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Identifying relationships between sleep posture and non-specific spinal symptoms in adults: A scoping review

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Abstract

Objectives: The aims of this scoping review were to (a) determine the body of evidence regarding relationships between sleeping postures and spinal symptoms and (b) provide suggestions as to what sleeping postures can be recommended by clinicians.

Design: Scoping review.

Data sources: PEDro, Embase, Cumulative Index to Nursing and Allied Health Literature, Cochrane Library, Medline, ProQuest, PsycINFO, SportDISCUS and grey literature from inception to April 10, 2018.

Data selection: Using a modified Arksey and O'Malley framework, all English language studies in humans that met eligibility criteria using key search terms associated with sleep posture and spinal symptoms were included.

Data extraction: Data were independently extracted by 2 reviewers and mapped to describe the current state of the literature. Articles meeting the search criteria were critically appraised using the Downs and Black checklist.

Results: From 4186 articles, four articles were identified, of which three were exploratory and one interventional. All studies examined three or more sleep postures, all measured sleep posture using self-report and one study also used infrared cameras. Two studies examined symptoms arising from the lumbar spine, one the cervical spine, and one the whole spine. Waking pain and stiffness were the most common symptoms explored and side lying was generally protective against spinal symptoms.

Conclusions: This scoping review highlights the importance of evaluating sleep posture with respect to waking symptoms. Side lying appears protective of cervical symptoms and possibly spinal symptoms in general, however there is a general paucity of studies from which to draw firm conclusions for all sleep postures. It is recommended future research consider group sizes and population characteristics to achieve research goals, that a validated measure be used to assess sleep posture, that characteristics and location of spinal symptoms are clearly defined and that the side lying posture is subclassified.

Strengths and Limitations of this Study

- This is the first scoping review collating and synthesising the available literature on sleeping posture and non-specific spinal symptoms
- A critical appraisal of evidence assessment was undertaken for each included study
- The lack of studies and small group sizes prevented firm recommendations being provided for all sleep posture

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Competing Interest

None declared.

Data Sharing Statement

No additional data are available.

Introduction

Cervical and lumbar symptoms are the leading cause of musculoskeletal disability in most countries and most age groups. Of those who report cervical and lumbar pain, the proportion is higher in females for both cervical (59%)(1) and lumbar (52%) pain(2). The prevalence of both cervical and lumbar pain has increased markedly over the past 25 years(cervical 21.1% and lumbar 17.3%), and these rates are expected to continue rising(3). Cervical and lumbar pain contribute to large economic and societal costs and are major sources of work disability, being either the first or second ranked cause of years lived with disability between the ages of 20 and 79 years(3-5). Research indicates that remissions in symptoms are temporary rather than permanent(6, 7) and cervical and lumbar pain becomes chronic in 25 to 60% of cases(8). Identification of modifiable risk factors contributing to the onset and chronicity of cervical and lumbar pain and other symptoms, is critical(9) to improve the management of cervical and lumbar pain.

A potentially modifiable risk factor that aggravates spinal symptoms, is sleep posture. Sleep is considered essential for human mental and physical recovery. Yet, every night some people go to bed, only to wake with spinal symptoms not present the prior evening, while others with existing spinal symptoms, wake with exacerbations of their symptoms(10, 11). For example, in young air force personnel, 33% experienced their most intense spinal pain during the evening and on first waking(10). It has been postulated that poor sleep posture may be a factor in the development of both waking cervical(12-14) and lumbar symptoms(15, 16).

Habitual sleep postures may influence the amount of load applied to spinal tissues when sleeping. When upright, compressive load due to gravity and muscle contraction(17, 18) is likely to be far less during the day than during sleep, creating a low compression environment. In a 25-year review on the fundamentals of spinal biomechanics, it was noted that spinal movements decrease under a superimposed compression load. The author postulated this was due to increased anular stiffness and increased zygopophyseal joint (ZPJ) contact(19). Conversely, when lying down, the sources of spinal compression are minimal, creating a low compression environment, potentially allowing an increased range of spinal movement. The combination of increased range and asymmetrical loading posture may result in altered and/or additional loading of viscoelastic collagenous restraints like the ZPJ capsule and ligaments(20). Viscoelastic tissues are vulnerable to sustained or repeated low elongation loads, and undergo predictable mechanical and viscoelastic changes. Ligaments in feline spines exposed to 60 minutes of repeated low load, demonstrate a significant increase in the expression of pro-inflammatory chemicals, compared with control ligaments from the same spine, indicating acute inflammation and tissue degradation in ligaments subjected to the cyclic loading(21). Additionally, sustained non-symmetrical sleep postures can induce structural spinal changes in humans(22, 23). Sleep postures have been shown to be modifiable(15, 24) and identification of modifiable risk factors related to spinal pain, have been highlighted as a priority in managing disabling lumbar pain(25).

Some sleep postures, such as prone, are clinically believed to increase load on spinal tissues, reducing recovery and provoking waking spinal symptoms(16, 26, 27). While some sleep research has examined the role sleep posture may have on spinal symptoms(11, 15, 28), there has been no synthesis of the literature in regards to sleep posture and spinal symptoms.

Methods

Search Framework

This scoping review was developed using the methodological framework proposed by previous authors(29), further refined by other independent authors and institutes(30-32) and reported in line with key PRISMA-ScR guidelines(33).

Research Question

Following an individual review of the literature and a group meeting, an authors' consensus was reached to determine the following research question; is there a relationship between sleep posture and spinal symptoms?

Aim and Objectives

The aim of this scoping review was to gain a clear understanding of the current knowledge base in relation to the identified research question. To achieve this aim, an iterative process involving electronic meetings and communication between authors was used to determine the following research objectives:

- Identify what study designs and participant populations have been studied to answer the research question.
- Identify the types of specific methodology used in the body of evidence to address the research question.
- Identify common results, conclusions and recommendations from the body of evidence regarding the research question.

Eligibility Criteria

Eligibility criteria were based upon the population, intervention, comparison and outcome (PICO) framework. A draft list of eligibility criteria was initially determined following the independent screening of relevant articles by two reviewers. Criteria were then developed iteratively between two reviewers and a finalised list of criteria were uploaded to Covidence(34), as a reference for data charting reviewers.

Inclusion Criteria

For inclusion in this scoping review, the prior research needed to study participants 18 years or older, with either pain, stiffness or bothersomeness in the cervical, thoracic or lumbar spine. Any observational or interventional study examining the relationship between sleep posture and spinal symptoms was considered. Articles that either compared sleep posture change (e.g., before and after an intervention) or had no comparator (e.g., epidemiological) were included. Articles needed to use a subjective or objective measure for symptoms and sleeping posture.

Exclusion Criteria

Articles were excluded if they involved animals, cadavers or included participants diagnosed with sleep apnoea, spinal stenosis, migraine, red flag pathologies (e.g., neoplasm, inflammatory conditions, fractures or infections); participants with pain of known non-spinal origin (e.g., kidney disease, post-operative pain, temporomandibular joint, shoulder pain); participants with neurological conditions (e.g., multiple sclerosis, cerebrovascular accident); or participants that were unable to move freely in bed (e.g., using continuous positive airway pressure therapy or in the last trimester of pregnancy). Articles were excluded if they did not isolate the intervention when a group of interventions were implemented (e.g., spinal injection and sleeping posture) or if they compared sleep systems (e.g., mattress, base and or pillow) or changes in sleep systems but did not report the change in sleep posture. Further, articles using actigraphy to measure movement or articles that only examined the quality or efficacy of sleep were excluded. Finally, editorials, opinion-based articles, review articles (systematic or narrative) and articles not written in English were excluded.

Patient and Public Involvement

Patients and the public were not involved in this scoping review.

Search Terms and Strategy

The population, intervention, comparison and outcome (PICO) framework was used to assist in the collation of all elements relevant to clinical research questions. Population: Terms used for the search strategy were chosen to be representative of the areas and symptoms, likely to be experienced by a population with non-specific spinal symptoms. Non-specific symptoms are those not related to fracture, infection, inflammatory disease, tumor or spinal stenosis. Intervention: Terms representative of interventions aimed at changing sleep posture in association with spinal symptoms were considered for inclusion, while other terms not associated with spinal symptoms e.g. apnoea were excluded. Comparison: Terms were considered that were indicative of any type of comparison. Outcome: Any terms to indicate the subjective measure of pain, stiffness or bothersomeness or objective measure used to evaluate sleep posture, were considered.

Identified key search terms were then used in the search strategy to identify all relevant articles. An initial search was conducted in two of the four databases, recommended(35) for physiotherapy related topics; PEDro, and Embase (via Ovid) from inception to December 2017. The initial search was used to determine if the search terms and strategy were appropriate, and informed the development of the final search terms and strategy.

The final search strategy was conducted using the search terms and Boolean logic as described in Supplementary File Search Strategy for the Scopus Database and adapted for eight electronic databases (PEDro, Embase, Cumulative Index to Nursing and Allied Health Literature, Cochrane Library, Medline, ProQuest, PsycINFO, SportDISCUS) with the assistance of a health sciences information specialist. Grey literature (espace, Google Scholar (top 100 references scanned for relevance), and Web of Science) was searched for difficult to locate or unpublished material that had not already been included. The final step involved manual searching the reference sections of relevant articles and publications by key authors for additional articles, not identified in the original search.

Study Selection

All search results were imported into the reference management software package, Endnote X8(36) and duplicates removed. Remaining results were imported into Covidence(34) and additional duplicates removed. Using Covidence, two reviewers independently performed Level 1 (title and abstract) and Level 2 (full text) screening, based on the eligibility criteria. Differences of opinion in which articles progressed to the next level, were first resolved with discussion between reviewers and if necessary, with input from a third reviewer.

Data Charting

The data charting form was developed and revised iteratively between reviewers to ensure data relevant to the three research objectives were collected. A definitions and instructions document was developed to ensure that data was collected consistently by the independent reviewers. The data charting form was then independently pilot tested in duplicate on a random sample of four potential articles. Following identification of articles for inclusion in this review, data were independently charted in duplicate using a data charting form created in Excel and based on the three research objectives. An attempt was made to contact authors of eligible articles where authors reported that data relevant to our scoping review had been collected but was not publicly available, and to clarify points relevant to our data charting.

Quality of Evidence

Non-assessment of methodological quality and the risk of bias is consistent with current guidelines on conducting a scoping review(30, 32). However, a focus of this scoping review was on methodology; therefore, a methodological assessment of quality was included. The Downs and Black checklist(37) was chosen, as it has documented criterion validity, face and content validity, intra-rater (r = .88) and inter-rater reliability (r = .75) and guidelines for use(38). A modified version of the Downs and Black checklist(39), where a dichotomous score for power (question 27) was used. As a result, the maximum score for randomised trials was 28 and non-randomised trials 25. The Downs and Black checklist was independently completed for each article in duplicate. Differences in scoring were first resolved by consensus between reviewers and if required, by a third independent reviewer. Study limitations noted by authors were collected to compliment the Downs and Black checklist.

Results

Search Results

An overview of the article identification process is provided in the PRISMA flow diagram in Figure 1. Articles excluded due to wrong outcomes, were those that did not include a measure of sleep posture or only examined sleep posture and not symptoms, tested a sleeping system (e.g., mattress or pillow) in relation to spinal symptoms but not posture, or studied sleep posture in relation to sleep quality. Articles excluded due to wrong study design included treatment guidelines, opinion and editorial piece and summaries.

FIGURE 1 PRISMA FLOW DIAGRAM (SEPARATE FILE)

Table 1. Mapping of Study Design and Population Characteristics

Author	Study Design	Population Type	Sample Size (Gender)	Age *M* (*SD*)
Abanobi et al., 2015	Case controlled	Welders in Owerri, Nigeria	100 (male = 100)	35 (9)
Cary et al., 2016	Cross sectional	Population of convenience in Esperance, Western Australia	15 (male = 7)	44 (17)
Desouzart et al., 2016	Controlled pilot	Elderly participants in physical activity program at Polytechnic Institute of Leiria, Portugal	20 (male = 0)	62 (4)
Gordon, Grimmer and Trott, 2007a Gordon, Grimmer and Trott, 2007b	Epidemiological	Every third household in Port Lincoln in South Australia	812 (male = 261)	Female 61 (10) Male 59 (11)

Notes. *M* = Mean, *SD* = Standard deviation

Study Design and Population Characteristics

The designs of the four included studies were mixed (Table 1). One study included information that was presented in two separate articles(11, 40).

Methodology: Sleep Posture Measurement

All studies examined participants in their domestic environment (Table 2) and described as a minimum the three common sleep postures; supine, side lying and prone. One study described four sleep postures, dividing side lying into two sleep postures and named them supportive side lying and ¾ side lying(41). Another described five postures, adding “upright” and “varies”, to the common three sleep postures(11). One study used three different postures, but combined side lying and prone for analysis, due to small number of prone sleepers, of whom none reported lumbar pain(42). All studies used self-report questionnaires to assess sleep posture. Studies focused on different time points when questioning about sleep posture. Two specifically focused on night and waking posture; “in what sleep posture do you usually go to sleep”, “in what sleep posture do you usually wake up” and “in what sleep posture do you spend most of the night”(11)(p. 7), and “which posture most closely resembles the posture you are lying in when you fall asleep?” and “which posture most closely resembles the posture you are lying in when you wake up?"(41)(Appendix 1.). The other two studies were non-specific, "usual sleep posture"(42)(p. 335) and "informal questionnaire for ... sleeping position"(15)(p. 237). In addition to using self-report, the authors of one study used an objective method of assessment, twin camera infrared video recording, to verify sleep posture(41).

Table 2. Mapping of Sleep Posture Measurement and Symptoms

Author	Sleep Environment	Standard three sleep postures	Number of sleep postures	Sleep posture outcome measurement	Anatomical Area	Symptom Type	Symptom(s) Characteristics	Symptom Outcome Measurement
Abanobi et al., 2015	Domestic	Y	3	SR	Lumbar	Pain	Past and present history	Questionnaire - face to face interview
Cary et al., 2016	Domestic	Y	4	SR + Video recording	Cervical, Lumbar, Both, Other	Pain, Stiffness	Frequency (month) Waking symptoms	Questionnaire written
Desouzart et al., 2016	Domestic	Y	3	SR	All spine	Pain	Intensity	Questionnaire written - pain VAS
Gordon, Grimmer and Trott, 2007	Domestic	Y	5	SR	Cervical	Pain, Stiffness, HA, Shoulder blade/arm pain	Frequency (week), duration Waking symptoms	Questionnaire - structured telephone interview

Notes. NS = Not stated, Y = Yes, SR = Self-report, HA = Headache, VAS = Visual analogue scale

Methodology: Measurement of Symptoms

The anatomical location, characteristics and method of measuring spinal symptoms are presented in Table 2. One study included non-spinal symptoms (e.g., hip and legs) classified as “other”(41). All studies examined pain (with two studies examining additional symptoms), but differed in regards to examining intensity, frequency, period of symptoms and diurnal/nocturnal presence. In one study, participants answered a “question on LBP history, such as present and past low back history”(42)(p. 333) and another asked participants “the frequency and location of morning symptoms of spine pain and stiffness that occurred during the past month”(41)(p. 2). In the other two studies, one described the frequency and duration of morning pain and stiffness over the prior week, but not intensity(11) while the other used a visual analogue scale (VAS) to measure pain intensity “at moment of response” but not frequency or duration(15)(p. 237).

Methodology: Interventions and Follow-ups

Only participants in the treatment group of the intervention study(15) received sleep posture education. Those with dorsal or lumbar symptoms were advised to sleep supine, those with cervical symptoms were advised to sleep in side lying and prone sleepers were advised to adopt either of the prior recommended sleep postures. Participants were also educated about the use of pillows and how to get up and lie down. The control group received no instruction and neither group received further contact until reassessment. The intervention phase lasted 4 weeks. A significant reduction in pain was reported in the treatment group but not the control group. However, sleep posture was not objectively confirmed at baseline or after the intervention period.

Results, Conclusions and Recommendations

Results from all studies reported trends or significant associations between spinal pain and certain sleep postures (Table 3). The authors from three studies reported increased symptoms, one associated with supine(42) one upright(11) and the other prone or ¾ side lying(41) sleep postures. The authors from two studies reported significantly decreased symptoms, one with side lying(11) and the other a combination of side lying and supine(15). In the intervention study the authors reported (M = mean, SD = standard deviation) a significant reduction in pain VAS (M

Table 3 Mapping of Results, Conclusions and Recommendations

= 3.00, *SD* = 1.63, p = .009) for the intervention group but not the control group (*M* = 3.90, *SD* = 3.21, p = .472)(15). Between groups comparisons were not reported, possibly because it was a pilot study. We used an online calculator(43) to determine effect size and confidence intervals between groups, using baseline to post intervention data. Baseline to post intervention change was used because a significant difference between groups existed at baseline. This identified an overlap in effect size confidence intervals between groups, indicating a probable lack of significance between groups, based on the proportion of overlap in effect size confidence intervals(44).

Conclusions from authors of all four studies, were that sleep posture could increase or decrease spinal pain, and that addressing sleep posture could reduce the development of spinal pain. Using self-report, side lying was reported as protective of spinal symptoms(11, 15) and participants that slept in supported side lying were found to have less symptoms than those sleeping in ¾ side lying or prone(41). In regards to supine, one study found supine increased the likelihood of lumbar pain by 1.9 times(42), another study recommended supine in combination with side lying sleep postures to reduce lumbar pain(15) and a third reported supine was not significantly protective of cervical waking symptoms(11).

Author	Results	Conclusions	Recommendations
Abanobi et al., 2015	Prone and side lying groups combined. “Sleeping with back (face up) increases the risk of developing low back pain by 1.9 times.” (p. 355) (95% CI 4.31-8.56)^^ p = .31.	“The result showed the possibility of reducing the burden of LBP by appropriate training and improvement in habits such as...bad sleeping postures.” (p. 336)	Not provided
Cary et al., 2016	“The time spent in each of the sleeping postures ... expressed as a percentage of the time spent asleep, did not differ significantly according to the level of morning symptoms” (p. 5) Independent Samples Kruskal-Wallis Test p = .17.	“participants that spent greater periods of time in SSL, had less mornings of symptoms per month than those that slept in ¾ SL or prone.” (p. 5)	Not provided
Desouzart et al., 2016	No between group comparison reported, unlikely to be significant. See text for more details.	“It may be concluded that the indication of the ideal way to lie down, which corresponds to a recommended sleeping posture with the ideal position to place the pillows, as well as the ideal way to get up.” (p. 239)	Ideal sleep posture, pillow use and way to get up, as per experimental group, “is an added value for the prevention and decrease of the pain and/or discomfort in the spine in active seniors.” (p. 239)

Gordon, Grimmer and Trott, 2007a Gordon, Grimmer and Trott, 2007b	"Subjects who reported sleeping mostly in an upright position were significantly more likely to report all waking symptoms but this finding may be related to the medical status of those who adopt this sleep position." (p. 6) Waking cervical pain OR 2.5 (95% CI 1.1-5.5), cervical stiffness OR 2.6 (95% CI 1.1-5.8), headache OR 2.2 (95% CI 1.0-5.0), scapular/arm pain OR 2.5 (95% CI 1.1-5.3). "Supine...was not found in this study to be significantly protective of waking symptoms, when compared to other sleep positions." (p. 6) Waking cervical pain OR 1.4 (95% CI 0.8-2.5) and cervical stiffness OR 0.9 (95% CI 0.5-1.6). "Prone...was not significantly associated with waking symptom" (p. 6) Cervical pain OR 1.5 (95% CI 0.7-3.2) and cervical stiffness OR 1.1 (95% CI 0.5-2.6). "Side sleep position was significantly protective of waking cervical and scapular/arm pain" (p. 6) Waking cervical pain OR 0.6 (95% CI 0.4-0.9) and scapular/arm pain OR 0.7 (95% CI 0.5-0.9).	"on the basis of this research side lying can be confidently recommended as the best sleep position in terms of minimising waking symptoms." (p. 6) "need for health professionals to consider individual's sleep position and waking symptom history, as part of clinical reasoning for treatment, and when developing a management plan for patients with troublesome waking symptoms." (p. 6)

Notes. LBP = Low back pain, SSL = Supported side lying, ¾ SL = ¾ side lying, VAS = Visual analogue scale, OR = Odds ratio, CI = Confidence interval

^^ The CI was recalculated as it was suspected wrong due a typographical error. The recalculated value was 0.431

Two studies recommended clinicians consider sleep posture to reduce cervical(11) and lumbar symptoms(15).

Quality of Evidence and Author Reported Limitations

The quality of evidence is summarised in Table 4. The Downs and Black checklist contains 27 questions distributed over five domains; reporting (aims, sampling and methods); external validity (generalisability); internal validity (study design, selection bias, performance and reporting bias); confounding; and power (37). Using the Downs and Black checklist as the appraisal tool, evidence levels have previously been categorised as strong (> 75%), moderate (50 - 74%), limited (25 – 49%) and poor quality (< 24%)(45). Questions 4, 8, 9, 13, 14, 15, 19, 23, 24, and 26 (see Table 4 for details) were not applicable to study designs that did not include an intervention group and were therefore excluded from the three exploratory studies(11, 41, 42). Question 27 was applicable for all but the cross sectional study(41). In the reporting subsection, questions one to 10, studies were well documented with one different applicable question not completed by each study, enabling readers to draw unbiased assessments of each study's findings. Questions 11 to 13 (external validity), were poorly reported, with all studies failing to quantify the proportion of participants that were asked, relative to the proportion of participants that were accepted into studies. All studies reported using either random(11, 15, 42) or consecutive sampling(41). Internal validity, questions 14 to 20, examined measurement bias and apart from question 15 were well documented. In all studies, no attempt was made to blind researchers measuring the outcome variables. However, in one exploratory study the interview method precluded the need for blinding of interviewers(11). All the remaining questions were well documented, except for question 25 which examined confounding factors. This was poorly documented except for one study(40), in which a multivariate analysis was reported in a subsequent study, using the same data. The body of evidence in this scoping review is rated as moderate to strong quality.

Table 4 Critical Appraisal of Included Studies Using the Downs and Black Checklist

Section	Questions		Abanobi et al., 2015	Cary et al., 2016	Desouzart et al., 2016	Gordon, Grimmer and Trott, 2007
Reporting	1	Is the hypothesis/aim/objective of the study clearly described?	Y	Y	Y	Y
	2	Are the main outcomes to be measured clearly described in the Introduction or Methods section?	N	Y	Y	Y
	3	Are the characteristics of the patients included in the study clearly described?	Y	N	Y	X
	4	Are the interventions of interest clearly described?	X	X	Y	X
	5	Are the distributions of principal confounders in each group of subjects to be compared clearly described?	*Y	X	*Y	*Y
	6	Are the main findings of the study clearly described?	Y	Y	Y	Y
	7	Does the study provide estimates of the random variability in the data for the main outcomes?	Y	Y	Y	Y
	8	Have all important adverse events that may be a consequence of the intervention been reported?	X	X	N	X
	9	Have the characteristics of patients lost to follow-up been described?	X	X	Y	X
	10	Have actual probability values been reported (e.g., 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	Y	Y	Y	N
External Validity	11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	Y	Y	N	Y
	12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?	U	N	N	N

	13	Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?	X	X	Y	X
Internal Validity: Bias	14	Was an attempt made to blind study subjects to the intervention they have received?	X	X	U	X
	15	Was an attempt made to blind those measuring the main outcomes of the intervention?	X	X	N	X
	16	If any of the results of the study were based on "data dredging", was this made clear?	Y	Y	Y	Y
	17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?	Y	X	Y	X
	18	Were the statistical tests used to assess the main outcomes appropriate?	Y	Y	Y	Y
	19	Was compliance with the intervention/s reliable?	X	X	U	X
	20	Were the main outcome measures used accurate (valid and reliable)?	Y	Y	Y	Y
Internal Validity: Confounding	21	Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?	Y	X	Y	Y
	22	Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time?	Y	X	Y	X
	23	Were study subjects randomised to intervention groups?	X	X	Y	X
	24	Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?	X	X	U	X

	25	Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?	N	N	N	Y
	26	Were losses of patients to follow-up taken into account?	X	X	Y	X
Power	27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?	N	X	N	N
Score			14/17	9/12	19/28	12/14
Percentage			82	75	68	86
Notes. N = No = 0, Y = Yes = 1, *Y = 2 points, U = Unable to determine = 0, X = Not applicable (see Quality of Evidence section)						

Authors identified reliance on self-report to examine sleep posture(15) and symptoms(40) as a limitation. Authors identified small sample sizes, as limiting their ability to draw firm conclusions from the obtained results(11, 15). Authors identified restricted time as a limitation, for the period available for data collection(42), and for participants to learn a new sleeping habit(15). Limitations as reported by authors are described in Supplementary File Author Reported Limitations.

Discussion

To our knowledge, this scoping review is the first to establish the body of evidence regarding the research question; relationships between sleeping posture and spinal symptoms. Generally, there was limited available research. In regards to Objective 1; research designs and populations studied for the research question, a variety of study designs, participant populations and sample sizes were used. One study was a controlled pilot trial. With regards to Objective 2; methods used to address the research question, sleep was assessed in a domestic environment in all studies, with self-report used to measure sleep posture in all studies. Pain was the most common outcome measure of symptoms. In respect to Objective 3; common conclusions regarding the research question, most authors recommended side lying as the sleep posture least likely to provoke spinal symptoms, be they cervical or lumbar. Studies included in this scoping review were of moderate quality as assessed using the Downs and Black critical appraisal tool.

The study designs identified in this scoping review were appropriate to use for the research question. The variety of study designs prevented data pooling and a scoping review remained the most appropriate approach to synthesise the research. The average age and gender ratios used in studies were representative of both cervical and lumbar pain populations, however, the results of the included studies need to be interpreted with caution. There was a strong gender bias in two studies(15, 42), and a restricted age of included participants in one study(15). In general, small sample sizes were used. The type of study designs and patient populations identified in this scoping review have provided preliminary information regarding relationships between sleep posture and spinal symptoms, but there were not enough studies to adequately answer our research question.

The most common adult sleep postures are side lying, supine and prone (26, 46, 47), which were the postures examined by the studies in this review. Side lying is the sleep posture that greater than 60% of European adults adopt for the majority of the night(26, 46, 47). For this reason, one study divided side lying into two sleep postures, based upon symmetry and plausible spinal load. These authors identified a trend that participants spending more time in symmetrical side lying reported less morning symptoms than those in asymmetrical side lying(41). Although all studies in this review utilised self-report to report sleep posture, some authors identified this as a limitation (11, 15, 41) and inaccuracy associated with sleep posture self-report can be as high as 33% (48, 49). It therefore seems prudent to not rely purely on self-report and clinicians would have higher confidence when advising people with pain about sleep posture, if research included both self-report and a valid and reliable measure of sleep posture, such as included in one study(41).

The anatomical features of the cervical and lumbar spine are different and it is plausible that sleeping postures could affect each area differently. For example, studies in this review indicated sleeping in supine was associated with lumbar symptoms(42), but not associated with cervical symptoms(11). Pain was measured in all studies, which is appropriate given cervical and lumbar pain are leading contributors across all age groups and countries to musculoskeletal disability(3). However, characteristics like intensity, frequency or the onset time of pain were not consistently measured and are important to better understand the overall impact pain is having on daily function(50). With regards to the relationship between sleep posture and time of onset of spinal symptoms, only half of the studies examined waking symptoms(11, 41). Waking spinal symptoms are rarely present every morning, which may be due to an individual's variation in sleep posture routine. Therefore, to better understand relationships between sleep posture and spinal symptoms, it would be important that spinal symptoms are recorded on first waking and over several days.

Spinal pain is a major and growing global health problem with increasing rates of disability(3). For the past 20 years there has been a strong biomedical focus on patho-anatomy as the cause of spinal pain. However, in the case of lumbar pain, only 8-15% of cases has a specific tissue identified as the cause(51). Concurrently, there has been an escalation in imaging, opioid prescription, injections and surgery, with questionable benefit(52-54) and higher risks(8, 55). Changing physical risk factors like type of movement pattern(56), level of strength and conditioning(57, 58) and sustained or repeated postures(59, 60) , are relatively risk free, cost effective and show great potential. Sleep posture is an example of a sustained physical risk factor that is modifiable(61, 62). Clinical recommendations from this review include considering sleep posture when developing management plans for people with waking spinal symptoms(11) and education to change symptomatic sleep postures (42). With regards to recommending a sleep posture to minimise spinal symptoms, this review finds that the side lying posture was the most consistent in protecting the cervical spine(11), and that side lying and supine were the sleep postures recommended for those with lumbar spinal pain(15).

It is recommended that future research uses group sizes large enough to achieve statistical goals and that study sample demographics are representative of those in the general population with cervical and lumbar pain. As side lying appears to be associated with less cervical and possibly spinal symptoms generally, it would be worthwhile further exploring whether subtypes of side lying postures are more appropriate than others. Further research should use a validated measure of sleep posture. To better understand the effect of sleep posture on spinal symptoms, symptom location, a variety of outcome measures with associated characteristics should be included and an emphasis is placed on symptom timing (e.g., first thing in the morning). Sleep posture is potentially modifiable following education(15). Education is a non-invasive and low-cost intervention and should be further explored with larger scale studies.

Author Contributors

DC, LM and KB designed the study. DC and LM collected data and conducted data analysis. DC wrote the manuscript. DC, and LM undertook interpretation of findings and were involved in drafting the manuscript and revising it critically. All authors gave final approval to this manuscript.

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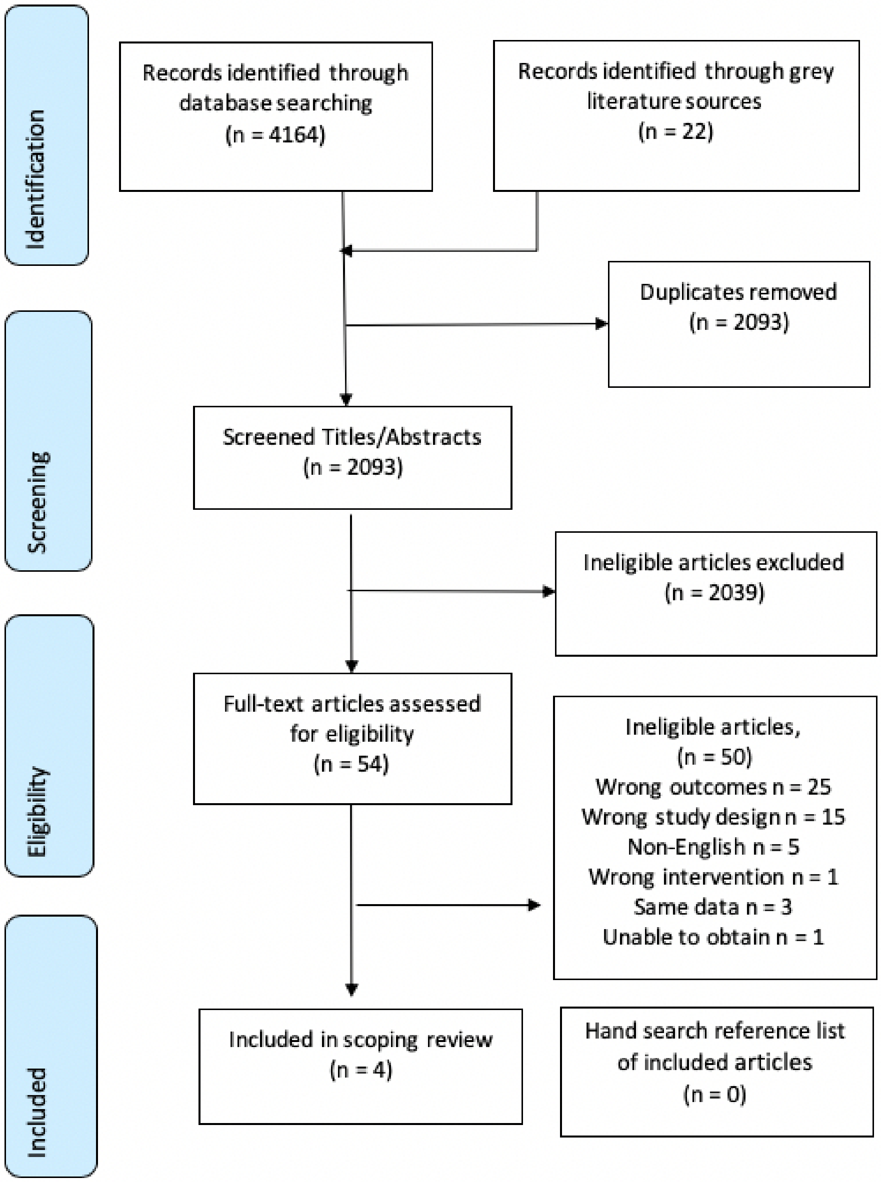

PRISMA Flow diagram

Supplementary File: Search Strategy for Scopus Database

Search Strategy for the Scopus Database (adapted for other databases)

Date	7/4/2018	
Strategy	#1 AND #2 AND #3 NOT #4	
Rule	Domain	Search Terms
#1	Area of symptoms	lumbar or "low back pain" or cervical or "neck pain" or "musculoskeletal pain" or "spinal pain"
#2	Posture	postur* or position* or prone or supine or lateral or side lying
#3	Sleep	sleep* or slumber* or nighttime or nocturnal or bed
#4	Exclusions	apnoea or apnea or CPAP

Supplementary File: Author Reported Limitations

Author Reported Limitations

Author	Comments
Abanobi et al., 2015	"Inability to compare the effect of duration of habits and age at onset of habit" (p. 336) "Limited time set aside for the surveillance exercise" (p. 336)
Cary et al., 2016	"Mismatch in time frame of measurement" (p. 6). Recording of sleep posture occurred over 2 nights but participants questioned about symptoms over prior 1 month.
Desouzart et al., 2016	Due to the population studied it was "not possible to use a homogenous sample and larger number of participants." (p. 239) "The four weeks may not have been sufficient to create habits in participants, however, and because of the time limitations of this study, it was not possible to have a longer time." (p. 239) "results are based on the statements of the participants" (p. 239)
Gordon, Grimmer and Trott, 2007	"As small subject numbers constrained confidence in the findings, further research is required into the contributors to waking symptoms. for upright sleepers" (p. 6)

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Identifying relationships between sleep posture and non-specific spinal symptoms in adults: A scoping review

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Identifying relationships between sleep posture and non-specific spinal symptoms in adults: A scoping review

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Subject headings: Rehabilitative Medicine
Keywords: sleep posture, sleep position, spinal symptoms, pain, stiffness, education

Abstract

Objectives: The objectives of this scoping review were to identify (a) study designs and participant populations (b) types of specific methodology and (c) common results, conclusions and recommendations from the body of evidence regarding our research question**; is there a relationship between sleep posture and spinal symptoms.**

Design: Scoping review.

Data sources: PEDro, Embase, Cumulative Index to Nursing and Allied Health Literature, Cochrane Library, Medline, ProQuest, PsycINFO, SportDISCUS and grey literature from inception to April 10, 2018.

Data selection: Using a modified Arksey and O'Malley framework, all English language studies in humans that met eligibility criteria using key search terms associated with sleep posture and spinal symptoms were included.

Data extraction: Data were independently extracted by 2 reviewers and mapped to describe the current state of the literature. Articles meeting the search criteria were critically appraised using the Downs and Black checklist.

Results: From 4186 articles, four articles were identified, of which three were exploratory and one interventional. All studies examined three or more sleep postures, all measured sleep posture using self-report and one study also used infrared cameras. Two studies examined symptoms arising from the lumbar spine, one the cervical spine and one the whole spine. Waking pain and stiffness were the most common symptoms explored and side lying was generally protective against spinal symptoms.

Conclusions: This scoping review highlights the importance of evaluating sleep posture with respect to waking symptoms and has provided preliminary information regarding relationships between sleep posture and spinal symptoms. However, there were not enough high-quality studies to adequately answer our research question. It is recommended future research consider group sizes and population characteristics to achieve research goals, that a validated measure be used to assess sleep posture, that characteristics and location of spinal symptoms are clearly defined and that the side lying posture is subclassified.

Strengths and Limitations of this Study

- This is the first scoping review collating and synthesising the available literature on sleeping posture and non-specific spinal symptoms
- A critical appraisal of evidence assessment was undertaken for each included study
- The lack of studies and small group sizes prevented firm recommendations being provided for all sleep posture

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Competing Interest

None declared.

Data Sharing Statement

No additional data are available.

Introduction

Cervical and lumbar symptoms like pain, are the leading cause of musculoskeletal disability in most countries and most age groups (1). Of those who report cervical and lumbar pain, the proportion is higher in females for both cervical (59%)(2) and lumbar (52%) pain(3). The prevalence of both cervical and lumbar pain has increased markedly over the past 25 years (cervical 21.1% and lumbar 17.3%), and these rates are expected to continue rising(1). Cervical and lumbar pain contribute to large economic and societal costs and are major sources of work disability, being either the first or second ranked cause of years lived with disability between the ages of 20 and 79 years(1, 4, 5). Research indicates that remissions in symptoms are temporary rather than permanent(6, 7) and cervical and lumbar pain becomes chronic in 25 to 60% of cases(8). Other types of symptoms like stiffness and bothersomeness, still important to patients are less well investigated (9, 10). Identification of modifiable risk factors contributing to the onset and chronicity of cervical and lumbar pain and other symptoms, is critical(11) to improve the management of cervical and lumbar pain.

A potentially modifiable risk factor that aggravates spinal symptoms, is sleep posture. Sleep is considered essential for human mental and physical recovery. Yet, every night some people go to bed, only to wake with spinal symptoms not present the prior evening, while others with existing spinal symptoms, wake with exacerbations of their symptoms(12, 13). For example, in young air force personnel, 33% experienced their most intense spinal pain during the evening and on first waking(12). It has been postulated that poor sleep posture may be a factor in the development of both waking cervical(14-16) and lumbar symptoms(17, 18).

Habitual sleep postures may influence the amount of load applied to spinal tissues when sleeping. Compressive load due to gravity and muscle contraction(19, 20) is likely to be far more during the day than during the night. In a 25-year review on the fundamentals of spinal biomechanics, it was noted that spinal movements decreased under a superimposed compression load. The author postulated this was due to increased anular stiffness and increased zygopophyseal joint (ZPJ) contact(21). Conversely, when lying down, the sources of spinal compression are minimal, creating a low compression environment, potentially allowing an increased range of spinal movement. The combination of increased range and asymmetrical loading posture may result in altered and/or additional loading of viscoelastic collagenous restraints like the ZPJ capsule and ligaments(22). Viscoelastic tissues are vulnerable to sustained or repeated low elongation loads, and undergo predictable mechanical and viscoelastic changes. Ligaments in feline spines exposed to 60 minutes of repeated low load, demonstrate a significant increase in the expression of pro-inflammatory chemicals, compared with control ligaments from the same spine, indicating acute inflammation and tissue degradation in ligaments subjected to the cyclic loading(23). Additionally, sustained non-symmetrical sleep postures can induce structural spinal changes in humans(24, 25). Sleep postures have been shown to be modifiable(17, 26) and identification of modifiable risk factors related to spinal pain, have been highlighted as a priority in managing disabling lumbar pain(27).

Some sleep postures, such as prone, are clinically believed to increase load on spinal tissues, reducing recovery and provoking waking spinal symptoms(18, 28, 29). While some sleep research has examined the role sleep posture may have on spinal symptoms(13, 17, 30), there has been no synthesis of the literature in regards to sleep posture and spinal symptoms.

Methods

Search Framework

This scoping review was developed using the methodological framework proposed by previous authors(31), further refined by other independent authors and institutes(32-34) and reported in line with key PRISMA-ScR guidelines(35).

Research Question

Following an individual review of the literature and a group meeting, an authors' consensus was reached to determine the following research question; is there a relationship between sleep posture and spinal symptoms?

Aim and Objectives

The aim of this scoping review was to gain a clear understanding of the current knowledge base in relation to the identified research question. To achieve this aim, an iterative process involving electronic meetings and communication between authors was used to determine the following research objectives:

- Identify what study designs and participant populations have been studied to answer the research question.
- Identify the types of specific methodology used in the body of evidence to address the research question.
- Identify common results, conclusions and recommendations from the body of evidence regarding the research question.

Eligibility Criteria

Eligibility criteria were based upon the population, intervention, comparison and outcome (PICO) framework. A draft list of eligibility criteria was initially determined following the independent screening of relevant articles by two reviewers. Criteria were then developed iteratively between two reviewers and a finalised list of criteria were uploaded to Covidence(36), as a reference for data charting reviewers.

Inclusion Criteria

For inclusion in this scoping review, the prior research needed to study participants 18 years or older, with either pain, stiffness or bothersomeness in the cervical, thoracic or lumbar spine. Any observational or interventional study examining the relationship between sleep posture and spinal symptoms was considered. Articles that either compared sleep posture change (e.g., before and after an intervention) or had no comparator (e.g., epidemiological) were included. Articles needed to use a subjective or objective measure for symptoms and sleeping posture.

Exclusion Criteria

Articles were excluded if they involved animals, cadavers or included participants diagnosed with sleep apnoea, spinal stenosis, migraine, red flag pathologies (e.g., neoplasm, inflammatory conditions, fractures or infections); participants with pain of known non-spinal origin (e.g., kidney disease, post-operative pain, temporomandibular joint, shoulder pain); participants with neurological conditions (e.g., multiple sclerosis, cerebrovascular accident); or participants that were unable to move freely in bed (e.g., using continuous positive airway pressure therapy or in the last trimester of pregnancy). Articles were excluded if they did not isolate the intervention when a group of interventions were implemented (e.g., spinal injection and sleeping posture) or if they compared sleep systems (e.g., mattress, base and or pillow) or changes in sleep systems but did not report the change in sleep posture. Further, articles using actigraphy to measure movement or articles that only examined the quality or efficacy of sleep were excluded. Finally, editorials, opinion-based articles, review articles (systematic or narrative) and articles not written in English were excluded.

Patient and Public Involvement

Patients and the public were not involved in this scoping review.

Search Terms and Strategy

The population, intervention, comparison and outcome (PICO) framework was used to assist in the collation of all elements relevant to clinical research questions. Population: Terms used for the search strategy were chosen to be representative of the areas and symptoms, likely to be experienced by a population with non-specific spinal symptoms. Non-specific symptoms are those not related to fracture, infection, inflammatory disease, tumor or spinal stenosis. Intervention: Terms representative of interventions aimed at changing sleep posture in association with spinal symptoms were considered for inclusion, while other terms not associated with spinal symptoms e.g. apnoea were excluded. Comparison: Terms were considered that were indicative of any type of comparison. Outcome: Any terms to indicate the subjective measure of pain, stiffness or bothersomeness or objective measure used to evaluate sleep posture, were considered.

Identified key search terms were then used in the search strategy to identify all relevant articles. An initial search was conducted in two of the four databases, recommended(37) for physiotherapy related topics; PEDro, and Embase (via Ovid) from inception to December 2017. The initial search was used to determine if the search terms and strategy were appropriate, and informed the development of the final search terms and strategy.

The final search strategy was conducted using the search terms and Boolean logic as described in Supplementary File Search Strategy for the Scopus Database and adapted for eight electronic databases (PEDro, Embase, Cumulative Index to Nursing and Allied Health Literature, Cochrane Library, Medline, ProQuest, PsycINFO, SportDISCUS) with the assistance of a health sciences information specialist. Grey literature (espace, Google Scholar (top 100 references scanned for relevance), and Web of Science) was searched for difficult to locate or unpublished material that had not already been included. The final step involved manual searching the reference sections of relevant articles and publications by key authors for additional articles, not identified in the original search.

Study Selection

All search results were imported into the reference management software package, Endnote X8(38) and duplicates removed. Remaining results were imported into Covidence(36) and additional duplicates removed. Using Covidence, two reviewers independently performed Level 1 (title and abstract) and Level 2 (full text) screening, based on the eligibility criteria. Differences of opinion in which articles progressed to the next level, were first resolved with discussion between reviewers and if necessary, with input from a third reviewer.

Data Charting

The data charting form was developed and revised iteratively between reviewers to ensure data relevant to the three research objectives were collected. A definitions and instructions document was developed to ensure that data was collected consistently by the independent reviewers. The data charting form was then independently pilot tested in duplicate on a random sample of four potential articles. Following identification of articles for inclusion in this review, data were independently charted in duplicate using a data charting form created in Excel and based on the three research objectives. An attempt was made to contact authors of eligible articles where authors reported that data relevant to our scoping review had been collected but was not publicly available, and to clarify points relevant to our data charting.

Quality of Evidence

Non-assessment of methodological quality and the risk of bias is consistent with current guidelines on conducting a scoping review(32, 34). However, a focus of this scoping review was on methodology; therefore, a methodological assessment of quality was included. The Downs and Black checklist(39) was chosen, as it has documented criterion validity, face and content validity, intra-rater ($r = 0.88$) and inter-rater reliability ($r = 0.75$) and guidelines for use(40). A modified version of the Downs and Black checklist(41), where a dichotomous score for power (question 27) was used. As a result, the maximum score for randomised trials was 28 and for non-randomised trials it was 25. The Downs and Black checklist was independently completed for each article in duplicate. Differences in scoring were first resolved by consensus between reviewers and if required, by a third independent reviewer. Study limitations noted by authors were collected to compliment the Downs and Black checklist.

Table 1. Mapping of Study Design and Population Characteristics

Author	Study Design	Population Type	Sample Size (Gender)	Age *M* (*SD*)
Abanobi et al., 2015	Epidemiological: Case controlled	Welders in Owerri, Nigeria	100 (male = 100)	35 (9)
Cary et al., 2016	Epidemiological: Cross sectional	Population of convenience in Esperance, Western Australia	15 (male = 7)	44 (17)
Desouzart et al., 2016	Controlled pilot	Elderly participants in physical activity program at Polytechnic Institute of Leiria, Portugal	20 (male = 0)	62 (4)
Gordon, Grimmer and Trott, 2007	Epidemiological: Cross sectional	Every third household in Port Lincoln in South Australia	812 (male = 261)	Female 61 (10) Male 59 (11)

Notes. *M* = Mean, *SD* = Standard deviation

Results

Search Results

An overview of the article identification process is provided in the PRISMA flow diagram in Figure 1. Articles excluded due to wrong outcomes, were those that did not include a measure of sleep posture or only examined sleep posture and not symptoms, tested a sleeping system (e.g., mattress or pillow) in relation to spinal symptoms but not posture, or studied sleep posture in relation to sleep quality. Articles excluded due to wrong study design included treatment guidelines, opinion and editorial piece and summaries.

FIGURE 1 PRISMA FLOW DIAGRAM (SEPARATE FILE)

Study Design and Population Characteristics

The designs of the four included studies were mixed (Table 1).

Methodology: Sleep Posture Measurement

All studies examined participants in their domestic environment (Table 2) and described as a minimum the three common sleep postures; supine, side lying and prone. One study described four sleep postures, dividing side lying into two sleep postures and named them supportive side lying and ¾ side lying(42). Another described five postures, adding “upright” and “varies”, to the common three sleep postures(13). One study used three different postures, but combined side lying and prone for analysis, due to small number of prone sleepers, of whom none reported lumbar pain(43). All studies used self-report questionnaires to assess sleep posture. Studies focused on different time points when questioning about sleep posture. Two specifically focused on night and waking posture; “in what sleep posture do you usually go to sleep”, “in what sleep posture do you usually wake up” and “in what sleep posture do you spend most of the night”(13)(p. 7), and “which posture most closely resembles the posture you are lying in when you fall asleep?” and “which posture most closely resembles the posture you are lying in when you wake up?”(42). The other two studies were non-specific, “usual sleep posture”(43)(p. 335) and “informal questionnaire for ... sleeping position”(17)(p. 237). In addition to using self-report, the authors of one study used an objective method of assessment, twin camera infrared video recording, to verify sleep posture(42).

Table 2. Mapping of Sleep Posture Measurement and Symptoms

Author	Sleep Environment	Standard three sleep postures	Number of sleep postures	Sleep posture outcome measurement	Anatomical Area	Symptom Type	Symptom(s) Characteristics	Symptom Outcome Measurement
Abanobi et al., 2015	Domestic	Y	3	SR	Lumbar	Pain	Past and present history	Questionnaire - face to face interview
Cary et al., 2016	Domestic	Y	4	SR + Video recording	Cervical, Lumbar, Both, Other	Pain, Stiffness	Frequency (month) Waking symptoms	Questionnaire written
Desouzart et al., 2016	Domestic	Y	3	SR	All spine	Pain	Intensity	Questionnaire written - pain VAS
Gordon, Grimmer and Trott, 2007	Domestic	Y	5	SR	Cervical	Pain, Stiffness, HA, Shoulder blade/arm pain	Frequency (week), duration Waking symptoms	Questionnaire - structured telephone interview

Notes. NS = Not stated, Y = Yes, SR = Self-report, HA = Headache, VAS = Visual analogue scale

Methodology: Measurement of Symptoms

The anatomical location, characteristics and method of measuring spinal symptoms are presented in Table 2. One study included non-spinal symptoms (e.g., hip and legs) classified as "other"(42). All studies examined pain (with two studies examining additional symptoms), but differed in regards to examining intensity, frequency, period of symptoms and diurnal/nocturnal presence. In one study, participants answered a "question on LBP history, such as present and past low back history"(43)(p. 333) and another asked participants "the frequency and location of morning symptoms of spine pain and stiffness that occurred during the past month"(42)(p. 2). In the other two studies, one described the frequency and duration of morning pain and stiffness over the prior week, but not intensity(13) while the other used a visual analogue scale (VAS) to measure pain intensity "at moment of response" but not frequency or duration(17)(p. 237).

Methodology: Interventions and Follow-ups

Only participants in the treatment group of the intervention study(17) received sleep posture education. Those with dorsal or lumbar symptoms were advised to sleep supine, those with cervical symptoms were advised to sleep in side lying and prone sleepers were advised to adopt either of the prior recommended sleep postures. Participants were also educated about the use of pillows and how to get up and lie down. The control group received no instruction and neither group received further contact until reassessment. The intervention phase lasted 4 weeks. A significant reduction in pain was reported in the treatment group but not the control group. However, sleep posture was not objectively confirmed at baseline or after the intervention period.

Results, Conclusions and Recommendations

Results from all studies reported trends or significant associations between spinal pain and certain sleep postures (Table 3). The authors from three studies reported increased symptoms, one associated with supine(43) one upright(13) and the other in prone or ¾ side lying(42) sleep postures. The authors from two studies reported significantly decreased symptoms, one with side lying(13) and the other a combination of side lying and supine(17). In the intervention study the authors

Table 3 Mapping of Results, Conclusions and Recommendations

Author	Results	Conclusions	Recommendations
Abanobi et al., 2015	Odds ratios for LBP were in relation to a combined group of prone and side lying sleeping. "Sleeping with back (face up) increases the risk of developing low back pain by 1.9 times." (p. 355) (95% CI 0.43-8.56)^^	"The result showed the possibility of reducing the burden of LBP by appropriate training and improvement in habits such as...bad sleeping postures." (p. 336)	Not provided

reported a significant reduction in pain VAS for the intervention group but not the control group (17). Between groups comparisons were not reported, possibly because it was a pilot study. We used an online calculator(44) to determine an effect size with 95% confidence intervals between groups, using baseline to post intervention data in two steps. Baseline to post intervention change was used because a significant difference between groups existed at baseline. Firstly, a pooled standard deviation for each group was calculated for change from baseline to final measure. Then this pooled standard deviation from each group was used to calculate the between group effect size and 95% confidence interval (see Table 3). The resultant confidence interval indicates that significant differences between groups was unlikely. To calculate an effect size for Cary et.al. (42), the independent samples Jonckheere-Terpstra test (45) was used to calculate a z-score, which was then converted into an effect size (r_j) (46).

Conclusions from authors of all four studies, were that sleep posture could increase or decrease spinal pain, and that addressing sleep posture could reduce the development of spinal pain. Using self-report, side lying was reported as protective of spinal symptoms(13, 17) and participants that slept in supported side lying were found to have less symptoms than those sleeping in ¾ side lying or prone(42). In regards to supine, one study found supine increased the likelihood of lumbar pain by 1.9 times(43), another study recommended supine in combination with side lying sleep postures to reduce lumbar pain(17) and a third reported supine was not significantly protective of cervical waking symptoms(13).

Cary et al., 2016	"The time spent in each of the sleeping postures... expressed as a percentage of the time spent asleep, did not differ significantly according to the level of morning symptoms" (p. 5) Independent Samples Jonckheere-Terpstra Test; supine r_j = 0.03; SSL r_j = 0.00; ¾ SL r_j = 0.34; prone r_j = 0.31.	"participants that spent greater periods of time in SSL, had less mornings of symptoms per month than those that slept in ¾ SL or prone." (p. 5)	Not provided
Desouzart et al., 2016	No between group comparison reported. Between group effect size calculated to be 0.81 (95% CI -0.11 to 1.72).	"It may be concluded that the indication of the ideal way to lie down, which corresponds to a recommended sleeping posture with the ideal position to place the pillows, as well as the ideal way to get up." (p. 239)	Ideal sleep posture, pillow use and way to get up, as per experimental group, "is an added value for the prevention and decrease of the pain and/or discomfort in the spine in active seniors." (p. 239)
Gordon, Grimmer and Trott, 2007	"Subjects who reported sleeping mostly in an upright position were significantly more likely to report all waking symptoms of interest compared to subjects who slept in other positions." (p. 6) Waking cervical pain OR 2.5 (95% CI 1.1-5.5), cervical stiffness OR 2.6 (95% CI 1.1-5.8), headache OR 2.2 (95% CI 1.0-5.0), scapular/arm pain OR 2.5 (95% CI 1.1-5.3). "Supine...was not found in this study to be significantly protective of waking symptoms, when compared to other sleep positions." (p. 6) Waking cervical pain OR 1.4 (95% CI 0.8-2.5) and cervical stiffness OR 0.9 (95% CI 0.5-1.6). "Prone...was not significantly associated with waking symptom" (p. 6) Cervical pain OR 1.5 (95% CI 0.7-3.2) and cervical stiffness OR 1.1 (95% CI 0.5-2.6). "Subjects who reported that they slept mostly on their side were significantly less likely to report waking cervical pain... compared with subjects who slept in any other position." (p. 4) Waking cervical pain OR 0.6 (95% CI 0.4-0.9) and scapular/arm pain OR 0.7 (95% CI 0.5-0.9).		"on the basis of this research side lying can be confidently recommended as the best sleep position in terms of minimising waking symptoms." (p. 6) "need for health professionals to consider individual's sleep position and waking symptom history, as part of clinical reasoning for treatment, and when developing a management plan for patients with troublesome waking symptoms." (p. 6)

Notes. LBP = Low back pain, SSL = Supported side lying, ¾ SL = ¾ side lying, VAS = Visual analogue scale, OR = Odds ratio, CI = Confidence interval, r_{j} = effect size r for Jonckheere-Terpstra Test

^^ The CI was recalculated as it was suspected wrong due a typographical error. The original value was 0.431

Two studies recommended clinicians consider sleep posture to reduce cervical(13) and lumbar symptoms(17).

Quality of Evidence and Author Reported Limitations

The quality of evidence is summarised in Table 4. The Downs and Black checklist contains 27 questions distributed over five domains; reporting (i.e., aims, sampling and methods); external validity (i.e., generalisability); internal validity (i.e., study design, selection bias, performance and reporting bias); confounding; and power (39). Using the Downs and Black checklist as the appraisal tool, evidence levels have previously been categorised as strong (> 75%), moderate (50 - 74%), limited (25 - 49%) and poor quality (< 24%)(47). Questions 4, 8, 9, 13, 14, 15, 19, 23, 24, and 26 (see Table 4 for details) were not applicable to study designs that did not include an intervention group and were therefore excluded from the three exploratory studies(13, 42, 43). Question 27 was applicable for all but the cross sectional study(42). In the reporting subsection, questions one to 10, studies were well documented with one different applicable question not completed by each study, enabling readers to draw unbiased assessments of each study's findings. Questions 11 to 13 (external validity), were poorly reported, with all studies failing to quantify the proportion of participants that were asked, relative to the proportion of participants that were accepted into studies. All studies reported using either random(13, 17, 43) or consecutive sampling(42). Internal validity, questions 14 to 20, examined measurement bias and apart from question 15 were well documented. In all studies, no attempt was made to blind researchers measuring the outcome variables. However, in one exploratory study the interview method precluded the need for blinding of interviewers(13). All the remaining questions were well documented, except for question 25 which examined confounding factors. This was poorly documented except for one study(48), in which a multivariate analysis was reported in a subsequent study, using the same data. The body of evidence in this scoping review is rated as moderate to strong quality.

Table 4 Critical Appraisal of Included Studies Using the Downs and Black Checklist

Section		Questions	Abanobi et al., 2015	Cary et al., 2016	Desouzart et al., 2016	Gordon, Grimmer and Trott, 2007
Reporting	1	Is the hypothesis/aim/objective of the study clearly described?	Y	Y	Y	Y
	2	Are the main outcomes to be measured clearly described in the Introduction or Methods section?	N	Y	Y	Y
	3	Are the characteristics of the patients included in the study clearly described?	Y	N	Y	X
	4	Are the interventions of interest clearly described?	X	X	Y	X
	5	Are the distributions of principal confounders in each group of subjects to be compared clearly described?	*Y	X	*Y	*Y
	6	Are the main findings of the study clearly described?	Y	Y	Y	Y
	7	Does the study provide estimates of the random variability in the data for the main outcomes?	Y	Y	Y	Y
	8	Have all important adverse events that may be a consequence of the intervention been reported?	X	X	N	X
	9	Have the characteristics of patients lost to follow-up been described?	X	X	Y	X
	10	Have actual probability values been reported (e.g., 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	Y	Y	Y	N
External Validity	11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	Y	Y	N	Y
	12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?	U	N	N	N

	13	Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?	X	X	Y	X
Internal Validity: Bias	14	Was an attempt made to blind study subjects to the intervention they have received?	X	X	U	X
	15	Was an attempt made to blind those measuring the main outcomes of the intervention?	X	X	N	X
	16	If any of the results of the study were based on "data dredging", was this made clear?	Y	Y	Y	Y
	17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?	Y	X	Y	X
	18	Were the statistical tests used to assess the main outcomes appropriate?	Y	Y	Y	Y
	19	Was compliance with the intervention/s reliable?	X	X	U	X
	20	Were the main outcome measures used accurate (valid and reliable)?	Y	Y	Y	Y
Internal Validity: Confounding	21	Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?	Y	X	Y	Y
	22	Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time?	Y	X	Y	X
	23	Were study subjects randomised to intervention groups?	X	X	Y	X
	24	Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?	X	X	U	X

	25	Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?	N	N	N	Y
	26	Were losses of patients to follow-up taken into account?	X	X	Y	X
Power	27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?	N	X	N	N
Score			14/17	9/12	19/28	12/14
Percentage			82	75	68	86

Notes. N = No = 0, Y = Yes = 1, *Y = 2 points, U = Unable to determine = 0, X = Not applicable (see Quality of Evidence section), Evidence levels = strong (> 75%), moderate (50 - 74%), limited (25 – 49%) and poor quality (< 24%) (47).

Authors identified reliance on self-report to examine sleep posture(17) and symptoms(48) as a limitation. Authors identified small sample sizes, as limiting their ability to draw firm conclusions from the obtained results(13, 17). Authors identified restricted time as a limitation, for the period available for data collection(43), and for participants to learn a new sleeping habit(17). Limitations as reported by authors are described in Supplementary File Author Reported Limitations.

Discussion

To our knowledge, this scoping review is the first to establish the body of evidence regarding the research question; relationships between sleeping posture and spinal symptoms. Generally, there was limited available research. In regards to Objective 1; research designs and populations studied for the research question, a variety of study designs and participant populations were used. One study was a controlled pilot trial. With regards to Objective 2; types of specific methodology used to address the research question, sleep was assessed in a domestic environment in all studies, with self-report used to measure sleep posture in all studies. Pain was the most common outcome measure of symptoms. In respect to Objective 3; results, conclusions and recommendations, authors recommended side lying as the sleep posture least likely to provoke cervical or lumbar spinal symptoms. Studies included in this scoping review were of moderate to strong quality as assessed using the Downs and Black critical appraisal tool. Nonetheless, considerably more research including longitudinal studies are required before causal relationships between sleep posture and spinal symptoms could be concluded.

The study designs identified in this scoping review were appropriate to use for the research question. The variety of study designs prevented data pooling and a scoping review remained the most appropriate approach to synthesise the research. The age and gender ratios of included studies were not representative of typical cervical and lumbar pain populations (1-3). Generalisation of the results of the included studies needs to be considered with some caution because of a strong gender bias in two studies(17, 43) and a restricted age of included participants in one study (17). In general, small sample sizes were used. The type of study designs and patient populations identified in this scoping review have provided preliminary information regarding relationships between sleep posture and spinal symptoms, but there were not enough high-quality studies to adequately answer our research question.

The most common adult sleep postures are side lying, supine and prone (28, 49, 50), which were the postures examined by the studies in this review. Side lying is the sleep posture that greater than 60% of European adults adopt for the majority of the night(28, 49, 50). For this reason, one study divided side lying into two sleep postures, based upon symmetry and plausible spinal load. These authors identified a trend that participants spending more time in symmetrical side lying reported less morning symptoms than those in asymmetrical side lying(42). Although all studies in this review utilised self-report to report sleep posture, some authors identified this as a limitation (13, 17, 42) and inaccuracy associated with sleep posture self-report can be as high as 33% (51, 52). It therefore seems prudent to not rely purely on self-report and clinicians would have higher confidence when advising people with pain about sleep posture, if research included both self-report and a valid and reliable measure of sleep posture, such as included in one study(42).

The anatomical features of the cervical and lumbar spine are different and it is plausible that sleeping postures could affect each area differently. For example, studies in this review indicated sleeping in supine was associated with lumbar symptoms(43), but not associated with cervical symptoms(13). Pain was measured in all studies, which is appropriate given cervical and lumbar pain are leading contributors across all age groups and countries to musculoskeletal disability(1). However, characteristics like intensity, frequency or the onset time of pain were not consistently measured and are important to better understand the overall impact pain is having on daily function(53). With regards to the relationship between sleep posture and time of onset of spinal symptoms, only half of the studies examined waking symptoms(13, 42). Waking spinal symptoms are rarely present every morning, which may be due to an individual's variation in sleep posture routine. To better understand the temporal relationships between sleep posture and spinal symptoms, it would be important to record spinal symptoms on first waking.

Spinal pain is a major and growing global health problem with increasing rates of disability(1). For the past 20 years there has been a strong biomedical focus on patho-anatomy as the cause of spinal pain. However, in the case of lumbar pain, only 8-15% of cases has a specific tissue identified as the cause(54). Concurrently, there has been an escalation in imaging, opioid prescription, injections and surgery, with questionable benefit(55-57) and higher risks(8, 58). Changing physical risk factors like type of movement pattern(59), level of strength and conditioning(60, 61) and sustained or repeated postures(62, 63) , are relatively risk free, cost effective and show great potential. Sleep posture is an example of a sustained physical risk factor that is modifiable(64, 65). Clinical recommendations by authors included in this review included considering sleep posture when developing management plans for people with waking spinal symptoms(13) and education to change symptomatic sleep postures (43). With regards to recommending a sleep posture to minimise spinal symptoms, this review finds that the side lying posture for the cervical spine(13), and side lying and supine were the sleep postures recommended by authors for those with lumbar spinal pain(17). However, there is a lack of high-quality studies from which to draw firm recommendations.

Based on the findings of this scoping review we offer the following recommendations to improve the quality of future research. Research samples should be large enough to achieve statistical goals and sample demographics should be representative of those in the broader population with cervical and lumbar pain. Ideally studies should account for confounding factors such as age and gender through study design or statistical analysis. It would be preferable to differentiate spinal symptoms according to location, rather than considering spinal symptoms as a single group, due to differences in spinal anatomy, function and referral of symptoms. It is also recommended to divide spinal symptoms into categories such as pain, stiffness, and bothersomeness, to determine if one or more have greater clinical relevance. Using a valid, objective measure of sleep posture instead of self-report, would also enable determination of time spent in each sleep posture and the number of sleep posture changes. As side lying appears to be associated with less cervical and possibly spinal symptoms generally, it would be worthwhile in future research to confirm this relationship and to further explore whether some subtypes of side lying postures are less provocative of spinal symptoms than others. It would also be informative to consider the temporal aspect of spinal symptoms. That is, recording spinal symptoms on first waking before they are influenced by daytime activities. Sleep posture is potentially modifiable following education(17) and education is a non-invasive and low-cost intervention which should be further explored in future research using larger scale longitudinal studies.

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Author Contributors

DC, LM and KB designed the study. DC and LM collected data and conducted data analysis. DC wrote the manuscript. DC, and LM undertook interpretation of findings and were involved in drafting the manuscript. All authors were involved in revision of the manuscript gave final approval for submission and publication.

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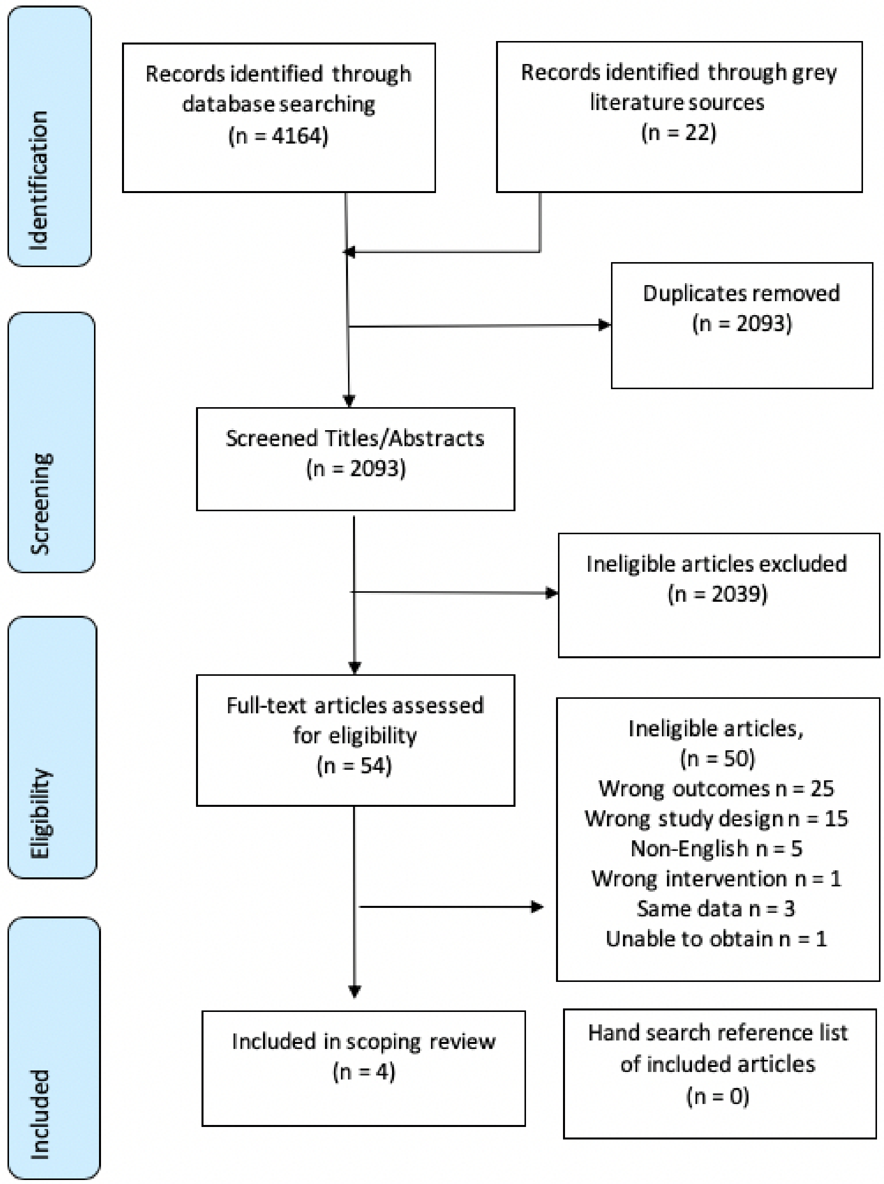

PRISMA Flow diagram

Supplementary File: Search Strategy for Scopus Database

Search Strategy for the Scopus Database (adapted for other databases)

Date	7/4/2018	
Strategy	#1 AND #2 AND #3 NOT #4	
Rule	Domain	Search Terms
#1	Area of symptoms	lumbar or "low back pain" or cervical or "neck pain" or "musculoskeletal pain" or "spinal pain"
#2	Posture	postur* or position* or prone or supine or lateral or side lying
#3	Sleep	sleep* or slumber* or nighttime or nocturnal or bed
#4	Exclusions	apnoea or apnea or CPAP

Supplementary File: Author Reported Limitations

Author Reported Limitations

Author	Comments
Abanobi et al., 2015	"Inability to compare the effect of duration of habits and age at onset of habit" (p. 336) "Limited time set aside for the surveillance exercise" (p. 336)
Cary et al., 2016	"Mismatch in time frame of measurement" (p. 6). Recording of sleep posture occurred over 2 nights but participants questioned about symptoms over prior 1 month.
Desouzart et al., 2016	Due to the population studied it was "not possible to use a homogenous sample and larger number of participants." (p. 239) "The four weeks may not have been sufficient to create habits in participants, however, and because of the time limitations of this study, it was not possible to have a longer time." (p. 239) "results are based on the statements of the participants" (p. 239)
Gordon, Grimmer and Trott, 2007	"As small subject numbers constrained confidence in the findings, further research is required into the contributors to waking symptoms. for upright sleepers" (p. 6)

1

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	NA
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	4
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	5
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	5
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	5-6
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Data items extracted are noted in Table 1, 2, 3, 4 and Supplementary File (pg 7, 8, 10, 12-13)
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and	6

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
		how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	6
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	PRISMA Supplementary File
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Table 1, 2, 3, 4 and Supplementary File (pg 7, 8, 10, 12-13). Reference list
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	12-13
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Table, 1, 2, 3 and 4
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Table 1, 2, 3 and 4
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	14
Limitations	20	Discuss the limitations of the scoping review process.	14-16
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	15
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	16