

Manuscript Details

Manuscript number	ANR_2018_212_R1
Title	DO NOISE REDUCTION INTERVENTIONS WORK IN ADULT WARD SETTINGS? A SYSTEMATIC REVIEW & META ANALYSIS
Article type	Research Paper

Abstract

International studies show that high levels of environmental noise in hospitals disturb sleep. We know little about effective interventions to address this problem. We aimed to review primary research that tested noise-reduction interventions in ward-settings. Design: Systematic review and meta-analysis in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Data Sources: Health-related and acoustic databases searched from inception to 2017 with no language restrictions. Review methods: Experimental, quasi-experimental and observational studies assessing the effect of interventions on patient outcomes and/or environmental noise were included. Results: 834 records were identified with 9 meeting inclusion criteria. Data from 6 studies were pooled. Quality appraisal showed that the level of evidence was generally weak. A random effects meta-analysis determined that a synthesised estimate for the standardised mean difference in total hours sleep (no intervention – intervention) was -0.11 hours (95% CI -0.46 to 0.25 hours; $p=0.556$), with moderate statistical heterogeneity. A synthesised estimate for the standardised mean difference in awakenings (no intervention – intervention) was 0.05 (95% CI -0.20 to 0.29; $p=0.715$), with negligible statistical heterogeneity. A random effects meta-analysis determined that a synthesised estimate for the odds ratio for disturbed nights (no intervention: intervention) was 0.75 (95% CI 0.55 to 1.01; $p=0.059$), with low statistical heterogeneity. Conclusions: Individual studies show that noise reduction interventions are feasible and have the potential to improve patients' sleep experiences. However meta-analyses show insufficient evidence to support their use. Robust studies are required to identify effective interventions to address this significant and ubiquitous problem.

Keywords	Hospital; Noise; Sleep; Systematic review
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Research Data Related to this Submission

There are no linked research data sets for this submission. The following reason is given:
No data was used for the research described in the article

Dear Editor

I am pleased to submit this revised manuscript following your request for minor revisions. Please note we have updated the title from 'Do noise reduction interventions work in adult ward settings: a systematic review and meta analysis' to 'Are noise reduction interventions effective in adult ward settings? A systematic review & meta analysis'. We have fully reviewed the paper highlighted by tracked changes and in responses to the reviewers' comments.

To reiterate, the review was commissioned by the General Nursing Council as part of a larger research project. The project was conducted by a team which included Dr Joanne Garside (JG, lead reviewer), Prof Felicity Astin (FA), Prof Mary Morrell (MM), Dr John Stephenson (JS, statistician) (all based at University of Huddersfield), Helen Curtis (Calderdale & Huddersfield NHS Trust) and Prof Mary Morrell (MM) (Imperial College). All team members have a variety of academic and project management experiences.

On behalf of the team thank you for consideration of our paper

With kind regards

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<p>This reviewer has a major concern with including quality improvement 'projects' with research studies in this analysis. Use of QI studies and QI research is not clearly delineated. Including studies of quality improvement research already introduces greater heterogeneity but can be acceptable. However, including quality improvement projects increases variability and can significantly impact results since projects do not involve the same design requirements that quality improvement research and traditional research studies demand. Further, QI projects do not provide the outcomes required for a meta-analysis e.g. Wilson et al 2017, Murphy et al 2013, and Thomas et al 2012 only provide descriptive statistics.</p>	<p>We have reviewed and updated this section. We understand the reviewers concern regarding this issue however all studies met the pre-set inclusion criteria and informed the outcomes of the review. Only the 6 studies with adequate data and clear measureable outcomes were included in the meta analysis undertaken by an experienced statistician.</p> <p>We have provided a detailed quality appraisal presented in section 3.2 highlighting that the quality of included studies is rather weak, and the lack of randomised controlled trials has limited any robust conclusions about the value of noise reduction/sleep promoting interventions implemented that can draw from our analysis. One of the key findings of the SR is that the quality of research on the topic could be improved.</p>
<p>Discussion (4.0): The authors make several substantial claims in the Discussion section without providing references to support these statements (please see attached)</p>	<p>The review email did not have an attachment but we have carefully reviewed the discussion section which has been updated and any unsubstantiated statements removed or referenced</p>
<p>Minor concerns: · Intervention criteria (2.1.3): The authors state as part of the inclusion criteria, interventions impacting sleep must be conducted to reduce noise at night, but continue to add a 24-hour duration requirement. Why is this the case if sleep at night is the desired outcome?</p>	<p>The focus of the study was noise at night – any intervention is likely to take time to have effect therefore we only included studies that reported an explicit aim to test an intervention designed to reduce noise at night in hospital, applied for at least 24 hours, to ensure that interventions had been in place long enough to impact on sleep quality/quantity – section 2.1.3 has been updated to reflect this.</p>
<p>Although included in the analyses, the authors do not clearly state in their initial objective that studies should not only reduce noise levels but impact sleep quantity and quality.</p>	<p>Section 2.1.4 reads: Studies were included that had a primary outcome of measured environmental noise levels or patient-related outcomes, including objective and self-reported measures of sleep quality and quantity.</p>
<p>Authors state in 2.1.4 that studies should examine sleep and 'other patient outcomes'. What are these outcomes? It would benefit to focus on one outcome to reduce impact of heterogeneity of studies.</p>	<p>We agree with the reviewer however when planning the SR the protocol specified that the primary outcomes included Quantitative measure of sleep quality and quantity including objective and self-reported measures. In planning we highlighted potential secondary</p>

	outcomes as Falls, Delirium, Inflammatory Response, Mental health (e.g. anxiety/depression/distress) or psychological wellbeing but these outcomes were not reported in the studies selected from the predetermined criteria
Overall copy-editing is needed to improve grammar and sentence structure in various sections of the paper	Review undertaken and changes tracked through the resubmitted document
Improve labelling of tables and figures (Search Strategy table; study summary table on pages 17 & 18).	All labels of the tables and figures have been reviewed and updated
Table 1 and Figure 1 are missing.	Now included
Authors state in “What this Paper Adds” section that “ <i>Noise reduction interventions may improve patients’ sleep experience in hospital.</i> ” How does this paper establish this outcome?	This ‘what the paper adds’ statement is written in the journal format and is further explained in implications for practice: <i>Although further research is recommended on the subject, this review indicates that noise reduction interventions can reduce noise and positively impact on sleep. Multi-faceted noise reduction interventions are reported to have a cumulative effect (Murphy et al., 2013) but no one factor can be claimed to have the most impact (Richardson et al., 2009).</i>
Paper formatting is awkward, e.g. criteria and interventions types listed as sections or headings. Providing an initial listing of these items and then elaborating using section headers may improve flow.	We have added to the introduction to section 3.0 to clearly signpost the flow of the following sections
The abstract states that 801 studies were retrieved while the Results section states 834.	Thank you for spotting this - 801 papers were identified through database searching and 33 through alternative sources, totalling 834 – the abstract has been updated
No information on studies in different languages and if this had an impact on the analysis.	Despite the criteria of including studies in any language, all selected papers were in English – this has been clarified in section 3.1

What is known about the topic

- Noise levels in hospital impact on quantity and quality of sleep and patient experience.
- Disturbed sleep can have a detrimental impact on health and extend patient recovery.
- Noise reduction interventions do not receive the priority they deserve.

What this paper adds

- A comprehensive review of noise reduction interventions used in general ward settings.
- Noise reduction interventions show the potential to reduce environmental noise and improve patient sleep ratings.
- Appropriately designed studies are required to provide definitive evidence to demonstrate the effectiveness of noise reduction intervention in ward settings.

Title page

DO NOISE REDUCTION INTERVENTIONS WORK IN ADULT WARD SETTINGS? A SYSTEMATIC REVIEW & META ANALYSIS

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ARE NOISE REDUCTION INTERVENTIONS EFFECTIVE IN ADULT WARD SETTINGS? A SYSTEMATIC REVIEW & META ANALYSIS

Abstract

Objective: High levels of environmental noise in hospitals disturbs sleep. We aimed to identify, critically appraise and summarise primary research that reports studies that tested interventions to reduce night-time noise levels in ward-settings.

Design: Systematic review and meta-analysis in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.

Data Sources: Key health-related and specialist acoustic databases (CINAHL, EMBASE, MEDLINE, The Cochrane Library, PsycINFO, NHS Evidence, Knovel, Journal of the Audio Engineering Society, Journal of the Acoustical Society of America, IEEE Xplore Digital Library, Acta Acustica and Acoustics in Practice) were searched from their inception to April 2017, with no language restrictions.

Review methods: Experimental, quasi-experimental and observational study designs assessing the effect of noise reduction interventions on patient outcomes and/or environmental noise levels were included. Two reviewers independently conducted a quality appraisal using a published framework.

Results: In total, 834 records were identified with nine studies meeting inclusion criteria. Quality appraisal showed that the level of evidence was generally weak. A range of noise reduction interventions were identified: one study implemented a single intervention, whilst the remainder were complex, multi-faceted interventions. Findings from individual studies showed mixed results but preliminary evidence suggests that noise reduction interventions can reduce environmental noise levels in ward settings and improve patients' sleep ratings. Quantitative data from 6 studies were pooled. A random effects meta-analysis determined that a synthesised estimate for the standardised mean difference in total hours sleep (no intervention - intervention) was -0.11 hours (95% CI -0.46 to 0.25 hours; $p=0.556$), with moderate statistical heterogeneity. A random effects meta-analysis determined that a synthesised estimate for the standardised mean difference in awakenings per night (no intervention - intervention) was 0.05 (95% CI -0.20 to 0.29; $p=0.715$), with negligible statistical heterogeneity. A random effects meta-analysis determined that a synthesised estimate for the odds ratio for disturbed nights (no intervention: intervention) was 0.75 (95% CI 0.55 to 1.01; $p=0.059$), with low statistical heterogeneity.

Conclusions: Individual studies show that noise reduction interventions are feasible in ward settings and suggest they have potential to improve patients' in-hospital sleep experiences. However meta-analyses show insufficient evidence to support the use of such interventions at present. There is a lack of appropriately designed studies to test intervention effectiveness. Robust studies are required to identify the most effective interventions to address this significant and ubiquitous problem.

What is known about the topic

- Noise levels in hospital impact on quantity and quality of sleep and patient experience.
- Disturbed sleep can have a detrimental impact on health and extend patient recovery.
- Noise reduction interventions do not receive the priority they deserve.

What this paper adds

- A comprehensive review of noise reduction interventions used in general ward settings.
- Noise reduction interventions show the potential to reduce environmental noise and improve patient sleep ratings.
- Appropriately designed studies are required to provide definitive evidence to demonstrate the effectiveness of noise reduction intervention in ward settings.

1.0 INTRODUCTION

Ideally, hospitals should provide a quiet and calm environment to promote rest, healing and well-being for patients. However, in reality, hospitals across the world tend to have high levels of environmental noise with levels at night which often exceed World Health Organisation (WHO) recommendations for [optimising sleep](#): <30dB(A) for continuous background noise and <45dB(A) for individual noise events (Choiniere, 2010, Kahn et al., 1998, WHO, 2009). WHO further recommend noise levels in hospital do not exceed 35dBA during the day and 30dBA at night. Levels of 30-40dB impact on self-reported sleep disturbances and arousals. When levels reach 40-55dB, noise starts to have adverse health effects (Hume et al., 2012). Excessive noise can lead to increased stress, poor sleep and even learned helplessness (Hatfield, 2002, Zaharna, 2010).

[Environmental noise levels in hospital settings have increased over the last 45 years \(Busch-Vishniac et al., 2005\). Not surprisingly quality of care complaints from patients about their hospital stay often refer to noise disturbances at night \(Fillary et al., 2015\). Excessive environmental noise contributes to poor quality sleep \(Freedman, 2001, Hume et al., 2012, Lei et al., 2009\). Between 30-50% of people admitted to hospital suffer from significant sleep disturbance or reduced sleep patterns during their hospital stay \(Doğan et al., 2005, Lane and East, 2008\). Yoder demonstrated that noise in hospital was markedly higher than recommended levels and clearly evidenced a link to sleep loss for patients \(Yoder et al., 2012\).](#)

[The physiological responses to noise and stress are similar, with detrimental effects such as causing autonomic arousals from sleep accompanied by increased heart rate and vasoconstriction, or neutral arousals from sleep characterised by a K-complex, an increase in the frequency of the brain activity and typically body movements \(Edholm and Weiner, 2012\). The secondary effects of sleep deprivation include low mood and performance, although any long-term cardiovascular consequences are still unclear \(Overman Dube et al., 2008\).](#)

[Over time, sleep disturbance has a detrimental impact on physical health and recovery rates \(Choiniere, 2010, Overman Dube et al., 2008\). Sleep is essential for physical healing and the maintenance of mental health and wellbeing \(Fillary et al., 2015; Lei et al., 2009; Freedman et al., 2001\). Lack of sleep or interrupted sleep is a significant problem and can have a major impact on psychological health and increased stress levels, particularly for the vulnerable in our society including children, older people and those \[with long-term illness\]\(#\) \(Hume et al., 2012, Morrison et al., 2003\).](#)

As well as having a negative impact on patient experiences in hospitals, high noise levels also have an impact on annoyance, stress and potentially burnout of hospital staff (Joseph and Ulrich, 2007, Morrison et al., 2003). As a result, high noise levels may have a

detrimental impact on patient safety through increase noise-induced distractions (Taylor-Ford et al., 2008).

Environmental noises for in-patient settings fall broadly into two categories. Firstly, environmental noise produced by 'people', which includes other patients, visitors and staff: Christensen (2005) demonstrated a positive relationship between the number of staff on duty and an increased recorded level of noise. Secondly, environmental noise from 'Hospital equipment', which includes monitor alarms, telephones, TVs and computers (Fillary et al., 2015, Montague et al., 2009, Wiese and Wang, 2011). Hospital activity is typically constant regardless of time of day, with noise from wheelchairs, trolleys, deliveries, cleaning activities and footsteps all contributing to environmental noise levels and associated high acoustics, leading to sleep disruption (Overman Dube et al., 2008). Moreover, the increasing clinical acuity levels of hospital in-patients with complex conditions requiring close monitoring using advanced technology has an associated cacophony of alarm systems. In fact, patients also identified environmental noise from medical equipment to be of primary concern and a key cause of fragmented sleep (Fillary et al., 2015; Wiese and Wang, 2011). Yoder et al. (2012) concurs, reporting sources of environmental noise disturbances by hospital in-patients to include staff conversation (reported by 65% of patients), other patients/roommates (54%), alarms (42%), intercoms (39%), and pagers (38%). Different frequencies of noise are linked to sleep disturbance, with higher intensity noises, rather than lower intensity being responsible for interrupted sleep (Muzet, 2007).

Noise management and staff knowledge of the issues associated with reduced sleep and care requirements is poor (Fillary et al., 2015; Christenson et al., 2005). Both patients and staff would benefit from quieter environments to enhance patient outcomes. Sleep promotion is part of the nurses' role, but to date has received little attention. Practitioners and hospital managers/administrators alike need to identify ways to reduce noise in ward environments to improve patients' sleep experience.

Following a detailed search of the literature, to our knowledge, this is the first systematic review and meta-analysis with the specific aim to identify primary research studies designed to test the effectiveness of noise reduction interventions in general wards settings.

2.0 METHODS

A systematic review of published literature informed by reporting guidelines for Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA, 2015) was performed. The review protocol is available from the corresponding author on request.

2.1 Eligibility criteria

Studies were selected according to the following criteria:

2.1.1 Study designs

We included experimental studies (randomised controlled trials, controlled trials), cross-sectional, cohort, case control studies or quasi-experimental studies with a pre and post measures design. Qualitative studies were excluded.

2.1.2 Participants and setting

The target population was adults (over 18 years) who were hospital patients from any acute and mental health in-patient settings. In line with international convention for sleep studies, patients must have had an overnight stay in hospital with admission before 22:00. Due to their specialist nature and different staff skills mix and staff patient ratios, studies conducted in paediatric, intensive care and nursing home settings were excluded.

2.1.3 Intervention

Studies that reported an explicit aim to test an intervention designed to reduce noise at night in hospital were included. Any intervention is likely to take time to have effect; therefore interventions applied for at least 24 hours, to an entire ward or cubicle were included. Interventions could have single or multiple elements, including equipment modification, architecture, staff members (e.g. education programmes) or patient interventions (e.g. ear plugs).

2.1.4 Outcomes

Studies were included that had a primary outcome of measured environmental noise levels or patient-related outcomes, including objective and self-reported measures of sleep quality and quantity.

2.1.5 Language

Studies published in any language were included in the review.

2.2 Information sources and searches

The literature search was conducted in a range of databases: AMED, BNI, CINAHL, EMBASE, Health Business Elite, Health Management Information Consortium, MEDLINE, The Cochrane Library, PsycINFO, NHS Evidence and Google Scholar. We also searched specialist acoustic resources: Knovel, Journal of the Audio Engineering Society, Journal of the Acoustical Society of America, IEEE Xplore Digital Library, Acta Acustica and Acoustics in Practice. Search terms were selected and piloted by a team of researchers and an information technologist (see Table 1). The final search was undertaken in April 2017; no date limits were applied. (An exemplar search strategy is included as a supplementary data [\(Table 1.0\)](#)).

Table 1: The data base search strategy - [Insert here please]

Figure 1: PRISMA Flow diagram - [Insert here please]

2.3 Study Selection

Records of the searches were compiled and duplicates removed. Two reviewers (JG and CD) independently screened titles and abstracts against the review criteria. Full texts of potentially relevant studies were retrieved and independently screened for eligibility. Reviewers were not blinded to study authors, their affiliations or the title of the journal. Any disagreements were resolved through the advisory team meetings (all review authors), although due to the specific criteria these were minimal, all decisions were recorded.

2.4 Data collection process

The data extraction from full text versions of each study was carried out using a data extraction form, based on the Cochrane's Data Extraction Template and Cochrane Handbook (Higgins and Green, 2011). The form was piloted prior to use.

2.5 Quality appraisal

A checklist was applied independently, by two of the review authors (JG and FA) to each study and used to evaluate study quality, internal and external validity and reporting quality (Downs and Black 1998). Several tools were considered, but the checklist selected allows an in-depth and transparent account of method for both randomised and non-randomised studies for health care interventions. If data was insufficient or unclear, we attempted to contact authors to provide further details. Any methodological quality issues were clearly reported; however, we did not exclude studies that met the review's criteria on the grounds of quality. For each included study we assessed for problems that could put it at risk of bias, or any important or influencing high/low risks, and considered any bias that may impact on the study findings (see table 2).

Table 2: Quality appraisal (Downs and Black, 1998) – [-Insert here please]

2.6 Synthesis of results

After qualitative synthesis available data was pooled. Meta-analyses of appropriate studies was conducted using Stata statistical software (version I/C 14). The meta analyses provided: a pooled estimate and associated confidence interval (CI) for the effect of noise reduction interventions after combining included studies; a test for statistical significance of the interventions; and tests for heterogeneity of the effect of interventions between studies. Amongst studies selected for inclusion, a meta-analysis was conducted on each outcome common to two or more studies.

Random effects models were derived in all cases, due to clinical and methodological heterogeneity being identified between included studies. Any study testing multiple interventions was combined into a single pairwise comparison, following recommended procedures (Higgins and Green, 2011).

For dichotomous outcomes, odds ratios (ORs) with associated 95% (CIs) were derived using the Mantel-Haenszel method. For continuous outcomes, standardized mean differences (SMDs), between groups with associated 95% CIs were derived, using the inverse variance method. Standardised measures were used as the parameters of the intervention programmes tested in the included studies were not the same in all studies.

Statistical heterogeneity was assessed using a standard χ^2 test and the I^2 statistic (Higgins, 2003). Any sources of heterogeneity were explored. An I^2 estimate of around 75% accompanied by a significant result from the χ^2 statistic was interpreted as evidence of substantial levels of heterogeneity (Higgins and Green, 2011). A Z-test for overall effect and the between-study variance (τ^2 statistic) were also calculated for each meta-analysis conducted.

Forest plots were used to present individual and synthesized effects, with associated 95% CIs. Funnel plots were not drawn due to a lack of suitable number of studies for any of the outcomes.

3.0 RESULTS

The search and study selection process (PRISMA flow diagram Figure 1.0) identified 834 records. Nine studies were included in the final review and [data from 6 studies](#) was included in the meta-analysis ([Table 3.0 provides an overview of the selected studies](#)). [Section 3 presents the characteristics of the included studies and outcomes of the quality appraisal; this is followed by the narrative from the synthesised qualitative review and the findings of the meta analysis.](#)

[Table 3 Overview of selected studies – \[insert here please\]](#)

3.1 Study characteristics

The included studies [were all published in English and](#) used a variety of study designs to test the noise reduction intervention. Most studies were [designated as “quality improvement” initiatives](#) (Haddock, 1994, Hinkulow, 2014, Murphy et al., 2013, Norton et al., 2015, Wilson, 2017); [however, these studies included pre- and post-test evaluations formatted in a standard manner and comparable to those found in other included papers. Hence there was no systematic design difference between those studies designated as quality improvement and those designated using other means.](#) Thomas et al., (2012) and Richardson [et al., \(2009\)](#) compared objectively measured noise levels and patient reported outcomes using researcher generated surveys with unknown psychometric properties. Wilson et al., 2017; Hinkulow, 2014 and Murphy et al., 2013 drew data from ‘quiet at night’ questions posed by the patient satisfaction survey, Hospital Consumer Assessment of Healthcare Providers Systems (HCAHPS), used by all hospitals in the United States. Gathecha et al. (2016) was the only study that tested the noise reduction intervention with objective and subjective sleep parameters using validated sleep questionnaires and actigraphy.

Four studies used inferential statistics (Gathecha et al., 2016, Lareau et al., 2008, Richardson et al., 2009, Thomas et al., 2012) but there was a lack of detail about whether studies were sufficiently powered to make robust conclusions. Lareau et al. (2008) conducted a feasibility study and Gathecha et al. (2016) a quasi-experimental pilot study; both with an experimental and control group. Participants were randomly allocated to each group to minimise selection bias. However, in the Lareau study, both the experimental group and control group were in the same ward area, making the minimisation of confounding factors difficult. No strategies were described concerning the blinding of the outcome assessors and study participants to minimise bias, but withdrawals and dropouts were reported.

3.2 Quality Appraisal

Table 2.0 shows the scores from the Down and Black's checklist (1998) designed to support the systematic appraisal of studies using a quantitative design. The scores of the included studies range from 4 to 22. The majority of included studies were quality improvements with audit data (Wilson et al., 2017, Norton et al., 2015, Hinkulow, 2014, Murphy et al., 2013, Thomas et al., 2012, Richardson et al., 2009, and Haddock, 1994) although some had a pre-post design. Two studies (Gathecha et al., 2016 and Lareau et al., 2008) described as, respectively, a pilot randomised controlled trial (RCT) and feasibility study, compared findings from experimental and control groups. The quality of the included studies was rated as Fair to Poor. This rating was predominantly due to limitations in reporting, small sample sizes and study designs which limited the level of evidence: there are many challenges associated with conducting studies of this nature in busy ward environments.

3.3 Noise-reduction interventions

A range of noise-reduction interventions were implemented in the nine included studies that aimed to reduce night-time noise levels in ward settings. One study implemented a single intervention (Haddock, 1994), whilst the remainder were complex, multi-faceted interventions (Gathecha et al., 2017; Wilson et al., 2017; Norton et al., 2015, Hinkulow 2014, Thomas et al., 2012; Richardson et al., 2009 and Lareau et al., 2008).

3.3.1 Ear plugs

Ear plugs were a simple noise-reduction intervention, implemented as a single method (Haddock, 1994) or part of the multifaceted strategies to reduce noise (Norton et al., 2015; Murphy et al., 2013). Haddock (1994) concluded that ear plugs were an acceptable and effective method of aiding sleep following evaluation of a small group of patients' night sleep using yellow soft foam ear plugs, compared to that during a separate night using none. We were unable to identify the effectiveness of ear plugs as a single intervention from the other studies that used them as part of multiple approaches (Norton et al., 2015; Murphy et al., 2013). Interestingly, the use of ear plugs alone did not reduce patient-reported peak noise levels; however, they were useful as an approach to reduce background noise levels.

3.3.2 Noise warning systems

Two of the studies reviewed utilised visual noise warning systems as an approach to noise reduction (Murphy et al., 2013, Thomas et al., 2012). These included the 'sound ear' (Murphy et al., 2013) and a noise sensitive 'traffic light' system positioned at the hospitals nurses' station (Thomas et al., 2012). Both systems showed green lights when noise levels were at a satisfactory level; turning yellow when noise levels reach over 40dB and red when noise levels exceeded 50dB. Murphy et al. (2013) concluded that such warning systems were useful in the short-term to raise staff awareness, but over time lost their impact, and were eventually ignored by staff.

3.3.3 Noise awareness and Education

Staff education or awareness was highlighted as an essential element of six of the nine studies (Gathecha et al., 2016; Wilson et al., 2017; Norton et al., 2015, Murphy et al., 2013, Thomas et al., 2012 and Richardson et al., 2009). Interestingly, Gathecha et al. (2016) included education for staff and patients. The content of the education sessions detailed included awareness of patient feedback and the associated consequences for increased noise, along with details of the noise reduction intervention to be implemented. Follow-up to the educational session through various strategies such as email and visual reminders were deemed essential to maintain staff engagement in the long-term (Richardson et al., 2009).

3.3.4 Environmental review

Environmental reviews and repairs, such as installing window blinds and turning down equipment alarms, were reported to improve patients' experience of sleep (Norton et al., 2015; Richardson et al., 2009). Hinkulow (2014) implemented a project entitled HUSH (Hospital's Ultimate Silence for Healing). The HUSH initiative included closing doors, dimming lights and promoting quiet talking. The combined approaches contributing to HUSH time were reported as a much appreciated repose for patients, allowing undisturbed rest. The HUSH approach was subsequent to the evaluation, rolled out across the hospital and deemed to create a foundation for future research (Hinkulow 2014).

3.3.5 Leadership

Many of the strategies involved a key lead or strategy group to co-ordinate or 'champion' the implementation of the initiatives. Many were multi-professional, or included staff at strategic and operational levels (Norton et al., 2015, Hinkulow 2014, Thomas et al., 2012, Richardson et al., 2009 and Lareau et al., 2008). The use of a lead role prevented potential inconsistency or applications of protocols and maintained awareness and promoted ongoing staff impetus (Lareau et al., 2008).

3.3.6 Guidance

Sleep rounds/checklists or clinical guidelines/protocols included combined light and noise control measures to promote sleep (Murphy et al., 2013, Thomas et al., 2012, Richardson et al., 2009 and Lareau et al., 2008). The strategies included relatively simple reminders for staff to ensure that they closed doors, used torches to check patients, rather than turning on lights, avoided conversations in hallways, turned televisions off or provided headphones for patients watching television, had pagers on vibrate and ensured that 21.00 to 06.00 were quiet hours (Murphy et al., 2013). In addition, Thomas et al. (2012) promoted temperature-control measures, supporting the philosophy that small changes have a cumulative effect and implementation of simple measures is feasible and effective. No one factor could be singled out or be claimed to have the most or least impact on noise reduction or sleep promotion (Richardson et al., 2009).

3.4 Results of studies

Noise-reduction interventions with outcome measures related to environmental noise levels or patient related outcomes, including objective and self-reported measure of sleep quality or quantity.

3.4.1 Ward noise levels

Of the studies that monitored ward noise levels; following implementation of the noise reduction intervention, Wilson et al. (2017) found a reduction in noise readings from 83.8 dB and 90.7 dB pre-intervention, to 53.44 dB and 55.07 dB post-intervention, on surgical and medical units respectively. Similarly, Richardson et al. (2009) found pre-intervention average peak noise levels over 24 hours to be 96.48 dB(A) which reduced to 77.52 dB(A) post-intervention, with an overall significant reduction of peak noise levels on all 3 wards ($p < 0.001$). Murphy et al. (2013) found pre-intervention maximum noise levels on the first night to be 79.6 dB(A) and 86.0 dB(A) on the second night. These measurements were used to inform staff of the noise issue; yet no post-intervention measurements were monitored. Thomas et al. (2012) reported adequately low levels at night (35-40 dB), but these were not positively impacted by the interventions, although patients perceived noise to be worse when there was no intervention.

All three studies that used the HCAHPS as a measurement of noise reduction revealed an improvement from baseline during or post-intervention. The HCAHPS question focusing on noise asks patients during their hospital stay: 'How often was the area around your room quiet at night?'; with the following response options: *Always, Usually, Sometimes, Never*. Wilson et al. (2017) found that pre-intervention, 51.8% of patients reported a response of *Always* or *Usually* to this item. This proportion rose to 68% post-intervention. Similarly Hinkulow (2014) found 58% of patients gave the responses *Always/usually quiet* scores pre-intervention; this proportion rose to 66% post-intervention. Murphy et al. (2013) found that pre-intervention, 48% of patients stated night-time noise levels to be always quiet: this proportion rose to 60% post intervention.

3.4.2 Sleep quality and quantity

Several studies tested sleep quantity and quality during implementation of the various interventions. Gathecha et al. (2016) measured sleep parameters which indicated improvements in overall sleep time with a mean difference of 49.6 minutes ($p < 0.05$); sleep quality (mean difference of 0.46 self-reported scale points; $p < 0.05$) including refreshing sleep (mean difference of 0.54 points, $p < 0.05$) sleep interruptions (mean difference in number of incidences of -1.60, SE = -0.6, $p < 0.05$) with the intervention compared to control. Norton et al. (2015) reported baseline sleep ratings for 749 patients as *Good*: 270 (36%); *Fair*: 285 (38%) and *Poor*: 112 (15%). After 1 year of follow-up, sleep ratings had improved, with corresponding proportions (from 783 patients) of *Good*: 540 (69%) *Fair*: 180 (23%) and *Poor*: 63 (8%).

A sleep survey by Thomas et al. (2012) reported a median of 5 (IQR 3) hours of sleep per night, awoke a median number of 3 (IQR 3) times nightly and reported a median sleep latency of 11 to 15 minutes. There was no overall statistical difference throughout different phases of the intervention although the 'basic' sleep round saw an improvement in sleep latency from baseline. Patients reported significant difficulty sleeping in their 'washout' (no intervention) phase.

Lareau et al. (2008) noted no differences in sleep quality and duration between a control and intervention group; however, the intervention group experienced greater ability to remain asleep ($p = 0.001$) and used fewer sleep medications than the control group ($p = 0.044$). Patient surveys by Haddock (1996) showed that patients reported increased sleep quality through the intervention.

3.4.3 Meta-analysis for total sleep on ward (hours)

Studies by Gathecha et al. (2016), Lareau et al. (2008) and Thomas et al. (2012) were included in a meta-analysis of total hours sleep on the ward. A range of sleep-promoting interventions trialled by Gathecha et al. resulted in a significant improvement in mean number of hours sleep from 6.22 hours per night (SD 1.76 hours) to 7.03 hours per night (SD 1.87 hours) ($p = 0.002$). The sleep protocol implemented by Lareau et al. (2008) did not result in a significant change in nightly hours of sleep, with means of 6.61 hours (SD 1.55 hours) recorded in the control group; and 6.52 hours (SD 1.92 hours) in the intervention group ($p = 0.997$). The two interventions tested in the Thomas study ("Basic Sleep Rounds" and "Deluxe Sleep Rounds) which were combined into a single pairwise comparison, as recommended by Higgins and Green (2011), also did not result in a significant change in nightly hours of sleep, with means of 6 hours (SD 2.96 hours) recorded in a pre-implementation control group, and 5.78 hours (SD 2.67 hours) in the combined intervention group ($p = 0.580$).

Due to variations in the outcome measures utilised in the included studies, and other aspects of clinical and methodological heterogeneity, a random effects meta-analysis was

conducted on this outcome. The meta-analysis determined that a synthesised estimate for the standardised mean difference in total hours sleep (no intervention – intervention) was -0.11 hours (95% CI -0.46 to 0.25 hours). A Z-test for overall effect revealed no evidence that this value was non-zero ($Z=0.59$, $p=0.556$). Individual estimates for the standardised mean difference ranged from -0.45 (Gathecha et al, 2016) to 0.08 (Thomas et al 2012).

Cochran's Q test revealed evidence for statistical heterogeneity at the 0.1 significance level (reflecting the low power of this test: $\chi^2_{(2)}=5.12$; $p=0.077$). The I^2 statistic was 60.9%, indicating moderate statistical heterogeneity. The τ^2 statistic (between-study variance) was calculated to be 0.0579. The data is summarised in a forest plot (Figure 2).

Figure 2: forest plot for total sleep on ward outcome – [insert here please]

3.4.4 Meta-analysis for number of awakenings

Studies by Lareau et al. (2008) and Thomas et al. (2012) were included in a meta-analysis of mean number of awakenings on the ward. The sleep protocol implemented by Lareau et al. (2008) did not result in a significant change in nightly hours of sleep, with means of 1.06 awakenings per night (SD 1.15) recorded in the control group; and 0.85 awakenings per night (SD 1.04 hours) in the intervention group ($p=0.190$). The two interventions tested in the Thomas study (“Basic Sleep Rounds” and “Deluxe Sleep Rounds”) which were combined into a single pairwise comparison, as recommended by Higgins and Green (2011), also did not result in a significant change in nightly hours of sleep, with means of 3 awakenings per night (SD 2.96) recorded in a pre-implementation control group, and 3 awakenings per night (SD 2.22) in the combined intervention group ($p=1.000$).

Due to variations in the outcome measures utilised in the included studies, and other aspects of clinical and methodological heterogeneity, a random effects meta-analysis was conducted on this outcome. The meta-analysis determined that a synthesised estimate for the standardised mean difference in awakenings per night (no intervention – intervention) was 0.05 (95% CI -0.20 to 0.29). A Z-test for overall effect revealed no evidence that this value was non-zero ($Z=0.37$, $p=0.715$). Individual estimates for the standardised mean difference ranged from 0.20 (Lareau et al., 2008) to 0.00 (Thomas et al., 2012).

Cochran's Q test revealed no evidence for statistical heterogeneity at the 0.1 significance level ($\chi^2_{(1)}=0.46$; $p=0.500$); The I^2 statistic was 0.0%, indicating negligible statistical heterogeneity. The τ^2 statistic (between-study variance) was calculated to be 0.000. The data is summarised in a forest plot (Figure 3).

Figure 3: forest plot for total awakenings per night outcome [insert here please]

3.4.5 Meta-analysis for proportion of disturbed nights

Studies by Hinkulow et al. (2014), Murphy et al. (2013) and Wilson et al. (2017) were included in a meta-analysis of proportion of disturbed nights on the ward. The noise reduction program implemented by Hinkulow et al (2014) resulted in a significant change in

proportion of disturbed nights, with the odds of a disturbed night pre-implementation of 0.71 and odds of a disturbed night post-implementation of 0.5; hence an odds ratio of 0.70 (95% CI 0.13 to 3.68). The quality improvement project implemented by Murphy et al (2013) resulted in a significant change in proportion of disturbed nights, with the odds of a disturbed night pre-implementation of 1.22 and odds of a disturbed night post-implementation of 0.67; hence an odds ratio of 0.55 (95% CI 0.33 to 0.91). The multi-modal initiative implemented by Wilson et al. (2017) did not result in a significant change in proportion of disturbed nights, with the odds of a disturbed night pre-implementation of 1.272 and odds of a disturbed night post-implementation of 1.096; hence an odds ratio of 0.86 (95% CI 0.84 to 1.16).

Due to variations in the outcome measures utilised in the included studies, and other aspects of clinical and methodological heterogeneity, a random effects meta-analysis was conducted on this outcome. The meta-analysis determined that a synthesised estimate for the odds ratio for disturbed nights (no intervention: intervention) was 0.75 (95% CI 0.55 to 1.01). A Z-test for overall effect revealed insufficient evidence at the 5% significance level that this value was non-zero ($Z=1.89$, $p=0.059$). Individual estimates for the odds ratio for disturbed nights (intervention: control) ranged from 0.86 (Wilson et al., 2017) to 0.55 (Murphy et al., 2013).

Cochran's Q test revealed no evidence for statistical heterogeneity at the 0.1 significance level ($\chi^2_{(2)}=2.29$; $p=0.318$); The I^2 statistic was 12.7%, indicating low statistical heterogeneity. The τ^2 statistic (between-study variance) was calculated to be 0.0121. The data is summarised in a forest plot (Figure 4).

Figure 4: forest plot for proportion of disturbed nights outcome - [please insert here]

4.0 DISCUSSION

The need for sleep is increased when we are ill. However, there is clear evidence that average hours of sleep are significantly reduced for patients in hospital (Norton et al., 2015; Thomas et al., 2012). To our knowledge this is the first systematic review designed to identify evidence of interventions to aid sleep by reducing noise on general hospital wards.

Nine studies met the inclusion criteria in this systematic review which aimed to identify effective interventions designed to reduce noise in ward settings and promote sleep for in-patients. The selected studies originated from the United Kingdom (3), the USA (5) and Israel (1). A range of noise reduction interventions were implemented in the included studies. One study implemented a single intervention, whilst the remainder were complex, multi-faceted interventions. Evidence from the included studies shows that the average night time environmental noise levels recorded across a variety of ward settings generally exceeded WHO recommendations (Wilson et al., 2017, Murphy et al., 2013, Richardson et al., 2009). One exception was a quality improvement study conducted on a neurological

ward (Thomas et al., 2012) in the USA. The average baseline noise level reported in this study before the implementation of the quality improvement implementation was 35 dB. This is considerably lower than any other study but unfortunately no follow-up measure was recorded for comparison.

Where sound was measured, studies by Richardson et al. (2009), Murphy et al. (2013) and Wilson et al. (2016) found that levels were reduced when interventions were implemented, although Thomas et al. (2012) reported that the noise levels had not been positively impacted by the interventions. Gathecha et al. (2016) Thomas et al. (2012) and Lareau et al. (2008) all compared total sleep hours for the intervention and non-intervention groups allowing commonalities for meta-analysis, yet only Gathecha et al. (2016) demonstrated distinctively significant improvements. The total hours of sleep, however, is a complex concept and varies significantly between individuals, a factor not always considered in the research retrieved.

An important factor to consider is the physical environment of the ward setting, which can have a significant effect on environmental noise levels. This, in turn, impacts on patients' sleep patterns (Anjali & Mahbub, 2007). Most of the studies were conducted in the USA where wards tend to comprise single rooms, which may explain differences in international studies. This highlights the importance of reporting the details of the study setting with the inclusion of a diagram of the ward layout. Interventions designed to reduce environmental noise levels may be more successful in wards with single rooms compared to the older style Nightingale ward layout. The patient dependency, number of hours of nursing care per patients and skill mix of the nursing team is also likely to influence findings and should be reported.

The number of awakenings was a second commonality of two of the studies enabling meta-analysis; whilst Lareau et al. (2008) demonstrated no significant change in the total sleep hours or number of awakenings, in the pre- and post-intervention implementation of Thomas et al. (2012) both groups averaged 3 awakenings. The third meta-analysis was based on proportion of disturbed nights, with Hinkalow et al. (2014) and Murphy et al. (2013) demonstrating significant differences; in contrast to Wilson et al. (2017) who found no significant change to disturbances in the groups. This pattern of activity of the USA studies may have been motivated by the introduction of a 'pay for performance' strategy, which provided financial rewards for hospitals that reduced environmental noise levels. Organisational performance was evaluated by a national patient-reported experience measure (HCAHPS), with one specific item on noise levels at night (Wilson et al., 2017, Hinkalow et al., 2014, Murphy et al., 2013).

The quality and quantity of sleep that patients experience at home is an important factor to consider. Gathecha et al. (2016) reported that 85% of their participants reported poor

quality sleep at home. Decisions about when baseline self-reports about sleep quality are taken require careful consideration. The authors mention that any intervention is likely to take some time to have an effect (Gathecha et al., 2016). For this reason, wards where the patients are in for [more than one](#) night may show the most benefit from noise reductions designed to improve patients' sleep.

A wide variety of noise reduction interventions were used across studies, [precluding the comparison of the effectiveness of different types of interventions](#). [The meta-analyses revealed no evidence for the effectiveness of noise-reducing interventions in general, whilst not identifying any specific intervention to be ineffective](#).

In some cases, the patient uptake of certain elements of interventions was low e.g. *Do not disturb* signs (Wilson et al., 2017). This suggests that in some cases, the intervention components may not match with patients' preferences, but rather reflect those of the health professionals. The majority of studies did not report a significant degree of patient participation in the design of interventions. It is important to involve patients in the design of interventions that will be used by them. The protocols and equipment used across studies varied considerably. The development of a universal protocol with input and consensus from environmental sound experts could guide future studies and support meaningful comparisons. Consistency across the design of studies could be improved if there was agreement about what constructs should be measured to evaluate sleep quality (sleep latency, duration, self-reported sleep quality, number of disturbances and what constitutes sleep disturbance), and which measures were most appropriate. There may be a disconnect between environmental noise levels and patients self-reported sleep quality, as two studies objectively recorded environmental noise levels increased following Quality Improvement interventions (Wilson et al., 2017, Thomas et al., 2012). Alternative explanations may be the natural variation in noise levels that occur due to patterns of ward activity, or the impact of other factors such as ambient light, pain levels, anxiety or other factors that are known to impact on sleep quality and quantity.

4.1 Limitations

We conducted a comprehensive and systematic search of the literature with no date or language limits, and reviewed reference lists. However, we could only pool data from six studies for meta-analysis. The lack of randomised controlled trials limits robust conclusions about the value of noise reduction/sleep promoting interventions implemented in the included studies. That said it must be acknowledged that there are many challenges associated with conducting studies of this nature in busy ward environments. However, there is evidence to suggest that the implementation of noise reduction interventions in a ward setting is at least feasible.

4.2 Implications for practice and further research

Noise and its association with sleep quantity and quality is a complex issue with significant impact on patient experiences in hospital. Although [our review concludes that there is](#)

insufficient evidence to draw firm conclusions, it seems that noise reduction interventions are feasible in a ward setting and show potential as an approach to reduce environmental noise levels which can improve patient sleep ratings. Multi-faceted noise reduction interventions are reported to have a cumulative effect (Murphy et al., 2013), but no one factor can be claimed to have the most impact (Richardson et al., 2009). It seems likely that multifaceted complex interventions are more effective than single interventions, but further research is warranted to identify the effective ingredient in complex interventions designed to reduce noise levels to promote sleep in ward settings. In most cases improvements in patient reported sleep quality and/or quantity was noted, although Wilson et al. (2017) recognised that respondent bias may influence their outcomes. To support the future design of robust studies, consensus is required on the most effective patient-reported outcome measure to assess sleep quality and quantity and consistency regarding measurable constructs such as awakenings and disturbances.

5.0 CONCLUSIONS

There is a lack of appropriately designed studies that test the effectiveness of noise-reduction interventions in ward settings. The meta analyses did not reveal any evidence that noise reduction interventions had a beneficial effect on sleep, howsoever measured. Pilot trials and observational studies show some promise, with multifaceted interventions being the most frequently used. Within the context of the limited quality of included studies and variation in the interventions utilised, the meta-analyses reveal that the sleep-promoting interventions lead to a substantial reduction in disturbed nights, which approaches statistical significance at the 5% significance level. However, the meta analyses do not reveal any evidence for the beneficial effect of sleep-promoting interventions in terms of total hours' sleep on the ward and total number of awakenings per night; although small improvements in patient experience with respect to both of these outcomes are recorded. Robust studies are required to identify the most effective interventions to address this significant and ubiquitous problem. As patient satisfaction is receiving increasing priority in hospital quality reporting and high noise levels have a negative impact on this data (Wilson et al., 2017, Hinkulow et al., 2014, Murphy et al., 2013) investment in noise reduction and sleep promotion interventions alongside further robust research is essential.

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PRISMA 2009 Checklist

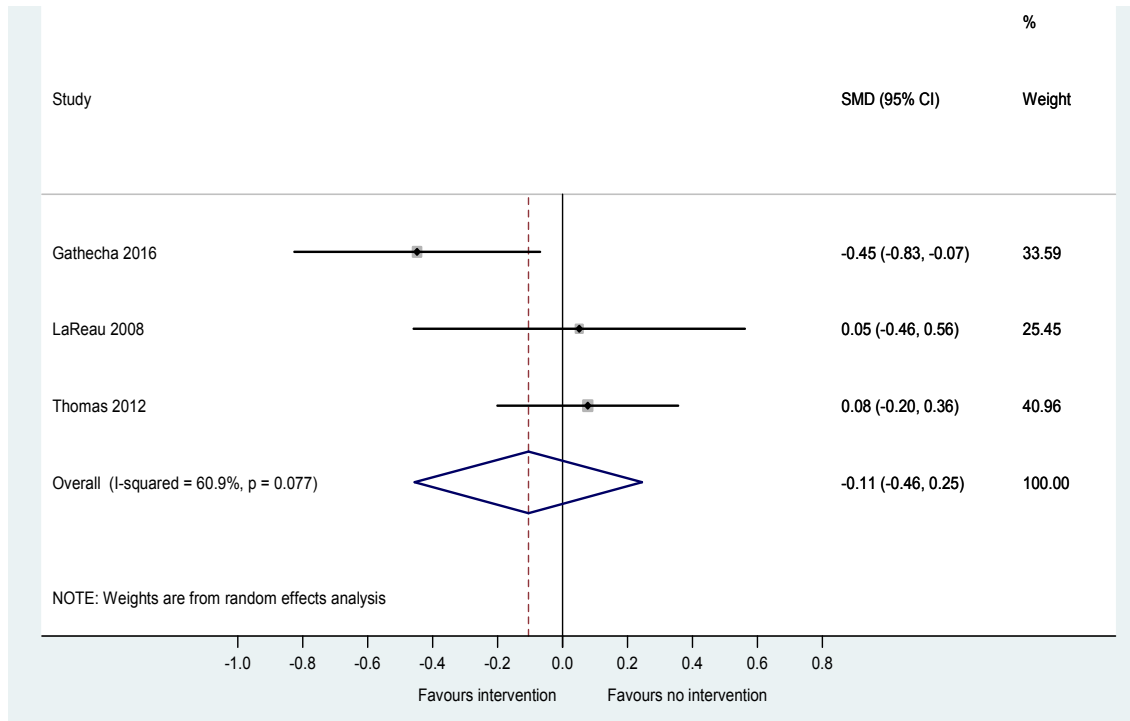


Figure 2: forest plot for total sleep on ward outcome

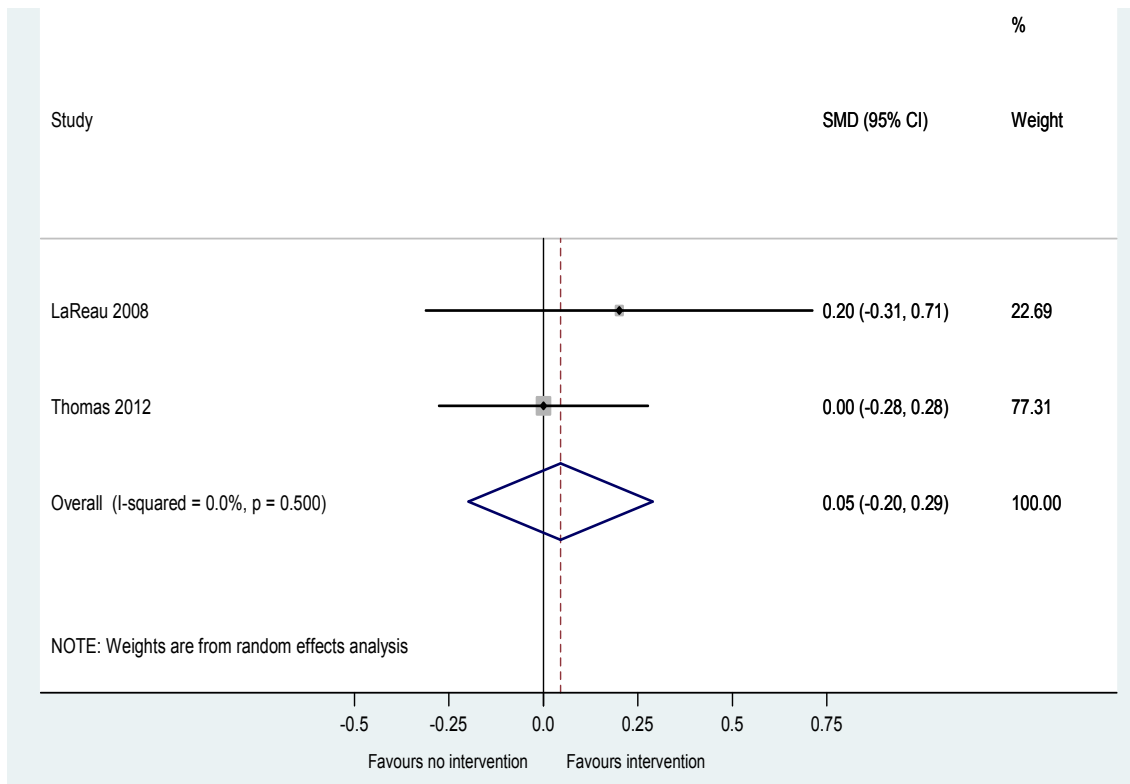


Figure 3: forest plot for total awakenings per night outcome



PRISMA 2009 Checklist

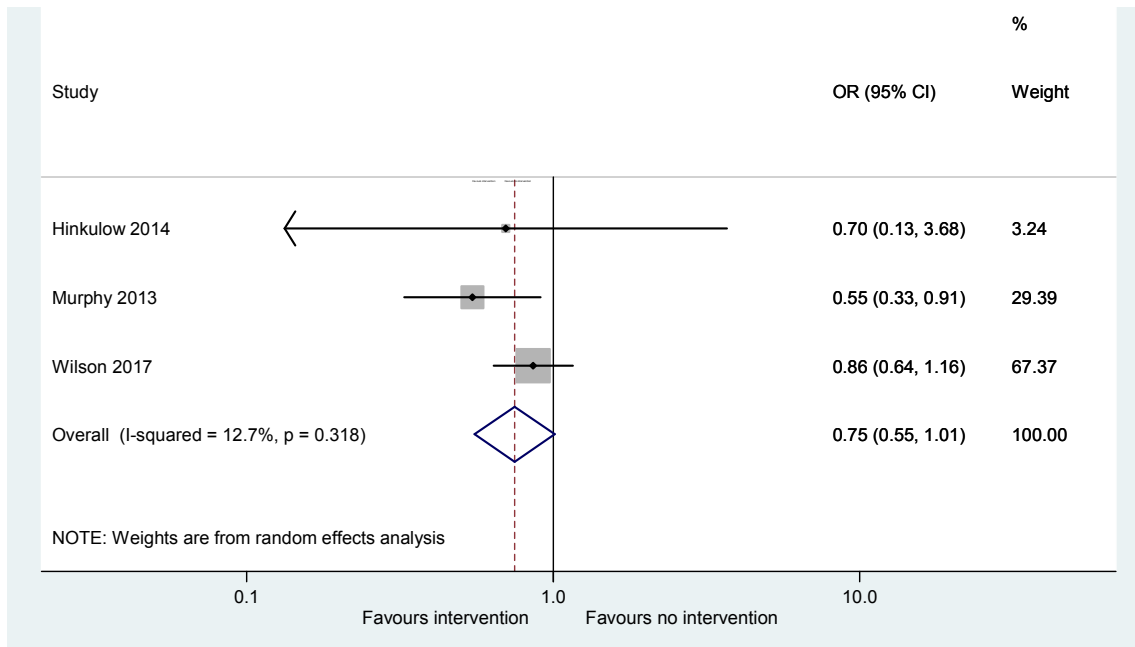


Figure 4: forest plot for proportion of disturbed nights outcome

Table 2 PRISMA Flow Diagram of Literature search and study selection

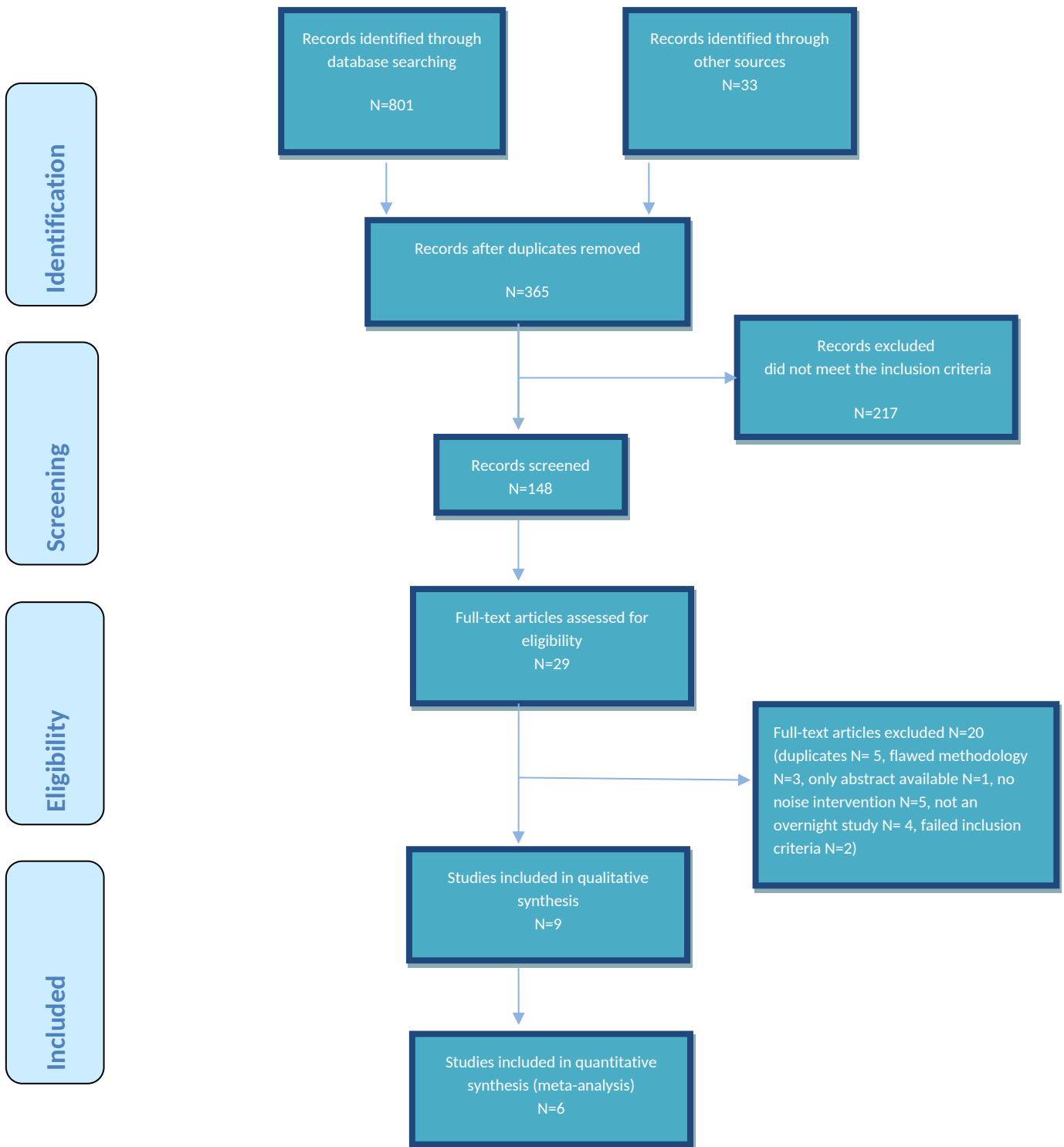


Table 2.0 Quality appraisal (Down and Black, 1998)

Authors, year, study design	Score on each domain					Sum of all domains	Methodological quality
	Reporting (12 items)	External validity (4 items)	Internal validity/Bias (7 items)	Internal validity/Confounding (6 items)	Power (1 items)		
Gathecha et al., 2016 Quasi-experimental prospective study	11	3	3	4	0	22	Fair
Wilson et al., 2017 Quality Improvement Project	5	1	2	1	0	9	Poor
Norton et al., 2015 Quality Improvement Project	5	1	1	2	0	9	Poor
Hinkulow, 2014 Mixed Method evaluation	2	0	0	2	0	4	Poor
Murphy et al., 2013 Quality Improvement Project	3	0	0	2	0	5	Poor
Thomas et al., 2012 Prospective, observational quality improvement study	11	1	3	2	0	17	Poor
Richardson et al., 2009 Pre and post audit	5	1	3	2	0	11	Poor
Lareau et al., 2008 Environmental pilot study	10	2	3	4	0	19	Poor
Haddock 1994 Researcher generated questionnaire	3	1	0	2	0	6	Poor

The data base search strategy

1. Noise	2. Setting	3. Sleep	4. Outcome	5. Intervention
NOISE/ OR NOISE, OCCUPATIONAL/ "noise reduction strateg*" OR "noise reduction" OR "noise reduction interventions" SOUND/ "noise spectrum" OR "reverberation time" OR "noise level*" OR "sound level" ACOUSTICS/	night OR night-time INPATIENTS/ HOSPITALIZATION HEALTH FACILITY ENVIRONMENT HOSPITALS/ NURSING STAFF, HOSPITAL/ HOSPITALS/ PATIENTS PATIENTS' ROOMS/ NIGHT CARE/	SLEEP/ SLEEP DEPRIVATION/ sleep ADJ disturbance OR quality OR depriv* OR fragmentation sleep ADJ (promot* OR support*) OR initiat* "sleep parameters" WAKEFULNESS/	ACCIDENTAL FALLS/ DELIRIUM/ SYSTEMIC INFLAMMATORY RESPONSE SYNDROME/ ANXIETY/ DEPRESSION/ FATIGUE QUALITY OF LIFE/ TREATMENT OUTCOME/ LENGTH OF STAY/ RISK MANAGEMENT/	HOSPITAL DESIGN AND CONSTRUCTION/ "ward design" OR "hospital design" "hospital layout" OR "ward layout" "work station*" OR "nurses station*" OR "doctors station" "sound reduction strateg" OR "sound reduction" OR "sound reduction interventions" EQUIPMENT AND SUPPLIES/ "equipment modification" "patient room design" OR "nursing unit design" OR "work station design" OR "ear protective devices" OR "ear plugs" OR "sound masking" bin OR "waste disposal" carpet OR "floor covering" EAR PROTECTIVE DEVICES/ EDUCATION, NURSING/

Authors/Year, Country and study design Citations Oct 17	Sample, source, setting and age	Intervention	Outcomes	Results
Gathecha et al., 2016 United states Quasi-experimental prospective study (pilot) No citations	112 adult patients, two general medical units, one intervention and one control (43% in intervention group) Mean age of 58 years, 55% female	Nurse-delivered sleep promoting interventions augmented by sleep hygiene education and environmental control designed to minimize sleep disruption	Objective and subjective measurement of sleep parameters using validated sleep questionnaires, daily sleep diary and actigraphy monitor	Indicated improvements during hospitalisation with intervention compared to control. Mean differences in: overall sleep time 49.6 minutes (p<0.05); <u>s</u> leep quality (0.46, p<0.05); <u>r</u> efreshing sleep (0.54, p<0.05); <u>s</u> leep interruptions (-1.60, p<0.05)
Wilson et al., 2017 United states Quality improvement project No citations	Patients and staff on two pilot adult surgical and medical units - pre- and post-intervention, no demographic data 350-bed acute care hospital which constantly received low scores in HCAHPS score	Multifaceted noise reduction program to decrease noise at night including: leadership rounds; staff education; sleep promotions care and equipment review	Patient interviews – categorised according to source of noise, staff, equipment, other patients, noise on the unit by earplugs or doors closed or no complaint of noise. Hospital consumer assessment of healthcare providers and systems (HCAHPS) data dB levels pre- and post-interventions	Reduction in dB readings 83.8/90.7 pre to 53.44/55.07 on surgical and medical unit respectively. Patient preference doors closed (56%) earplugs (45%). HCAHPS data dB levels pre and post interventions pre 51.8%, during 23.3% and then increasing to 68% by the end
Norton et al., 2015 United Kingdom Quality improvement project 4 citations	18 acute hospital wards Baseline: 749 patients plus 186 patients interviews Post-intervention: 783 patients	Action plan, ear plugs, environment repairs.	Outcome of electronic survey at baseline and one year	Overall sleep rating baseline Good: 270 (36%) Fair: 285 (38%) Poor: 112 (15%) Subjective assessment of hours slept 1 year follow-up Good: 540/783 (69%) Fair: 180 (23%) Poor: 63 (8%)

Hinkulow, 2014 United states Mixed method evaluation 1 citation	Oncology Unit Phase 1: 12 patients pre- and post-intervention Phase 2: 25 nurses interviewed	HUSH time – noise reduction programme, including closing doors, dimming lights and attending to quiet talking	Phase 1: HCAHPS outcomes pre- and during HUSH Phase 2: content analysis	Phase 1: Pre-HUSH: Always/usually quite 58% During – Always/usually 66% Phase 2: Calmness/Uninterrupted rest and sleep HUSH time became a much appreciated repose for patients to rest undisturbed.
Murphy et al. 2013 Israel Quality Improvement project 13 citations	44 bedded <u>m</u> edical/surgical unit pre-intervention 120 patients post-intervention (specified as percentage of total sample)	S trategies: Champion; d oor closing; ear plugs and bookmarks; flash lights [torches] to check patients; avoid conversations in hallway; headphones for people wanting TV on; staff education; pagers on vibrate; dim hall lights; 9-6 quiet hours; sounding of ear noise warning	HCAHPS survey Pre-noise monitoring Tracking patient ratings HCAHPS post-intervention	HCAHPS survey 32 questions patients' perceptions – question asking how often quiet at night: 48% always; Pre Noise Max night 1: 79.6 dB; night 2: 86dB Tracking patient ratings HCAHPS post-intervention 60% 'always' quiet at night
Thomas et al., 2012 United States Prospective, observational quality improvement study 15 citations	Neuro ward 253 sleep surveys in 4 phases: P1 – baseline – sleep surveys, Press Ganey Survey & noise meter recordings (10 weeks) P2 - Implemented 'Basic Sleep Rounds' P3 – Wash-out phase P4 – Deluxe Sleep Rounds P2 & 4 sleep rounds implemented for 2 weeks before data collected P1 (32) P2 (33) P3 (30)	Sleep rounds, lights out, TV off, temperature a) Staff education b) sleep rounds – lights out, TV off, Temperature Basic and Deluxe c) Noise sensitive traffic lights at station Yellow over 40dB Red over 50dB	Sleep and patient satisfaction	Patients reported 5 (interquartile range [IQR] 3) hours of sleep per night, awoke 3 (IQR 3) times nightly, and reported a median sleep latency of 11 to 15 minutes. Pain, staff interruptions, and roommates were the most significant barriers to good sleep. Noise levels were adequately low (35–40 dB) at night but were not positively impacted by our sleep-promoting interventions. Patients perceived noise on the unit to be worse during phases of the study in which there was no intervention.
Richardson et al., 2009 United Kingdom Pre- and post-audit 60 citations	Acute surgery, medicine, orthopaedic wards Staff from UK Teaching hospital – three wards - Acute surgical ward (30 beds) 29 staff - Acute medical ward (30 beds) 31 staff	a. Sleep promotion clinical guideline b. environmental review c. staff awareness d. follow up e. posters	P1 & P3 noise levels measured over 24 hours	Reduction in average peak noise – (A _{eq} Peak) = 0.64 Significant reduction of peak noise levels on all 3 wards, and all wards combined (p<0.01 in each case) Likely to be attributed to the

	Acute orthopaedic (32 beds) 30 staff About 50% of staff received intervention programme			development and implementation of a multi method intervention approach – no one factor could be claimed to have the most impact
Lareau et al., 2008 United States Environmental Pilot study 44 citations	65 years or over Medicine or cardiology patients n=59 (29 exp/30 con) Total - 59 29 experimental & 30 control group	Sleep protocol including light and noise control Control – Usual care Experimental group – intervention	Ease of falling asleep, ability to maintain sleep, duration and quality. Effect of sleep protocol on number of medications.	Mean sleep hours: intervention 6.52; control 6.61 (p=0.997) No. of awakenings: intervention 0.85; control 1.06 (p=0.190) RCSQ scores: intervention 144.25; control 155.22 (p=0.667) No of sleep medications: intervention 6.52; control 6.61 (p=0.997)
Haddock 1994 United Kingdom Researcher-generated questionnaire 30 citations	18 patients (paired)	Yellow soft foam ear plugs Night 1 – no ear plugs Night 2 – Half (n=9) wore ear plugs Night 3 – Half (n-9) wore ear plugs Night sedation – 9 on Night 1	Sleep quality	Night 1: 13 (72%) reduced quality sleep compared to home Night 2: 6 ear plug wearers improved sleep and 3 same as Night 1 Reduced background noise and increase sleep quality also reported