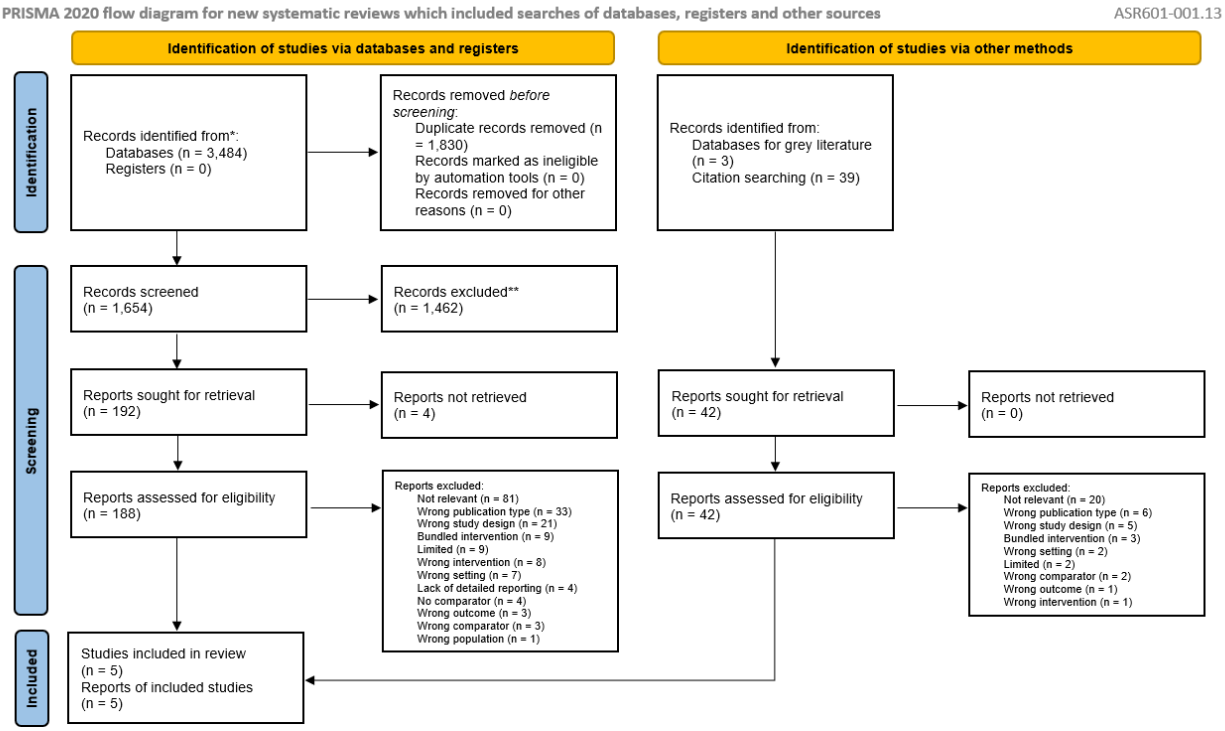
Database/ Search date	Search string	Limits	Hits
	care OR nursing) W/1 (facility OR facilities OR environment OR environments OR institution OR institutions OR unit OR units OR department OR departments OR ward OR wards OR home OR homes)) OR icu OR ccu OR itu) AND (design* OR construct* OR renovat* OR refurbish* OR architectur* OR ergonomic* OR "human factor" OR "human factors") AND ((window* OR door* OR "door set" OR "door way" OR entry OR entries OR entrance* OR exit OR exits OR "building opening") W/3 (placement* OR position* OR layout* OR configur* OR orient* OR frame* OR assembl* OR ironmongery OR size* OR shape* OR height* OR width* OR depth* OR thickness* OR weight* OR material* OR finish OR finishes OR finishing OR feature* OR component* OR aspect* OR mechanism* OR operat* OR project* OR barrier* OR facade* OR open OR opens OR opening OR opened OR openable OR close OR closes OR closed OR closing OR closable OR glass OR glazing OR curtain* OR lock* OR latch* OR catch OR catches OR handle* OR hing* OR slid* OR spacer* OR louvre* OR louver* OR grill OR grills OR grille OR grilles OR vent* OR circulat* OR airflow* OR "air flow" OR "cross flow" OR crossflow* OR cross-flow* OR "air gap" OR seal* OR rating* OR view OR views OR outlook* OR light OR lights OR lighting OR daylight* OR sunlight OR solar OR pane OR panes OR sill OR sills OR cill OR cills OR blind OR blinds OR shade* OR shading OR sash OR sashes OR bar OR bars OR shutter* OR fasten* OR stay* OR restrictor* OR restraint* OR reflect* OR illumin* OR "wall-ratio" OR "wall ratio" OR leaf OR leaves OR "light duty" OR "medium duty" OR "heavy duty" OR		

Database/ Search date	Search string	Limits	Hits
	"severe duty" OR "high security duty" OR "high-security duty" OR "x-ray grade" OR "penny farthing" OR penny-farthing OR automatic* OR swing* OR doorplate* OR "door plate" OR knob* OR undercut* OR under-cut* OR "vision panel" OR "buffer strip"))) AND PUBYEAR > 1979 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "NURS") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "MATE")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))		
Web of Science search 11/02/25	TS = (("hospital" OR hospitals) or (("health" or "healthcare" or "health care" OR acute OR "acute care" OR "intensive care" OR "critical care" OR "intensive treatment" or residential) NEAR/1 (facility or facilities or "environment" or environments or "institution" or institutions or "unit" or units or "department" or departments or "ward" or wards)) or ((care or nursing) NEAR/1 (facility or facilities or “environment” or environments or “institution” or institutions or “unit” or units or “department” or departments or “ward” or wards or home or homes)) or ICU or CCU or ITU) and TS = (design* or construct* or renovat* or refurbish* or architectur* or ergonomic* or “human factor” or “human factors”) and TS = ((window* OR door* OR "door set" OR “door sets” OR "door way" OR “door ways” OR entry OR entries OR entrance* OR “exit” OR exits or "building opening" or "building openings") NEAR/3 (placement* OR position* OR layout* OR configur* OR orient* OR frame* OR assembl* OR ironmongery OR size* OR shape* OR height* OR width* OR	Publication date: 1980-01-01 to 2025-12-31 Languages: English Document types: Article	791

Database/ Search date	Search string	Limits	Hits
	depth* OR thickness* OR weight* OR material* OR “finish” OR finishes OR finishing OR feature* OR component* OR aspect* OR mechanism* OR operat* OR project* OR barrier* OR facade* OR “open” OR opens OR opening OR opened OR openable OR “close” OR closed OR closing OR closable OR “glass” OR glazing OR curtain* OR lock* OR latch* OR “catch” OR catches OR handle* OR hing* OR slid* OR spacer* OR louvre* OR louver* OR “grill” OR grills OR “grille” OR grilles OR vent* OR circulat* OR airflow* OR "air flow" OR “air flows” OR "cross flow" OR “cross flows” OR crossflow* OR “cross-flow” OR “cross-flows” OR "air gap" OR “air gaps” OR seal* OR rating* OR “view” OR views OR outlook* OR “light” OR lights OR lighting OR daylight* OR sunlight OR solar OR “pane” OR panes OR “sill” OR sills OR cill OR cills OR “blind” OR blinds OR shade* OR shading OR “sash” OR sashes OR “bar” OR bars OR shutter* OR fasten* OR stay* OR restrictor* OR restraint* OR reflect* OR illumin* OR "wall-ratio" OR "wall ratio" OR leaf OR leaves OR "light duty" OR "medium duty" OR "heavy duty" OR "severe duty" OR "high security duty" OR "high-security duty" OR "x-ray grade" OR "penny farthing" OR “penny-farthing” OR automatic* OR swing* OR doorplate* OR "door plate" OR knob* OR undercut* OR “under-cut” OR “under-cuts” OR “under-cutting” OR "vision panel" OR “vision panels” OR "buffer strip" OR “buffer strips”))		

Appendix C PRISMA flow diagram

Figure C.1 - Preferred Reporting Items for Systematic Reviews and Meta-Analyses (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/

Appendix D Excluded reports

D.1 Excluded during database screening:

- 24/7 'lockdown' helps ease staff's concerns. ED Management: the monthly update on emergency department management 2008; 20: 40-41.
- Acosta I, Leslie RP and Figueiro MG. Analysis of circadian stimulus allowed by daylighting in hospital rooms. Lighting Research and Technology 2017; 49: 49-61.
- Adamu ZA and Price A. The design and simulation of natural personalised ventilation (NPV) system for multi-bed hospital wards. Buildings 2015; 5: 381-404.
- Adamu ZA, Price ADF and Cook MJ. Performance evaluation of natural ventilation strategies for hospital wards - a case study of Great Ormond Street Hospital. Building and Environment 2012; 56: 211-222.
- Aghaei P and Bayramzadeh S. Clinicians' experience with technology within the physical environment of trauma rooms: a focus group study. Facilities 2024; 42: 524-536.
- Ahern CC, Bieling P, McKinnon MC, et al. A recovery-oriented care approach: weighing the pros and cons of a newly built mental health facility. Journal of Psychosocial Nursing and Mental Health Services 2016; 54: 39-48.
- Ahmed S, Muhammad IB, Abdulrahman MEH, et al. Visual accessibility and inclusive wayfinding design in hospital environment in Nigeria. ICONARP International Journal of Architecture and Planning 2022; 10: 97-114.
- Aita M, Robins S, Charbonneau L, et al. Comparing light and noise levels before and after a NICU change of design. Journal of Perinatology: Official Journal of the California Perinatal Association 2021; 41: 2235-2243.
- All you ever needed to know about swinging doors. Healthcare Life Safety Compliance 2018; 21: 1-4.
- Alsarraf AA and Alobaidi MM. The effect of natural lighting on design of openings in hospital. Journal of Green Engineering 2020; 10: 8233-8250.
- Altman MT, Pulaski C, Mburu F, et al. Non-circadian signals in the intensive care unit: Point prevalence morning, noon and night. Heart & Lung: The Journal of Critical Care 2018; 47: 610-615.
- Amleh D, Halawani A and Haj Hussein M. Simulation-based study for healing environment in intensive care units: enhancing daylight and access to view, optimizing an ICU room in temperate climate, the case study of Palestine. Ain Shams Engineering Journal 2023; 14.
- Anderson DC. Bricks and morals-Hospital buildings, do no harm. Journal of General Internal Medicine 2019; 34: 312-316.

- Aomura D, Yamada Y, Harada M, et al. Hospital admission to a window-side bed does not prevent delirium: a retrospective cohort study of older medical inpatients in general wards. Frontiers in Medicine 2021; 8: 744581.
- Architects embrace UK's greatest single reform of fire safety legislation. Building Engineer 2007; 82: 22-23.
- Ayabaca C, Vila C, Reina S, et al. Collaborative manufacturing of ergonomic personal protective equipment (PPE) accessories to prevent infectious disease. Materials Today Proceedings 2022; 49: 1-7.
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Appendix E Study characteristics and findings

Table E.1 - Study characteristics and findings

Reference/ Country	Purpose	Report Type/ Application	Short Findings
Bae and Asojo (2022)[17] Interior environments in long-term care units from the theory of supportive design. (South Korea)	This study explored the perceptions of residents on their living environment in long term care facilities in Midwest USA, with reference to the theory of supportive design.	Qualitative	Findings suggested that residents hoped to have an openable window to let in fresh air. An openable window was related to the element of perceived control in the theory of supportive design.
Stiller et al. (2017)[18] ICU ward design and nosocomial infection rates: a cross-sectional study. (Germany)	This study examined the effect of different healthcare built environment design features, including openable windows, on nosocomial infection rates in patients in intensive care units, using the Krankenhause-Infektions-Surveillance-System (KISS), between March and June 2015.	Quantitative observational, cross-sectional analytical	Findings indicated that patient rooms with openable windows had a significantly lower likelihood of device-associated lower respiratory tract infections, compared to patient rooms with non-openable windows (odds ratio = 0.73, 95% confidence interval 0.58 to 0.90, $p < 0.01$). There was no association between the availability of an air conditioning system in patient rooms and device-associated infection rates.

Reference/ Country	Purpose	Report Type/ Application	Short Findings
Kembel et al. (2012)[16] Architectural design influences the diversity and structure of the built environment microbiome. (USA)	This study examined the effect of mechanical and natural ventilation on the structure and diversity of microbiome in patient rooms in an acute hospital in Milwaukie, Oregon, USA, in February 2010.	Quantitative observational, cross-sectional analytical	Findings suggested there was a significant difference in the structure of the microbiome in patient rooms with mechanical ventilation, compared to rooms with an open window (R^2 = 0.66, p < 0.01), where the latter exhibited a more diverse environment. It is important to note that other environmental conditions, including relative humidity (R^2 = 0.11, p = 0.05) and air changes per hour (ACH) (R^2 = 0.11, p = 0.1), were associated with the structure of the microbiome in patient rooms, as well as ventilation type. The relative abundance of potentially pathogenic bacteria (that is, with a 97% or greater sequence similarity to known human pathogens) in patient rooms was not associated with ventilation type (p = 0.2) but, instead, significantly decreased with

Reference/ Country	Purpose	Report Type/ Application	Short Findings
			increasing airflow rates (p = 0.04), including ACHs (p = 0.004), and relative humidity (p = 0.02).
Srikanth et al. (2024)[15] Low-cost interventions to improve ventilation in long-term care facilities. (USA)	This study investigated the effects of low-cost interventions, including door open/ closed, window open/ closed, window fan on/ off on air exchange rates in residents rooms in two long term care facilities in Sedro-Woolley and Mount Vernon, Washington, USA.	Quantitative experimental, quasi-experimental	Authors state that, regardless of whether the door is opened or closed, opening a window significantly increased the mean air exchange rate in residents' rooms compared to a closed window. It is important to note that, although both facilities had heating, ventilation, and air conditioning (HVAC) systems, they were not in operation in the Sedro-Woolley facility, and the facility in Mount Vernon only had coverage in hallways.
Xiao et al. (2024)[19] Influence of subjective factors on window use in maternity hospitals in Spring. (China)	This study examined pregnant women and their families' reasons for window opening/ closing in a maternity ward in Ningbo, China, in March 2019.	Quantitative observational, cross-sectional analytical	Findings suggested the most frequently reported thermal sensations for window opening and closing were 'a little hot' (55.10%) and 'cold' (50.34%), respectively. The most frequently

Reference/ Country	Purpose	Report Type/ Application	Short Findings
			reported reasons for window opening were ‘stuffy’ (65.99%), ‘hot’ (59.18%), and ‘low indoor air quality’ (57.14%). The most frequently reported reasons for window closing were ‘outdoor noise’ (59.18%), ‘cold’ (55.10%), and ‘windy’ (53.74%).

Appendix F Critical appraisal assessments

Cross sectional analytical

Table F.1 - Critical appraisal of eligible cross-sectional analytical studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Quality Score	Assessment
Xiao et al., 2024	Y	Y	Y	U	N/A	U	U	U	Y	50%	Moderate methodological concerns
Stiller et al 2017	Y	Y	Y	U	U	Y	Y	U	Y	67%	Minor methodological concerns
Kembel et al 2012	N/A	N/A	Y	Y	Y	Y	Y	Y	Y	100%	Very minor methodological concerns

Q1. Were the criteria for inclusion in the sample clearly defined? Q2. Were the study subjects described in detail? Q3. Was the setting described in detail? Q4. Was the exposure measured in a valid and reliable way? Q5. Were objective, standard criteria used for measurement of the condition? Q6. Were confounding factors identified? Q7. Were strategies to deal with confounding factors stated? Q8. Were the outcomes measured in a valid and reliable way? Q9. Was appropriate statistical analysis used?

Qualitative

Table F.2 - Critical appraisal of eligible qualitative studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Quality Score	Assessment
Bae and Asojo, 2022	Y	Y	N	Y	Y	Y	83%	Very minor methodological concerns

Q1. Was the recruitment strategy appropriate to the aims of the research? Q2. Was the data collected in a way that addressed the research issue? Q3. Has the relationship between researcher and participants been adequately considered? Q4. Have ethical issues been taken into consideration? Q5. Was the data analysis sufficiently rigorous? Q6. Is there a clear statement of findings?

Quasi-experimental

Table F.3 - Critical appraisal of eligible quasi-experimental studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Quality Score	Assessment
Srikanth et al 2024	Y	Y	Y	U	Y	N/A	Y	Y	Y	Y	89%	Very minor methodological concerns

Q1. Is it clear in the study what is the ‘cause’ and what is the ‘effect’ (that is there is no confusion about which variable comes first)? Q2. Were the participants included in any comparisons similar? Q3. Were the participants included in any comparisons receiving similar treatment/ care, other than the exposure or intervention of interest? Q4. Was there a control group? Q5. Were there multiple measurements of the outcome both pre and post the intervention/ exposure? Q6. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed? Q7. Were the outcomes of participants included in any comparisons measured in the same way? Q8. Were outcomes measured in a reliable way? Q9. Was appropriate statistical analysis used? Q10. Were potential confounders identified and appropriately controlled for in the analysis?

Appendix G Evidence grading assessments

G.1 Each review finding and accompanying assessment of the confidence in the evidence supporting that finding is given in the following tables. It is important to note that evidence within healthcare built environment research generally differs from other more established fields of clinical research. However, assessing the confidence in evidence within healthcare built environment research is essential, where these assessments examine whether findings are supported by a high-quality, robust, and reliable evidence base and help to determine implications for practice and future research. Further information on the criteria used for assessing the overall level of confidence in a finding (that is, a summary of the evidence), not the individual studies themselves can be found in Appendix A.

Table G.1 – Finding 1: Openable windows reduced nosocomial infection rates in patients in acute healthcare settings.

Criteria	Evidence summary	Assessment
Studies contributing to the review finding	Stiller et al.[18]	
Type of evidence and limitations	One cross-sectional analytical study[18] (minor methodological concerns, n = 1).	Minor concerns
Adequacy	There was only one study, albeit with a large sample size.	Serious concerns
Relevance	The study was directly relevant.	No or very minor concerns
Coherence	All contradictory data were considered. There was a vague definition in the study, where patient rooms with openable windows did not specify whether windows were, in fact, open or closed. This is a gap in support of a complex finding.	Minor concerns
Publication bias	There was only one study from a journal that was not considered to be high impact based on impact factor scores.	Serious concerns
Final assessment	There was only one study with a low level of evidence and minor methodological concerns. There were serious concerns regarding adequacy and publication bias.	**Very low confidence**

Table G.2 – Finding 2: Pregnant women and their families' reasons for window opening/ closing were linked to thermal comfort and other comfort-related factors, including indoor air quality and noise, in acute healthcare settings.

Criteria	Evidence summary	Assessment
Studies contributing to the review finding	Xiao et al.[19]	
Type of evidence and limitations	One cross-sectional analytical study[19] (moderate methodological concerns, n = 1).	Moderate concerns
Adequacy	There was only one study, albeit with a large sample size.	Serious concerns
Relevance	The study was directly relevant.	No or very minor concerns
Coherence	All contradictory data have been considered. There were no vague or inconsistent definitions. There were no gaps in support of complex findings.	No or very minor concerns
Publication bias	There was only study from a journal that was not considered to be high impact based on impact factor scores.	Serious concerns
Final assessment	There was only one study at a low level of evidence with moderate methodological concerns. There were serious concerns regarding adequacy and publication bias.	**Very low confidence**

Table G.3 – Finding 3: Openable windows were preferred among residents in non-acute healthcare settings.

Criteria	Evidence summary	Assessment
Studies contributing to the review finding	Bae and Asojo[17]	
Type of evidence and limitations	One qualitative study[17] (very minor methodological concerns, n = 1).	No or very minor concerns
Adequacy	There was only one study. There was limited data richness. Data saturation was not reported.	Serious concerns
Relevance	The study was partially relevant due to a non-acute healthcare setting.	Moderate concerns
Coherence	All contradictory data have been considered. There were no vague or inconsistent definitions. There were no gaps in support of complex findings.	No or very minor concerns
Publication bias	There was only one study from a journal that was not considered to be high impact based on impact factor scores.	Serious concerns
Final assessment	There was only one qualitative study with very minor methodological concerns. There were serious concerns regarding adequacy and publication bias. There were moderate concerns regarding relevancy.	**Very low confidence**

Table G.4 – Finding 4: Compared to a closed window, an open window significantly increases air exchange rates in residents' rooms in non-acute healthcare settings.

Criteria	Evidence summary	Assessment
Studies contributing to the review finding	Srikanth et al.[15]	
Type of evidence and limitations	One quantitative, quasi-experimental study[15] (very minor methodological concerns, n = 1).	No or very minor concerns
Adequacy	There was only one study, with a small sample size.	Serious concerns
Relevance	The study was directly relevant although it was conducted in non-acute healthcare setting where the phenomena was independent of setting.	No or very minor concerns
Coherence	All contradictory data have been considered. There were no vague or inconsistent definitions. There were no gaps in support of complex findings.	No or very minor concerns
Publication bias	There was only study from a journal that was not considered to be high impact based on impact factor scores.	Serious concerns
Final assessment	There was only one study with a moderate level of evidence and very minor methodological concerns. There were serious concerns regarding adequacy and publication bias.	**Very low confidence**

Table G.5 – Finding 5: Increasing indoor airflow rates, air changes per hour, and relative humidity reduced potentially pathogenic bacteria in healthcare settings.

Criteria	Evidence summary	Assessment
Studies contributing to the review finding	Kembel et al.[16]	
Type of evidence and limitations	One cross-sectional analytical study[16] (very minor methodological concerns, n = 1).	No or very minor concerns
Adequacy	There was only one study.	Serious concerns
Relevance	The study was partially relevant due to uncertainty around whether there was an acute or non-acute healthcare setting.	Moderate concerns
Coherence	All contradictory data were considered. There were no vague or inconsistent definitions. There were no gaps in support of complex findings.	No or very minor concerns
Publication bias	There was only one study from a high impact journal.	Serious concerns
Final assessment	There was only one study with a low level of evidence and very minor methodological concerns. There were serious concerns regarding adequacy and publication bias. There were moderate concerns regarding relevancy.	**Very low confidence**

Abbreviations

ACH: Air Changes per Hour.

BDaC: Building Design and Construction.

CASP: Critical Appraisal Skills Programme.

HAI-SCRIBE: Healthcare Associated Infection Systems for Controlling Risk in the Built Environment.

HERD: Health Environments Research and Design.

HVAC: Heating, Ventilation, and Air Conditioning

JBI: Joanna Briggs Institute.

KISS: Krankenhause-Infektions-Surveillance-System.

OSF: Open Science Framework.

PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses.

PROSPERO: International Prospective Register of Systematic Reviews.

RCT: Randomised Controlled Trial.

SME: Subject Matter Expert.