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Understanding Sleep Quality and Waking Cervico-Thoracic Symptoms

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Abstract
Purpose: Using data from an epidemiological study described elsewhere (Gordon et al 2002 & 2007), multivariate logistic regression models were constructed to explore the association between sleep position, factors related to sleep quality, and the prevalence of waking symptoms (cervical spine pain and stiffness, headache, and aching in scapulae or arm regions). Method: A causal model was developed in which putative exposures were tested for their association with sleep quality, which was considered as an antecedent cause of waking cervico-thoracic symptoms. Results: Factors which significantly constrained sleep quality were identified as the presence of a medical condition, past history of injury or accident to the cervical spine, sleep position, and nocturnal bruxism. Poor sleep quality was significantly related to waking cervico-thoracic symptoms. Conclusions: The significant relationships between these factors highlight the need for assessment of all possible causes of waking cervico-thoracic symptoms in the clinical setting.

Introduction

Sleep quality

Subjective reports of poor sleep quality have been related to longer delay to sleep after retiring, increased total time awake, decreased duration of night sleep, nightmares, and poor sleep continuity.[1,2,3] Hence any factor which decreases an individual's ability to quickly fall to sleep and maintain sleep should be considered a factor which decreases sleep quality. While there is strong evidence that factors related to poor sleep quality such as inflammatory and musculo-skeletal conditions may give rise to waking cervico-thoracic symptoms, the relationship remains largely uninvestigated between other factors related to sleep quality, such as other medical conditions, medication use, mental health, disruption to sleep caused by noise, shift work or young children, sleep position, alcohol intake, and waking cervico-thoracic symptom prevalence.[2,4-12]

The literature specifically reports links between waking headaches and sleep disorders including sleep apnea and snoring, nocturnal hypoglycemic attacks in diabetic patients, and insufficient and interrupted sleep.[13-16] Types of headache that can occur on awakening include those caused by, or related to, hypertension, depression, tension, or muscle contraction, brain tumour, alcohol consumption, and sinus disease.[13] Nocturnal bruxism, which occurs as a result of an autonomic arousal reaction associated with abrupt lightening of sleep, has also been reported to be a frequent cause of waking headache and neck pain.[5,17-19]

Sleep Position, sleep quality and waking cervico-thoracic symptoms

The companion paper to this publication reported that sleep position is significantly associated in a univariate sense with the prevalence of waking cervico-thoracic

symptoms and sleep quality. Side sleep position is protective of waking cervical, scapular, or arm pain and of low sleep quality, while the adoption of an upright sleep position was significantly associated with waking cervico-thoracic symptoms and poor sleep quality.[20] However, the relationship remains unclear between the adoption of a particular sleep position and other factors related to sleep quality.

Using the data set for which methodology, measures, and response rates were described by Gordon et al, this paper reports on the estimated strength of association between factors hypothesized and known to affect sleep quality, sleep position, and the prevalence of waking cervical pain and stiffness, headache, and scapular or arm pain.[21]

Methodology

The data for this study was collected by telephone survey in 1999 in a geographically-contained regional community in South Australia, the sample believed to be representative of the wider Australian population.[22] Using a specifically designed survey instrument, subjects were asked using Yes/ No responses, if they

- suffered from fibromyalgia, rheumatoid arthritis, or diabetes, or from any other medical condition that regularly affected their sleep
- regularly ground their teeth at night (bruxism). Subjects who were unsure about this were excluded from any statistical analyses considering the responses to this question
- found that their sleep was regularly disrupted for reasons other than a medical condition
- were taking prescribed medication for any condition (and if yes, they were asked to describe the type of medication)
- regularly consumed alcohol in the evening in a usual week (and if yes, how much)
- had ever had an injury or accident involving their neck (and if yes, the type of trauma)
- experienced waking cervical pain, cervical stiffness, headache, and scapular or arm pain in a usual week, and if so, how long these symptoms usually lasted, and
- experienced retiring cervical pain, cervical stiffness, headache, and scapular or arm pain in a usual week.[20]

Subjects were also asked to rate their sleep quality in a usual week (choosing from categories of excellent, good, fair, and poor). They also nominated the position in which they believed they spent most of the night when asleep, by choosing from side, supine, prone, and upright positions. Another option 'varies' was provided for those subjects who were unable to nominate one main position.

Data Management

The data were constructed into a form appropriate for the purposes of logistic regression analysis, requiring categorisation of data and identification of a default (comparison) level for each variable. Binary variables (Yes/No) described responses to the questions "Suffering from any medical condition that affected sleep," "taking any regular prescribed medication," "nocturnal bruxism," "alcohol consumption," "regular sleep disruption," and "previous injury to the neck." In all instances, the "no" classification was the default comparison category. The four sleep quality rating categories were dichotomised into high (excellent, good -- the default classification category) and low (fair, poor). Age was classified into three independent categories: young (less than 40 years -- designated as the comparison category), middle (40-59 years), and older age (60 years or older). Sleep position was classified as four independent categories, this decision underpinned by the hypothesised biomechanical effects of sleeping positions of the cervical spine, and by subject numbers nominating each sleep position. Sleep position was described as one category containing "varied" and "upright positions," and individual categories of supine, prone, and sidelying. For comparison purposes, the combined "upright and varied position" category was the designated default. Waking symptoms were considered as independent outcomes for analysis (waking with cervical pain, cervical stiffness, headache, or scapula and arm pain). Subjects could nominate more than one waking symptom outcome. A four-level new variable was constructed by combining reports of retiring and waking symptoms: 1=both retiring and waking with symptoms, 2=retiring with symptoms and waking without symptoms, 3=retiring without symptoms and waking with them, and 4=experiencing no symptoms on retiring and waking. Subjects who reported retiring and waking without symptoms were designed at the comparison group.

Statistical Analysis

Statistical analysis was undertaken using the logistic regression procedure in SAS Version 8.2. A causal model was proposed of putative exposures (medical condition, medication use, nocturnal bruxism, disrupted sleep, alcohol consumption, cervical injury/accident, gender, age, and sleep position categories) as predictors of an interim outcome variable (sleep quality), and then with main outcomes of waking cervical symptoms and combined retiring and waking symptoms. The strengths of association were expressed as odds ratios (OR -- 95% Confidence Intervals). Significant associations were identified when the value of 1 did not lie between the confidence intervals.

Univariate logistic regression models were first constructed to establish the strength of association with each proposed predictor with sleep quality, waking symptoms (using each symptom type), and with the combined retiring and waking symptom classifications. Estimates of association between interim outcome (sleep quality) and main outcomes (waking symptoms) were also established. Using the multivariate model construction approach outlined by d'Espaignet et al, the

significant predictors for each outcome measure were then prioritized by strength of association using hierarchical principles, and controlled against each other in stepwise order of entry into the model.[23] The significance of the change in the -2LogL measure for each addition to the model was calculated from critical chi-square values related to the degrees of freedom, as this provided a robust estimate of the variance accounted for when increasing the number of predictor components in the model.[24] The "best fit" form of each predictive model was identified when further additions of independent variables to the model produced non-significant changes to the deviance relative to the degrees of freedom in the model.

Results

Response and population descriptors

Our earlier paper reported age and gender distributions of subjects; however, this data is reported here for the convenience of the reader.[21] The questionnaire was completed by 551 females (68% sample) and 261 males (32% sample). Young age reflected 264 participants (33%), 300 middle age (37% participants) and 248 old age (31% participants).

Main outcome measures: Waking and retiring symptoms

As reported in the companion paper, waking at least once in the previous week with cervical pain was reported by 18.1% subjects, waking with cervical stiffness by 17.3% subjects, waking with headache by 19.3% subjects, and waking with shoulder blade/arm pain was reported by 25.4% subjects.[20] Retiring in the previous week with cervical pain was reported by 16.5% subjects, retiring with a stiff neck by 12.1% subjects, retiring headache by 12.5% subjects, and retiring with shoulder blade/arm pain was reported by 13.3% subjects. The frequency of combined retiring and waking symptoms is reported in Table 1. Approximately 11% of the sample regularly retired and woke with at least one cervico-thoracic symptom.

Table 1. Percentage of subjects with retiring and waking symptom combinations.
R = retiring, W = waking, Y = yes, N = no
RN = not retiring with symptoms, WN = not waking with symptoms etc

	Cervical pain	Cervical stiffness	Headache	Shoulder blade arm pain
RN & WN	75.8%	78.6%	74.6%	71.4%
RY & WN	6.1%	4.0%	6.1%	3.2%
RN & WY	7.7%	9.3%	12.9%	3.2%
RY & WY	10.5%	8.1%	6.4%	10.1%

Interim outcome measure: Sleep quality

In order of frequency of reporting, good sleep quality was reported by 49.0% subjects, fair sleep quality by 28.9%, excellent sleep quality by 14.6% and poor sleep quality by 7.6% of subjects. High quality sleep was therefore reported by 63.6% subjects and poor quality sleep was reported by 36.4%.

Proposed exposures

Medical conditions

There was a range of medical conditions believed by 235 subjects (28.9% total participants) to regularly affect their sleep. These consisted of musculoskeletal conditions (54% subjects), respiratory conditions (9%), stress (6%), insomnia (5%), snoring (4%), nose, throat, and gut conditions, central nervous system conditions, sleep apnea, and menopause (3% each), cardiac and inflammatory conditions (2% each), and one percent each reporting migraine headaches, pregnancy and vascular conditions.

Medication use

Of the 468 subjects (57.6% total participants) reporting regular medication use that potentially affected their sleep, 21% of the sample reported using anti-hypertensive medication, 13% used anti-inflammatory drugs, 12% were using HRT medication and cardiac medication, analgesics were reported by 9%, gastrointestinal medication and anti-depressants were reported by 7% each, 6% subjects were using asthma medication, and 4% were using diuretics, thyroid medication, anti-cholesterol and diabetic medication.

Reasons for disrupted sleep other than a medical condition

Reasons for disrupted sleep were provided by 271 subjects (33.4% total participants). These included children waking through the night (30%), respondents' nocturnal toileting needs (20%), stress (10%), poor sleeping by partner and being a light sleeper (9% respectively), shift work and noise (6% each), noisy pets (5%), temperature, dreams, and other reasons (2% each).

Alcohol consumption

Of the 248 subjects who reported consuming alcohol regularly in the evening before retiring (30.5% subjects), the median number of drinks was 2 (25th% to 75th% 1-3). Consuming six evening drinks or less was reported by 99.4% of this subset. The largest number of drinks consumed in an evening in the preceding week was 12 (reported by three subjects, representing 0.4% of the

sample).

Cervical spine injury

Previous cervical spine injury was reported by 159 subjects (19.6% subjects). Vehicle accidents accounted for 55% of these reports, falls (15%), sports (13%), work-related injury (8%), assault (4%), diving (3%), and lifting (2%). Of the 133 subjects who provided information on duration since injury, 24 (18%) reported injury occurrence five years or less ago, 41 (33%) reported injury occurrence between 5-10 years ago, and injury occurring more than 10 years ago was reported by 51% of subjects.

Sleep position

As reported in our companion publication, the most common sleep position was reported by 74.1% sample (N=610) as side lying. Supine sleepers comprised 96 subjects (11.8% sample).[20] Sleeping in an upright position [(N=31) 3.8% total], prone [(N=40) 4.9% total] and in variable positions [(N=66) 8.1% total] were less commonly reported. Sleep disturbance did not influence the position of most sleep.

Considering exposures and sleep quality ratings

Sleep quality ratings and sleep position

Table 2 reports the univariate association between putative exposures (medical condition, medication usage, nocturnal bruxism, disrupted sleep, alcohol consumption, cervical injury/ accident, age, gender, and sleep position) and the interim outcome variable, sleep quality. This table indicates that regularly disrupted sleep, suffering any medical condition, any accident/injury to the cervical spine, and regular nocturnal bruxism were significant predictors of low sleep quality (consisting of poor and fair quality reports), with 95% Confidence Intervals that did not embrace the value of 1. Sleep positions of prone, supine and side were significant predictors of good sleep quality compared with combined upright or variable sleep positions.

Using multivariate logistic regression analysis to take account of the effect of confounding, Table 3 reports on the influence of the non-significant predictors of sleep quality (gender, age, alcohol intake, and medication use) on the significant predictors. None of these variables significantly influenced the relationship between sleep quality and the five significant predictors (identified in Table 2). Conversely, Table 4 outlines the consistently significant confounding influence of the significant predictors on each other. Based on these findings, the best fit multivariate model under these conditions for poor sleep quality (OR 3.3; 95%CI 2.4 - 4.5) included disrupted sleep, suffering a medical condition, and nocturnal bruxism. The addition of the variables "injury to the cervical spine" and "sleep position" did not add significantly to the amount of deviance explained by the model. The best fit model explains 3.5% of the variance of sleep quality.

Table 2. Estimates of association (Odds Ratio, 95% Confidence Intervals) between sleep quality and predictors of poor sleep quality. * indicates a significant association.

Predictors of poor sleep	OR (95% CI)
Any medical condition	2.1 (1.6 - 2.9)*
Any regular medication usage	1.3 (0.9 – 1.7)
Regular nocturnal bruxism	2.3 (1.5 – 3.6)*
Regularly disrupted sleep	3.2 (2.3 - 4.3)*
Regular nocturnal alcohol consumption	1.2 (0.9 - 1.6)
Any previous cervical injury/accident	1.8 (1.3 - 2.5)*
Age ***Age < 40 years (comparator)*** ***Age 40-59 years*** *Age 60+ years*	 1 1.2 (0.9 - 1.7) 1.0 (0.7 - 1.4)
Gender (Female = 1)	0.9 (0.7 - 1.2)
Sleep position ***Combined upright, varied*** *Regular side* *Regular prone* *Regular supine*	1 0.5 (0.3-0.7)* 0.4 (0.2-0.8)* 0.4 (0.2-0.8)*

Table 3. Multivariate analysis considering the confounding influence of non-significant associates of sleep quality (adjusted OR (95%CI), change in -2LogL from the univariate model. The degrees of freedom (df) for each model is reported as df.

Predictors	statistics	gender df=2	age df=3	alcohol df=2	medication use df=2
disrupted sleep	OR (95%CI)	3.2 (2.3-4.3)	3.3 (2.3-4.4)	3.1(2.3-4.2)	3.2 (2.3-4.3)
	Change in -2LogL	*1.9*	*4.6*	*0.3*	*3.7*
medical condition	OR (95%CI)	2.1(1.6-2.9)	2.2(1.6-2.9)	2.2 (1.6-2.9)	2.1 (1.5-2.9)
	Change in -2LogL	0.4	2.5	1.7	0.0
cervical injury	OR (95%CI)	1.8 (1.3-2.5)	1.8 (1.2-2.5)	1.8 (1.2-2.5)	1.8 (1.2-2.5)
	Change in -2LogL	0.7	1.3	0.6	1.6
bruxism	OR (95%CI)	2.3 (1.5-3.6)	2.3 (1.5-3.7)	2.3 (1.5-3.6)	2.3 (1.5-3.7)
	Change in -2LogL	0.7	2.2	0.7	3.3
sleep position	OR (95%CI)				
side		0.5 (0.3-0.7)	0.5 (0.3-0.7)	0.5 (0.3-0.7)	0.5 (0.3-0.7) 0.4
prone		0.4 (0.2-0.8)	0.4 (0.2-0.8)	0.4 (0.2-0.8)	(0.2-0.9) 0.5
back		0.5 (0.3-0.8)	0.4 (0.2-0.8)	0.5 (0.3-0.8)	(0.3-0.9)
	Change in -2LogL	0.8	2.5	0.6	1.6

Table 4. Multivariate analysis considering the confounding influence of significant associates of sleep quality (adjusted OR (95%CI), change in -2LogL from the univariate model). The degrees of freedom (df) for each model is reported as df. Significant changes in -2LogL are asterisked.

		Potential confounders				
Predictors	**statistics**	**disrupted sleep** df2	**medical condition** df2	**cervical injury** df2	**bruxism** df2	**sleep position** df3
disrupted sleep	OR (95%CI)		3.3 (2.4-4.5)	3.1 (2.2-4.1)	3.2 (2.3-4.3)	3.1 (2.3-43)
	Change in -2LogL		*25.1**	*6.6**	*12.9**	*10.0**
medical condition	OR (95%CI)			2.1 (1.5-2.8)	2.1 (1.5-2.8)	2.1 (1.5-2.8)
	Change in -2LogL			*7.7**	*11.2**	*9.9**
cervical injury	OR (95%CI)				1.7 (1.2-2.5)	1.7 (1.2-2.5)
	Change in -2LogL				*12.2**	*12.0**
bruxism	OR (95%CI)					2.3 (1.4-3.5)
	Change in -2LogL					*12.0**

Sleep quality ratings and outcome measures

Sleep quality and waking symptom prevalence

Comparison of reports of sleep quality rating (low, high) with waking symptom reports found that low sleep quality ratings were significantly associated with all waking symptoms. The odds ratios and 95% Confidence Intervals of the association between low quality sleep and waking symptoms are for cervical pain 3.1 (95%CL 2.1-4.6), cervical stiffness 2.6 (95%CL 1.8-3.9), headache 2.9 (95%CL 2.0-4.2), and scapular or arm pain 1.7 (95%CL 1.2-2.4).

Sleep quality and combined retiring/waking symptom prevalence

Comparison of reports of sleep quality rating (low, high) with the combined retiring/waking symptom reports found again that low sleep quality ratings were significantly associated with all measures of retiring and waking symptoms. The odds ratios and 95% Confidence Intervals demonstrated significant associations between sleep quality, and the combined retiring/waking cervical pain measure (OR 3.1; 95%CI 2.1-4.5), the combined retiring/waking cervical stiffness measure (OR 2.6; 95%CI 1.8 - 3.8), the combined retiring and waking headache measure (OR 1.6; 95%CI 1.4- 1.8) and the retiring/waking scapular/arm pain measure (OR 1.7; 95%CI 1.2-2.3).

Association between exposures and main outcome measures (waking symptoms)

Table 5 reports on the univariate association between putative exposures and waking symptoms. Having a medical condition and previous cervical injury/accident were both strongly associated with all cervico-thoracic waking symptoms. Suffering from nocturnal bruxism was associated with cervical pain, cervical stiffness, and

scapula/arm pain. Disrupted sleep was associated strongly with waking headache and waking scapula/arm pain, while taking medication was associated with waking with scapula/arm pain. Being female was associated with waking headache, and sleeping on the side or prone were protective of waking with scapula/arm pain, compared with sleeping in upright or variable positions. Age and alcohol consumption were not associated with any of the waking symptoms.

Table 5. Strength of association between proposed exposures and waking symptoms (Odds Ratios, 95% CI). * indicates a significant association.

Exposure OR (CI)	Cervical pain	Cervical stiffness	Headache	Scapular or arm pain
Medical condition	2.7 (1.9-3.9)*	2.3 (1.6-3.4)*	2.3 (1.6-3.3)*	2.6 (1.8-3.5)*
Medication usage	1.2 (0.8-1.7)	1.3 (0.9-1.9)	1.2 (0.9-1.8)	1.8 (1.3-2.4)*
Nocturnal bruxism	2.0 (1.2-3.4)*	2.2 (1.3-3.6)*	1.6 (0.9-2.7)	1.6 (1.0-2.5)*
Disrupted sleep	1.1 (0.8-1.6)	1.3 (0.9-1.9)	1.4 (1.0-1.9)*	1.5 (1.1-2.1)*
Alcohol consumption	1.1 (0.7-1.6)	1.0 (0.7-1.6)	1.0 (0.7-1.5)	0.9 (0.6-1.3)
Cervical injury/accident	2.6 (1.7-3.9)*	2.7 (1.8-4.2)*	1.7 (1.1-2.5)*	1.9 (1.3-2.7)*
Age (Young) ***Middle*** ***Old***	1 1.0 (0.6-1.5) 0.8 (0.5-1.3)	1 1.1 (0.7-1.7) 0.7 (0.4-1.1)	1 1.3 (0.8-1.9) 0.7 (0.5-1.2)	1 1.2 (0.8-1.8) 1.4 (0.9-2.1)
Gender (Female)	1.1 (0.7-1.6)	0.9 (0.6-1.3)	2.5 (1.6-3.9)*	0.9 (0.7-1.4)
Sleep position (upright, varied) ***Regular side*** ***Regular prone*** ***Regular supine***	1 0.8 (0.4-1.5) 1.4 (0.5-3.5) 1.2 (0.6-2.6)	1 1.0 (0.5-2.0) 1.3 (0.4-3.4) 0.9 (0.4-2.2)	1 1.4 (0.7-2.8) 1.2 (0.4-3.4) 1.0 (0.4-2.5)	1 0.5 (0.3-0.8)*(P) 0.4 (0.2-1.0) 0.6 (0.3-1.1)

Table 6 reports the non-significant associations between the length of time since cervical injury and waking symptoms using the longest time duration as the comparator (10+ years). This indicates that the prevalence of waking cervico-thoracic symptoms after trauma does not change as a result of time lapse since injury.

Table 6. Association between length of time since cervical injury and waking symptom prevalence. Greater than 10 years since injury used as the comparator.

Time since injury	Cervical pain	Cervical stiffness	Headache	Scapula / arm pain
Less than 5 years	1.0 (0.3-2.8)	1.4 (0.5-3.9)	1.1 (0.3-3.3)	0.8 (0.3-2.3)
5-10 years	1.0 (0.4-2.5)	0.9 (0.4-2.2)	0.8 (0.3-2.2)	0.9 (0.4-2.2)
>10 years	1	1	1	1

Table 7 reports on the percentage of subjects in each sleeping position who woke with cervical symptoms. As anticipated from the univariate analysis reported in Table 5, the upright sleepers most commonly woke with symptoms of any type, although the small numbers in this group suggest that these findings should be interpreted with caution.

Table 7. The prevalence of cervical waking symptom reports for each sleep position

Position of most sleep	% Waking cervical pain	% Waking cervical stiffness	% Waking headache	% Waking scapular arm pain
Side	16.7	17.6	21.0	26.0
Supine	24.2	16.5	16.5	30.8
Prone	25.0	20.0	17.5	22.5
Upright	35.5	35.5	35.5	48.4
Varies	20.0	16.9	15.4	41.5

Table 8 reports on the univariate relationship between putative exposures and the variable of combined retiring/waking symptoms. For each retiring/waking symptom, the "disease positive" outcome included those subjects who went to bed with no symptoms yet woke with symptoms, or both retired and woke with symptoms. Similar to the waking symptom associations reported in Table 5, suffering a medical condition or a previous cervical injury/accident were strongly associated with all retiring/waking symptoms. Suffering from nocturnal bruxism was associated with cervical pain and scapula/arm pain, while disrupted sleep was associated strongly with retiring/waking scapula/arm pain. Taking medication was associated with retiring/waking cervical stiffness and headache. Being female was associated with retiring/waking headache, and sleeping on the side, back or prone was protective of retiring and waking with scapula/ arm pain, compared with sleeping upright or in variable positions. Sleeping on the side was also protective of retiring and waking with cervical pain, compared with sleeping upright or in variable positions.

Table 8. Uniivariate association between proposed exposures and combined retiring/waking symptoms reported as Odds Ratios (95% CI). * indicates a significant association, (P) indicates a protective association. ***NB*** *the positive disease outcome reflects those subjects who retired with no symptoms yet woke with symptoms, or both retired and woke with symptoms*

Exposures	Cervical pain	Cervical stiffness	Headache	Scapular or arm pain
Medical condition	2.7 (1.9 -3.9)*	2.3 (1.6-3.4)*	2.3 (1.6-3.3)*	2.6 (1.8-3.5)*
Medication usage	1.2 (0.8-1.7)	2.2 (1.3-3.6)*	1.7 (1.0-2.8)*	1.6 (0.9-2.5)
Nocturnal bruxism	2.1 (1.2-3.4)*	1.3 (0.9-1.9)	1.3 (0.9-1.8)	1.8 (1.3-2.4)*
Disrupted sleep	1.1 (0.8-1.7)	1.3 (0.9-1.9)	1.4 (0.9-1.9)	1.5 (1.1-2.1)*
Alcohol consumption	1.0 (0.7-1.6)	1.1 (0.7-1.6)	1.0 (0.7-1.5)	0.9 (0.6-1.3)
Cervical injury/accident	2.6 (1.8-3.9)*	2.7 (1.8-4.1)*	1.7 (1.1-2.5)*	1.9 (1.3-2.8)*
Age (Young)	1	1	1	1
Middle	0.9 (0.6-1.5)	1.1 (0.7-1.7)	1.3 (0.8-1.9)	1.2 (0.8-1.8)
Old	0.8 (0.5-1.3)	0.7 (0.4-1.1)	0.8 (0.5-1.2)	1.4 (0.9-2.1)
Gender (Female)	1.1 (0.7-1.6)	0.9 (0.6-1.3)	2.5 (1.6-3.9)*	0.9 (0.7-1.4)
Sleep position (upright, varied)	1	1	1	1
Regular side	0.5 (0.3-0.9)*	0.6 (0.4-1.1)	0.8 (0.5-1.4)	0.4 (0.3-0.6)*(P)
Regular prone	1.0 (0.4-2.3)	0.8 (0.3-2.1)	0.7 (0.3-1.8)	0.4 (0.2-0.9)*(P)
Regular supine	0.8 (0.4-1.6)	0.5 (0.2-1.1)	0.5 (0.2-1.1)	0.5 (0.3-0.9)*(P)

Table 9 summarises the significant univariate findings for sleep quality, and waking, and retiring/waking symptom combinations across the proposed predictors. For ease of reading, the columns reporting the combined symptom predictors are shaded. Considering sleep quality as the interim outcome, which was significantly associated with all waking symptoms, the consistently significant exposures for all five outcomes were suffering a medical condition and cervical injury. Nocturnal bruxism was associated with all outcomes except waking headache, and disturbed sleep was associated with sleep quality, waking headache, or waking scapula pain. Sleep position was associated only with sleep quality and waking scapula/arm pain, while gender was associated only with headache, and taking medication was associated only with waking scapula/arm pain. However, as each of these predictors was significantly inter-related as confounders in different predictive models involving the other variables, their importance in predicting good quality sleep and in diminishing waking symptoms cannot be discounted.

Table 9. Summary of significant univariate predictors for symptom outcome measures (waking symptoms, and combined retiring/ waking symptoms).

***** indicates a significant association, (P) indicates a protective association.

Exposure	**Sleep quality**	**Cx pain** *Waking*	*Retiring & Waking*	**Cx stiff** *Waking*	*Retiring & Waking*	**H.A.** *Waking*	*Retiring & Waking*	**Scap/arm p** *Waking*	*Retiring & Waking*
Medical condition	*	*	*	*	*	*	*	*	*
Medication usage					*		*	*	
Nocturnal bruxism	*	*	*	*				*	*
Disrupted sleep	*					*		*	*
Alcohol consumption									
Cervical injury	*	*	*	*	*	*	*	*	*
Age (Young)									
Middle									
Old									
Gender (Female)						*	*		
Sleep position (upright, varied)	*								
Regular side			*(P)					*(P)	*(P)
Regular prone									*(P)
Regular supine									*(P)

Tables 10a-d report on the four waking symptom outcomes using multivariate analysis to control for the potentially confounding effect of the proposed exposures (significant and non-significant) that were reported in Table 5 from univariate models. Because of the similarity in prediction of these exposures and the retiring/waking symptoms, only one set of multiple predictive models was constructed, this being for waking symptoms. Table

10a indicates that for the predictive model for cervical waking pain in which medical condition was the primary exposure, the only significant confounder was cervical injury. The adjusted odds ratio (AOR) for waking cervical pain from this model remained significant at 2.6 (95%CI 1.8-3.7), and the model accounted for 2.3% total variance. A similar and not surprising association was found for the predictive model in which cervical injury was the primary exposure and medical condition was the significant confounder, where the total amount of variance accounted for by the model was 3.3% and the AOR remained significant at 2.4 (95%CI 1.6-3.6). For the predictive model for cervical waking pain in which nocturnal bruxism was the primary exposure, the significant confounders were cervical injury and suffering a medical condition. The AOR accounting for these confounders remained significant at 1.7 (95%CI 1.0-2.9) and the amount of the deviance accounted for by the model was 5.5%.

Table 10a. Multivariate analysis considering the confounding influence of associates of ***cervical pain waking symptoms*** (adjusted OR (95%CI), and change in -2LogL from the univariate model). The degrees of freedom for each model is reported in subscript. Significant changes in -2LogL are asterisked. The significant univariate predictors are highlighted in bold italics.

Predictors	statistics	Medical condition	Bruxism	Cervical injury
Gender	**OR (95%CI)**	***2.7(1.9-3.9)***	2.0 (1.2- 3.4)	2.6 (1.7- 3.9)
df=2	Change in -2LogL	*0.3*	*0.2*	*0.1*
age	**OR (95%CI)**	**3.1 (2.0 -4.4)**	**2.0 (1.2-3.3)**	**2.6 (1.7-3.9)**
df=3	**Change in -2LogL**	*4.1*	0.6	*0.9*
alcohol	**OR (95%CI)**	**2.8 (1.9-4.0)**	**2.0 (1.2-3.4)**	**2.6 (1.7-3.9)**
df=2	**Change in -2LogL**	*0.4*	*0.03*	*0*
medication use	**OR (95%CI)**	2.9 (1.9-4.4)	2.0 (1.2-3.4)	2.6 (1.7- 3.9)
df=2	**Change in -2LogL**	*1.1*	*0.8*	*0.5*
disrupted sleep	**OR (95%CI)**	2.7 (1.9-3.9)	2.0 (1.2- 3.4)	2.6 (1.7-3.9)
df=2	**Change in -2LogL**	*0.4*	*0.04*	*0.02*
sleep position	**OR (95%CI)**	2.8 (1.9-4.1)	1.9 (1.2- 3.3)	2.6 (1.7-3.9)
df=4	**Change in -2LogL**	*7.4*	*6.6*	*7.4*
Bruxism	**OR (95%CI)**	2.6 (1.8-3.8)		2.5 (1.7-3.8)
df=2	**Change in -2LogL**	*5.1*		*5.6*
Cervical injury	**OR (95%CI)**	2.6 (1.8-3.7)*	1.9 (1.1-3.2)*	
df=2	**Change in -2LogL**	*16.4*	*16.6*	
Medical condition	**OR (95%CI)**		1.8 (1.1-3.1)*	2.4 (1.6-3.6)*
df=2	**Change in -2LogL**		*26.1*	*23.7*

Table 10b reports that for the predictive model for cervical waking stiffness in which medical condition was the primary exposure, the only significant confounder was cervical injury. The AOR from this model remained significant at 2.2 (95%CI 1.5-3.2) accounting for 2.5% of the total deviance. This same strong association was observed in reverse for the predictive model of waking cervical stiffness in which cervical injury was the primary exposure and medical condition was the confounder. The AOR in this model was 2.5 (95%CI 1.7-3.8) and the amount of deviance accounted for by the model was 2.2%. For the predictive model for cervical waking stiffness in which nocturnal bruxism was the primary exposure, the significant confounders were cervical injury and suffering a medical condition. The AOR from the multivariate model remained significant at 1.9 (95%CI 1.1-3.2) accounting for 4.7% total deviance.

Table 10c reports that for the predictive model for waking headache in which medical condition was the primary exposure, the significant univariate confounders were age and gender. The AOR from this model was significant at 2.6 (95%CI 1.8-3.8) accounting for 4% of the total deviance. For the predictive model of waking headache in which disrupted sleep was the primary exposure, the significant confounders were medical condition and gender. The AOR from this model reduced the strength of the univariate association (1.3; 95%CI 0.9-1.9). Thus, by de-confounding the association between waking headache and disrupted sleep by medical condition and gender, the association became non-significant. For the predictive model for waking headache in which cervical injury was the primary exposure, the significant confounders were suffering a medical condition and gender. The adjusted model retained the strength of its prediction (AOR 1.5; 95%CI 1.0-2.3) and accounted for 4.9% total deviance. For the predictive model of waking headache in which gender was the primary exposure, the significant confounders were disrupted sleep and suffering a medical condition.

The AOR from this model remained significant (2.6; 95%CI 1.7-4.1) and accounted for 3.1% deviance.

Table 10b. Multivariate analysis considering the confounding influence of associates of ***cervical stiffness waking symptoms*** (adjusted OR (95%CI), and change in -2LogL from the univariate model). The degrees of freedom for each model is reported as df. Significant changes in -2LogL are asterisked. The significant univariate predictors are highlighted in bold italics.

Predictors	statistics	Medical condition	Bruxism	Cervical injury
gender df=2	**OR (95%CI)**	2.3 (1.6- 3.4)	2.2 (1.3-3.6)	2.7 (1.8- 4.1)
	Change in -2LogL	*0.2*	*0.3*	*0.4*
age df=3	**OR (95%CI)**	2.5 (1.7- 3.8)	2.1 (1.3-3.5)	2.7 (1.8-4.0)
	Change in -2LogL	*6.9*	*3.3*	*3.1*
alcohol df=2	**OR (95%CI)**	2.4 (1.7- 3.4)	2.2 (1.3-3.6)	*2.7 (1.8- 4.1)*
	Change in -2LogL	*0.3*	*0.02*	*0*
medication use df=2	**OR (95%CI)**	2.3 (1.6-3.5)	2.2 (1.3-3.7)	2.7 (1.8- 4.0)
	Change in -2LogL	*0*	*2.4*	*1.8*
disrupted sleep df=2	**OR (95%CI)**	2.3 (1.6-3.4)	2.2 (1.3-3.6)	2.6 (1.7-3.9)
	Change in -2LogL	*2.1*	*1.8*	*0.9*
sleep position df=4	**OR (95%CI)**	2.4 (1.6-3.4)	2.1 (1.3-3.5)	2.7 (1.8- 4.1)
	Change in -2LogL	*3.4*	*3.2*	*3.9*
Bruxism df=2	**OR (95%CI)**	2.3 (1.5- 3.3)*		2.6 (1.7- 3.9)*
	Change in -2LogL	*6.4*		*6.7*
Cervical injury df=2	**OR (95%CI)**	*2.2 (1.5-3.2)**	2.0 (1.2- 3.4)*	
	Change in -2LogL	*18.2*	*20.3*	
Medical condition	**OR (95%CI)**		2.0 (1.2- 3.3)*	2.5 (1.7-3.8)*
	Change in -2LogL		*17.4*	*15.5*

Table 10c. Multivariate analysis considering the confounding influence of associates of ***headache waking symptoms*** (adjusted OR (95%CI), and change in -2LogL from the univariate model). The degrees of freedom for each model is reported as df. Significant changes in -2LogL are asterisked. The significant univariate predictors are highlighted in bold italics.

Predictors	statistics	Medical condition	Disrupted sleep	Cervical injury	Gender
age df=3	**OR (95%CI)**	2.4 (1.7-3.6)*	1.4 (0.9- 2.0)	1.6 (1.1- 2.5)	2.6 (1.7-4.1)
	Change in -2LogL	*8.1*	*6.1*	*4.9*	*7.6*
alcohol df=2	**OR (95%CI)**	2.3 (1.6- 3.3)	1.4 (0.9-1.9)	1.7 (1.1- 2.6)	2.7 (1.7- 4.2)
	Change in -2LogL	*0.2*	*0.0*	*0*	*1.6*
medication use df=2	**OR (95%CI)**	2.3 (1.6- 3.4)	1.4 (0.9- 2.0)	1.6 (1.1-2.5)	2.5 (1.6-3.8)
	Change in -2LogL	*0.1*	*1.6*	*1.3*	*1.1*
Sleep position df=4	**OR (95%CI)**	2.3 (1.6-3.3)	1.4 (0.9-1.9)	1.7(1.1- 2.6)	2.4 (1.6-3.8)
	Change in -2LogL	*2.8*	*2.6*	*2.9*	*1.9*
Bruxism df=2	**OR (95%CI)**	2.2 (1.6- 3.2)	1.4 (0.9-1.9)	1.7 (1.1-2.5)	2.5 (1.6-3.9)
	Change in -2LogL	*1.8*	2.8	*2.4*	*3.1*
Disrupted sleep df=2	**OR (95%CI)**	2.3 (1.6- 3.3)		1.6 (1.1-2.5)	2.4 (1.6-3.8)*
	Change in -2LogL	*3.0*		*2.1*	*21.7*
Cervical injury df=2	**OR (95%CI)**	2.2 (1.5- 3.1)	1.3 (0.9-1.9)		2.5 (1.7-3.9)*
	Change in -2LogL	*4.1*	*5.4*		*6.2*
Medical condition df=2	**OR (95%CI)**		1.4 (0.9-2.0)*	1.6 (1.0-2.3)*	2.6 (1.7-4.1)*
	Change in -2LogL		*19.9*	*17.8*	*21.7*
Gender df=2	**OR (95%CI)**	2.4 (1.7-3.5)*	1.3 (0.9-1.9)*	1.7 (1.1- 2.6)*	
	Change in -2LogL	*20.7*	*18.0*	*18.8*	

Table 10d reports that for the predictive model for waking with scapula/arm pain where medical condition was the primary exposure, the significant confounders were sleep position, disrupted sleep, and cervical injury. Adjusting by these variables provided a significant AOR of 2.4 (95%CI 1.7- 3.3) and the model accounted for 2.6% of the total deviance. For the predictive model for waking with scapula/arm pain where disrupted sleep was the primary exposure, the significant confounders were medical condition, medication use, sleep position, and cervical injury. De-confounding by these variables gave a significant AOR 1.4 (1.0-1.9) in which the model accounted for 5.6% of the total deviance. For the predictive model in which cervical injury was the primary exposure, suffering a medical condition, sleep position, and medication use were significant confounders. The AOR for waking with scapula/arm pain from this model was significant (1.7 (95%CI 1.2-2.5)) and the model accounted for 4.6% of the deviance. Considering medication use as the primary exposure for this outcome, the significant confounders were sleep position, disrupted sleep, cervical injury, and medical condition. The AOR for waking with scapula/arm pain in this multivariate model was non-significant (1.3; 95%CI 0.9-1.9) in which the model accounted for 4.9% of the deviance. The predictive model in which bruxism was the primary exposure was significantly confounded by sleep position, medication use, disrupted sleep, cervical injury and medical condition. De-confounding by these variables produced a non-significant adjusted odds ratio of 1.4 (95%CI 0.8-2.2) in which the model accounted for six percent of the deviance.

Table 10d. Multivariate analysis considering the confounding influence of associates of ***scapula/ arm waking symptoms*** (adjusted OR (95%CI), and change in -2LogL from the univariate model). The degrees of freedom for each model is reported as df. Significant changes in -2LogL are asterisked. The significant univariate predictors are highlighted in bold italics.

Predictors	statistics	Medical condition	Disrupted sleep	Cervical injury	Medication use	Bruxism
gender	**OR (95%CI)**	2.7(1.8- 3.5)	1.5 (1.1-2.1)	1.9 (1.3-2.8)	1.8 (1.3-2.4)	1.6 (1.0-2.5)
df=2	**Change in -2LogL**	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
age	**OR (95%CI)**	2.5 (1.8-3.5)	1.5 (1.1- 2.1)	1.9 (1.3-2.8)	1.8 (1.2- 2.5)	1.7 (1.0- 2.7)
df=3	**Change in -2LogL**	*0.6*	*3.36*	*4.2*	*0.01*	*4.2*
alcohol	**OR (95%CI)**	2.6 (1.8- 3.5)	1.5 (1.1-2.1)	1.9 (1.3- 2.8)	*1.8 (1.3-2.4)*	1.6 (1.0-2.5)
df=2	**Change in -2LogL**	*0*	*0.4*	*0.5*	*0.4*	*0.3*
Sleep position	**OR (95%CI)**	2.5 (1.8-3.4)	1.4 (1.0-2.0)*	1.8 (1.3-2.7)*	1.7 (1.2-2.3)*	1.5 (0.9-2.4)
df=4	**Change in -2LogL**	*12.3*	*14.5*	*14.7*	*13.1*	*15.3*
Medication use	**OR (95%CI)**	2.3 (1.6-3.2)	1.5 (1.1-2.1)*	1.9 (1.3- 2.7)*		1.6(1.0-2.7)*
df=2	**Change in -2LogL**	*3.3*	*13.3*	*13.2*		*13.3*
Bruxism	**OR (95%CI)**	2.5 (1.8-3.5)	1.5 (1.1-2.1)	1.9 (1.3- 2.7)	1.8 (1.3-2.5)	
df=2	**Change in -2LogL**	*2.1*	*2.8*	*2.8*	*3.9*	
Disrupted sleep	**OR (95%CI)**	2.6 (1.9-3.6)*		1.8 (1.3- 2.6)	1.8 (1.3-2.5)*	1.6 (1.0-2.5)*
df=2	**Change in -2LogL**	*6.4*		*4.6*	*6.6*	*5.9*
Cervical injury	**OR (95%CI)**	2.5 (1.8- 3.4)	1.4 (1.1- 1.9)*		1.8 (1.3-2.4)*	1.5 0.9- 2.4)
df=2	**Change in -2LogL**	*8.1*	*9.9*		*10.8*	*10.7*
Medical condition	**OR (95%CI)**		1.5 (1.1-2.1)*	1.7 (1.2- 2.5)*	1.4 (0.9-1.9)*	1.4(0.9-2.3)
df=2	**Change in -2LogL**		*32.3*	*30.6*	22.5	*30.6*

Discussion

This paper reports findings from a rare large-scale epidemiological study on sleep position, sleep quality, and waking symptoms in a representative Australian sample. The findings of this study suggest that a complex interplay exists between the presence of predictive factors for poor sleep quality and the

prevalence of waking cervical symptoms. The findings support the need for health professionals to consider individuals' sleep position, waking symptom history, and the presence of factors which may decrease sleep quality when developing a management plan for troublesome waking cervico-thoracic symptoms.

Previous reports of a relationship between poor sleep quality ratings and disrupted sleep are supported by this study. Not surprisingly reports of a medical condition which affected sleep quality were significantly associated with poor sleep quality reports. Reports of nocturnal bruxism or past cervical injury were also associated with reports of poor sleep quality.[2,3] All three factors – disrupted sleep, presence of a medical condition which disrupts sleep, and nocturnal bruxism – which predict poor sleep quality significantly confound each other. Nocturnal bruxism occurs as the result of an autonomic arousal reaction associated with abrupt lightening of sleep.[17] It is plausible that physical discomfort or anxiety related to the presence of a medical condition may also disrupt or lighten sleep. It is considered therefore that the factors identified in this study which predict poor sleep quality may be the result of physical or psychological responses which disrupt sleep.

The findings of this study did not concur with previous reports that nocturnal bruxism was related to reports of waking headache.[19,5,25,26] However, in agreement with Widmalm, a significant association was found between reports of nocturnal bruxism and cervical pain.[27] Further, this study identified a significant association between nocturnal bruxism and waking cervical stiffness which has not previously been reported. To improve validity of self-reports of nocturnal bruxism, respondents to this survey were encouraged to verify their response with their partner and on many occasions were heard to do so (during the telephone interview). Moreover, subjects were provided with the option of responding that they did not know if they bruxed nocturnally, and those subjects who reported this were excluded from statistical analysis. Concurring with findings of previous studies, a significant association was identified between reports of all waking symptoms and past injury to the cervical spine.[28,29] Furthermore the amount of time since the injury had occurred did not alter the strength of this association, indicating that a past injury to the cervical spine is associated with increased waking symptom reports irrespective of the amount of time since the injury.

It has previously been reported that cervical pain and stiffness are likely to occur together and are similar with respect to gender and age distribution.[21] This study identified that they share common predictive factors -- presence of a medical condition which affects sleep quality, past history of cervical injury and nocturnal bruxism -- and that these factors confound each other similarly for both symptom presentations. A possible hypothesis for the confounding influence of these factors on waking symptom reports was provided with respect to sleep quality and is considered to be applicable to the prevalence of waking cervical pain and stiffness. Increased disruption to sleep may impair the restorative function of sleep in terms of musculo-skeletal structures and increase their prevalence.

Because of the inherent limitations of self-reported survey data, it was not possible to determine the anatomical source of waking cervico-thoracic symptoms, particularly headache, scapular or arm pain. In contrast to other symptom types, reported waking headache was associated with age and gender; these relationships were, however, confounded by the presence of a medical condition which affected sleep quality, past history of cervical injury, and disruption to sleep.

Waking scapular and arm pain was the only symptom report significantly associated with the use of medication, but this association was confounded by reports of disrupted sleep, presence of a medical condition which affected sleep quality, and a past history of injury to the cervical spine. The lack of significance between medication use and other waking symptom reports and the consistent significant association between the presence of a medical condition which affects sleep quality indicates that use of medication cannot be considered a proxy for the presence of a medical condition when considering waking symptom reports.

It has been postulated that sleep in an upright position does not allow unloading of spinal structures from the effect of gravity, causing musculo-skeletal fatigue and symptom production.[31] This study identified that sleep in an upright or varied position was significantly associated with waking scapular or arm pain but that this association was confounded by the presence of a medical condition which affected sleep quality, past injury to the cervical spine, and disruption to sleep. Unfortunately, the small subject numbers constrained analysis of upright sleep position with waking symptoms for those subjects who did not report any of the known risk factors.

Conclusion

This study established that factors which decrease sleep quality, specifically the presence of a medical condition which affects sleep quality, past history of injury or accident to the cervical spine, and nocturnal bruxism are significantly associated with increased prevalence of waking cervico-thoracic symptoms. The confounding effect of these factors on waking cervico-thoracic symptoms indicates a complex interplay between factors which decrease sleep quality and waking musculo-skeletal symptom reports. It is important that health professionals consider these factors when establishing treatment plans for people who wake with cervico-thoracic symptoms.

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