

THE RELATIONSHIP BETWEEN MEDIAN NERVE
COMPRESSION IN THE CARPAL TUNNEL AND SLEEPING
POSITION: A SYSTEMATIC REVIEW

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ABSTRACT

Median nerve compression is reported to be the most common nerve compression in the upper extremity, especially in the carpal tunnel. Carpal tunnel syndrome (CTS) is a condition where the median nerve is entrapped in the narrow passageway that is covered by carpal bones and ligaments which is called the carpal tunnel. Despite the common symptoms such as numbness and tingling sensation in the median nerve distribution, many studies have agreed to characterize nocturnal paresthesia as one of the CTS symptoms. These symptoms have been frequently reported to cause a sleep disturbance to the patients at night. According to recent research, sleeping position is reported to be the provocative factor to the symptoms, while some studies reported that alteration in sleeping position can reduce the symptoms. Hence, this study objectively aims to identify the relationships between median nerve compression in the carpal tunnel and sleeping position through a systematic review. This review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as the main guideline. This study retrieved all selected articles from online databases such as PubMed, Scopus and ScienceDirect and from other sources such as Google Scholar that were published from 2010 to 2022. The articles were screened through the titles and abstract and were further reviewed and evaluated for eligibility. Only four articles that meet the inclusion criteria were included in this study. The included articles were then assessed for the risk of bias by using Crowe Critical Appraisal Tools (CCAT). The data from the selected articles were then analyzed and extracted for the results. Our assessment suggests that lateral side sleeping is the most preferred sleeping position in CTS patients that increased the symptoms at night. This study has a limitation where least research articles were published that are concerned about the association between nerve compression and sleeping position despite the frequent complaint of the symptoms at night. It is suggested for the future researchers to include the possible associations such as pain intensity, BMI, nature of work, the use of night splint and preferred hand position during sleeping in their study.

INTRODUCTION

Peripheral nerve compression syndrome (PNCS) is a condition that can be described as a chronic irritation or pressure palsies in the area of anatomical constriction (Assmus, Antoniadis & Bischoff, 2015). Besides, it also can be defined as a condition where the nerve is entrapped at various anatomical locations in the extremities (Strohl & Zelouf, 2017). According to Mansuripur, Deren and Kamal (2013), Doughty and Bowley (2019), and Nicholls and Furness (2019), upper extremities entrapment neuropathies are a common form of peripheral nerve compression, especially within the carpal tunnel at the wrist area that compresses the median nerve which is also known as Carpal Tunnel Syndromes (CTS).

Median nerve neuropathy is the most common peripheral nerve compression in the upper extremities where the frequently reported cases of entrapment were in the carpal tunnel of the wrist (Assmus et al., 2015). The statistic showed that median nerve entrapment cases that occur at various sites along with the median nerve distribution are approximately about 7% to 10% (Boyd, Singh, Robin, & Sharma, 2021). It is reported that the median nerve can also be compressed in four locations of the elbow where are at the supracondylar process, the lacertus fibrosus, at the origin of the flexor digitorum superficialis (FDS) and between the head of pronator teres (PT) between the humeral and ulnar head which can trigger to pronator teres syndrome (PTS) (Hussain & Winterton, 2016). However, the cases are very rare to be compared with median nerve entrapment in the carpal tunnel of the wrist (Dididze, Tafti & Sherman, 2018).

Prevalence showed an estimation of 10% to 15% of the incidence risk of CTS in a lifetime and approximately 2% in developed countries (Hussain & Winterton, 2016; Doughty & Bowley, 2019). CTS is widely known as an occupational disorder that occurs especially in men and affects bilaterally in about 50% of cases (Hussain & Winterton, 2016). It is mainly reported to be involved with a repetitive movement of the wrist flexion and extension and may be due to vibration of the wrist through machinery tools (Mansuripur et al., 2013; Hussain & Winterton, 2016; Meyer, Lintingre, Pesquer, Poussange, Silvestre & Dallaudière 2018; Nicholls & Furness, 2019).

Generally, median nerve compression shared the same clinical manifestation with another nerve compression in the upper extremities which affects the sensory and motor innervation (Hussain & Winterton, 2016). The common symptoms were neuropathic pain, numbness, loss of sensory and weakness of the muscle that may progress to functional disability depending on the affected nerve distribution (Mansuripur et al., 2013). According to Hussain and Winterton (2016), most CTS patients reported having numbness and tingling sensation, hand clumsiness and nocturnal paresthesia. This neuropathic pain may also cause a sleep disturbance for a patient at a chronic stage.

Prevalence shows that patients who complained of having chronic pain with sleep disturbance range between 50% to 80% and the severity of sleep disturbance depends on the pain intensity (Ferini-Strambi, 2017). Nocturnal pain or night paresthesia are commonly characterized as one of the early symptoms of CTS (Nicholls & Furness, 2019). According to Ferini-Strambi (2017), the relationship between neuropathic pain and sleep disturbance is bidirectional. McCabe, Uebele, Pihur, Rosales and Atroshi (2007) reported in their literature that there is a possible association that sleeping position is the causative factor of CTS. Wahab, Sanya, Adebayo, Babalola and Ibraheem (2017) also supported the statement by suggesting in

their literature that sustained hand or arm position could be the causative factor of CTS.

However, McCabe et al. (2007) mentioned in their study that the relationship between the sleeping position as the possible causative mechanism of the nerve compression syndrome, mainly in CTS, is still less clear and needs further study. Thus, this study aims to systematically review and evaluate and highlight the relationship mainly between median nerve compression in the carpal tunnel and sleeping position besides evaluating any preferred sleeping position in CTS patients as possible management to reduce the pain.

Nocturnal paresthesia that awakes CTS patients at night can be such a disturbance for the patients as it reduces sleep quality in most patients (Patel, McCabe & Myers, 2012; Patel, Culbertson, Patel, Hashem, Jacob, Edelstein & Choueka, 2014; Karatas, Kutluk, Akyuz, Karaahmet & Yalcin, 2020). It is reported by Patel et al. (2012) that approximately 80% of CTS patients complained of waking up at night from experiencing paresthesia of the wrist. It is supported by Karatas et al. (2020) who also reported that bilateral CTS patients in their findings also showed significantly higher results of waking at night especially in mild to moderate cases. This showed that it is indeed the symptoms that are disturbing and affecting the patient's sleeping quality.

According to the study by Karatas et al. (2020), some CTS patients are reported to change their sleeping position at night which they find comfortable and less painful in the wrist. In addition, McCabe et al. (2007) and Patel et al. (2014) suggested that malposition of the wrist can increase within the carpal tunnel and trigger the CTS symptoms during sleep. However, even though many studies noted that nocturnal paresthesia are characterized as one of the CTS symptoms (McCabe et al., 2007; Wahab et al. 2017; Boyd et al., 2021), there are still fewer studies that take sleep management such as altering sleeping position as the possible management to reduce the symptoms in CTS patients besides other common management such as physical therapy, medication and surgery (Patel et al., 2014).

The purpose of the study is to find the relevant relationship between a sleeping position with median nerve compression in the carpal tunnel. This is because, most of the research papers are studied about the effect of CTS symptoms on sleep disturbance and sleep quality (Patel et al., 2012; Patel et al., 2014; Karatas et al., 2020). However, there is very little evidence that taking the sleeping position is the causative factor that triggers CTS symptoms at night or as possible management in reducing the symptoms.

METHODOLOGY AND STATISTICAL ANALYSIS

This research study was conducted by systematically reviewing the previously published research papers that mainly focused on sleeping positions in CTS patients. According to Aromataris and Pearson (2014), the goal of systematic reviews is to present a thorough, objective synthesis of numerous pertinent studies in a single document (as cited in Lockwood & Oh, 2017). In this project, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were used as the guideline to extract the data and produce a good report writing systematically. PRISMA guidelines provide 4 steps in the selection of published articles which include; identification, screening, eligibility and included studies (Figure 3.1).

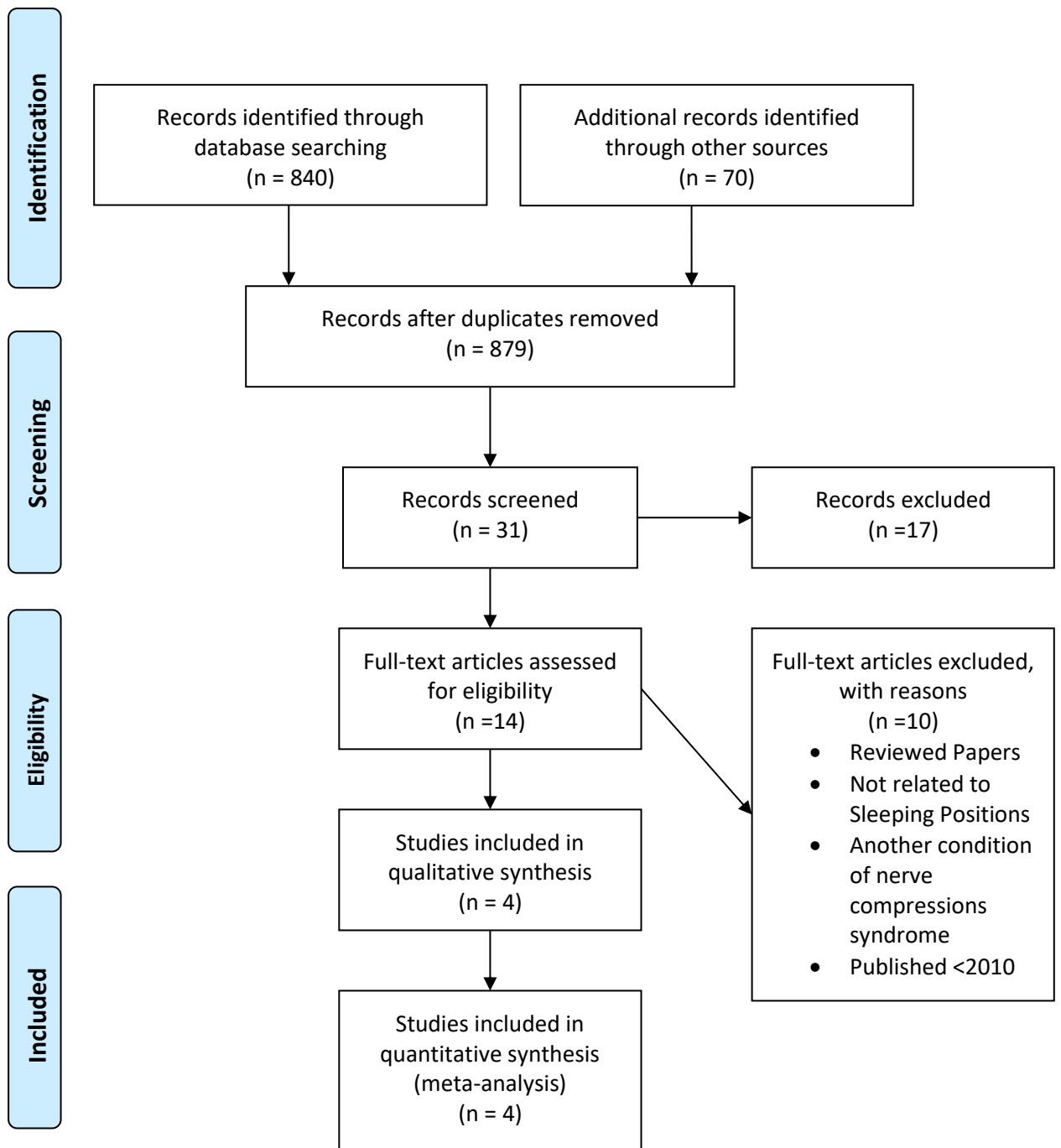


Figure 3.1 PRISMA Flow Diagram

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group*. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*, 151(4), 264-269. <https://doi.org/10.7326/0003-4819-151-4-200908180-00135>

IDENTIFICATION

Online databases were used in the process of identifying and searching for the literature related to the topics. Online databases that were used to access the articles are PubMed, and Science Direct. Besides, other sources such as Google Scholar also is used to search the articles. During the article searching process, the Boolean Operators which are simple words like ‘AND’, ‘OR’, and ‘NOT’ were used in the combining words. The specific keywords used during the searching process in the study are “Carpal Tunnel Syndrome” AND “Sleeping Position” AND “Median Nerve Compression” OR “Median Nerve Entrapment” AND “Night Paresthesia” OR “Nocturnal Paresthesia”. The number of the studies or articles found in the online databases and other sources were recorded to be screened.

SCREENING

The compilation of the selected studies is then screened to check for any irrelevant, duplication or redundancy of the articles. The articles were screened through the title and abstract to identify the correlation with the research objectives and research questions. Any irrelevant articles that did not meet the study objectives and research questions are excluded from the study. The remaining article that is relevant to the study objective and research question was to be reviewed and filtered by inclusion and exclusion criteria (Table 3.1). The reasons for the excluded articles were noted and the number of finalized articles was recorded.

Inclusion Criteria	Exclusion Criteria
Full-text articles	Non-assessable to full-text articles
Published within 2010-2022	Published < 2010
English language text	Non-English language text
Research studies	Reviewed articles
CTS patients with night paresthesia	Another peripheral nerve compression syndrome
Related to sleeping positions	Related to sleep disturbance or sleep quality

Table 3.1 List of inclusion and exclusion criteria

ELIGIBILITY

After the screening process, the selected articles were then evaluated to identify the eligibility of the research paper based on PICOS criteria (Population, Intervention, Comparison, Outcome and Study). According to Jain and Sharma (2016), PICOS criteria is an effective framework for reporting clinical characteristics, disease, intervention methods and group comparison. Any articles that meet the PICOS criteria will be finalized and included as review articles. The PICOS criteria are shown in (Table 3.2) below. A flow chart as shown in (Figure 3.2) is the process used to assess and select the relevant articles throughout the eligibility phase.

Population	Adult patients with Carpal Tunnel Syndrome (CTS)
Intervention	Preferred sleeping position that eases the symptoms
Comparison	Sleeping position that triggered the symptoms
Outcomes	Any reliable and valid outcome measures used to measure sleep and CTS symptoms
Study	Any experimental study related to CTS and sleeping position

Table 3.2 PICOS Criteria

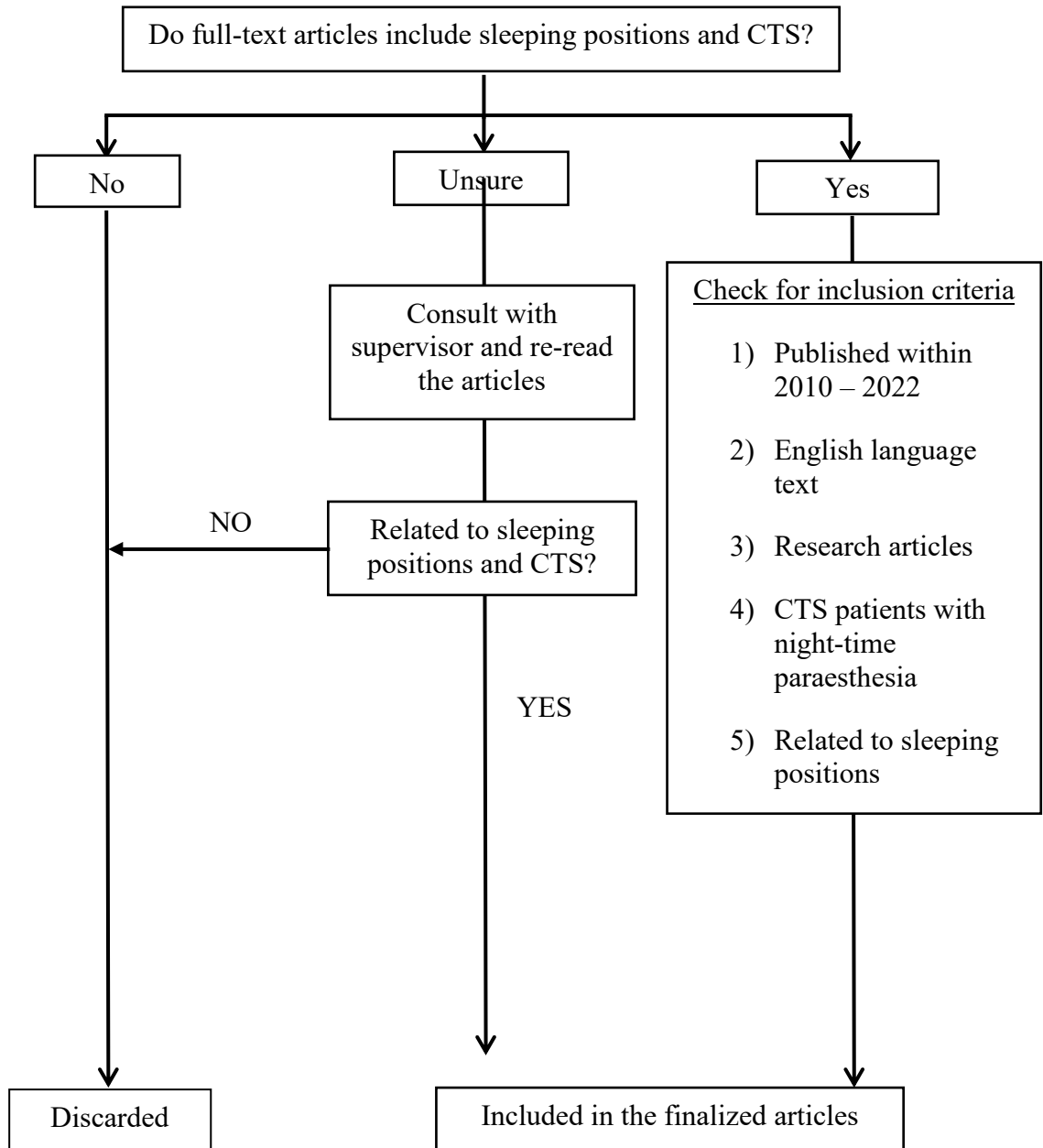


Figure 3.2 Flow chart of eligibility assessment

QUALITY OF ASSESSMENT

Critical appraisal is a structured method of evaluating research so that decisions can be made using the best evidence available (Crowe, Sheppard & Campbell, 2012). Hence, in this study, the quality of the finalized selected research paper is assessed by using the Crowe Critical Appraisal Tool (CCAT). In the CCAT checklist form, there are eight categories to be assessed which include preliminaries, introduction, design, sampling, data collection, ethical matters, results and discussion. Furthermore, Nicoll, MacRury, Woerden and Smyth (2018) stated that instead of focusing only on the overall study score, the CCAT highlights the value of measuring and documenting results for each of the areas. According to Crowe et al. (2011), CCAT was more reliable appraisal tools compared to informal appraisal of the research papers. Besides, CCAT assists researchers to analyze research papers more systematically and efficiently.

REPORTING RESULTS

The data from the selected relevant articles were presented in the form of a table adapted based on the Guidelines of Systematic Reviews by the American Occupational Therapy Association (AOTA), updated in December 2020. The data included in the table are the author and year of publication, title, study design, CCAT score, patients (number and inclusion criteria), results and outcomes of the studies.

RESULTS

STUDY SELECTION

This systematic review collected the articles from online databases such as PubMed ($n = 11$) and ScienceDirect ($n = 829$) which initially provided ($n = 840$) total number of articles. Besides, in other sources such as Google scholar, it yielded ($n = 70$) number of references. Hence, the subtotal of the overall identified studies was ($n = 910$) and ($n = 879$) of duplications were removed. Only ($n = 31$) articles are proceeded for screening through titles and abstract and ($n = 17$) articles were excluded with reasoning. The remaining articles were evaluated according inclusion and exclusion criteria as shown in (Table 3.1). From ($n = 14$) articles, only four articles that meet the inclusion criteria and were finalized to be included in the systematic review and the remaining articles were discarded.

STUDY CHARACTERISTICS

This study included a total of four articles that meet the inclusion criteria. The study design used in three out of four articles are cross-sectional study (Betlach et al., 2019; Iranmanesh et al., 2015; McCabe and Xue, 2010) while another remaining article used case-control study design (McCabe et al. 2011). All the articles included mainly studied the association of the preferred sleeping position in patients with CTS. (Table 4.1) listed the summary of the participants with inclusion criteria, main results, outcome measures and limitation of the included studies.

Table 4.1 Characteristics of the included studies

Author/Year Titles	Study design CCAT Score	Participants Inclusion Criteria	Main Results	Outcome Measures	Study Limitation
Betlach et al. (2019) Preferences in Sleep Position Correlate with Nighttime Paresthesias in Healthy People Without Carpal Tunnel Syndrome	Cross-sectional study 88%	<i>Participants</i> N = 396 <i>Inclusion criteria</i> Healthy Volunteers (above 23 years old) Patient populations Young adult population	<i>Significant findings</i> <i>a) Demographics</i> 1) Participants older than age 40 years are significantly frequent in experiencing nocturnal paresthesia (n = 33, 20.2%) compared to the age below than 21 years (n = 7, 5.0%) *Clinical insomnia is more likely to exhibit in those who frequently experience nocturnal paresthesia <i>b) Logistic Regression Analysis</i> 1) Frequently self-reported of nocturnal paresthesia were significantly associated with	<i>Insomnia Severity Index</i>	<i>Study Limitations</i> Limited evidence regarding sleep position as a potential cause of CTS Multifactorial disease using self-reported survey are not properly studied Lack of accuracy of the model that indicating potential risk factors for nighttime paresthesia in the survey Lack in assessing the relationship between the risk factors

BMI ($P < .001$) and diagnosis of CTS ($P = 0.001$) compared to those who reported of rare occurrence of the symptoms

2) Frequent nocturnal paresthesia is significantly associated with the wrist in a flexed position during sleeping ($P = 0.03$)

3) Reduce in nighttime paresthesia is significantly associated with sleeping position specifically on lateral side sleeping ($P = 0.003$)

c) Subgroup Analysis

1) Nighttime paresthesia is reportedly less significant in young adults below 21 years that preferred sleeping with straight wrist position compared to other preferred wrist positions ($P = 0.015$)

2) Increasing in nighttime paresthesia is significantly associated with young adults above 21 years old without

			<p>CTS diagnosis and with increase in BMI (P = 0.002)</p> <p>3) There is a significantly less frequent event of nocturnal paresthesia that associated with sleeping in wrist straight position (P = 0.016)</p> <p><i>Non-significant findings</i></p> <p>1) No significant association noted between preference of sleeping position and frequency of nocturnal paresthesia or with gender and BMI</p> <p><i>Other Findings:</i></p> <p>1) Increasing age in the study population, increasing preference in sleep only on the lateral position (P = 0.003)</p>		
Iranmanesh et al. (2015)	Cross-sectional study	<p><i>Participants</i></p> <p>N = 540 (two groups)</p> <p><i>Inclusion criteria</i></p> <p>n = 220 (patients)</p> <p>1) Patients with</p>	<p><i>Significant findings</i></p> <p>1) Frequency of sleeping positions is significantly less in patients compared to control groups (P = 0.04)</p>	<p><i>Electromyography</i></p> <p>(used to confirmed CTS diagnosis for inclusion criteria)</p>	<p><i>Study Limitation</i></p> <p>Lack of case-control studies conducted related to sleeping positions and CTS</p> <p>Not include snoring as potential sleep disorder</p>

syndrome	85%	<p>unidentified cause of CTS</p> <p>2) BMI < 30</p> <p>3) Able to identify sleeping positions</p> <p>4) Does not have any sleeping disorder</p> <p>5) Not an alcohol or drugs addict</p> <p><i>n</i> = 320 (control)</p> <p>1) Healthy participants</p> <p>2) Patients' relatives</p> <p>3) Same age and sex with the patients</p>	<p>2) Right side CTS is significantly associated with sleeping positions compared to the left side CTS (P = 0.0001)</p> <p><i>Non-significant findings</i></p> <p>1) Age and sex between two groups showed no significant difference</p> <p>2) Severity of CTS has no significant association with sleep position (P = 0.07)</p> <p><i>Other Findings</i></p> <p>1) Prevalence of CTS is significantly higher in lateral side sleeping compared to other sleeping positions</p>
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McCabe et al. (2011)	Case-control study	<p><i>Participants</i></p> <p>N = 206 (two groups stratified by age, gender and controlled BMI)</p> <p><i>Inclusion Criteria</i></p> <p><i>n</i> = 68 (patients)</p> <p>1) Patient who had</p>	<p><i>Significant findings</i></p> <p>1) A significantly difference showed in men with CTS preferred side sleeping compared to control population (28.6%; P<0.001)</p> <p>2) Women patients under age 60 years old significantly</p>	<p><i>Katz-Stirrat Hand Diagram</i></p> <p><i>CTS-6 probability instrument</i> (reported by Graham, 2008)</p> <p><i>CTS disease-specific symptom severity</i></p>	<p><i>Study Limitation</i></p> <p>1) Small sample size</p> <p>2) Not include work attribution of CTS</p>
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	<p>hand diagram score of “classic” or “probable”</p> <p>2) Patient with complaint of numbness and tingling sensation of the hands mainly due to CTS</p> <p>3) Have information gathered about sleep position before diagnosis and patient entry</p> <p>4) CTS cases that are not caused by the anatomic factor</p> <p><i>n = 138 (control)</i></p> <p>1) Patients from previous (2010) cross-sectional survey</p> <p>2) Patients reported had no history of waking at night due to paresthesia</p>	<p>showed higher preference in side sleeping compared to participants without CTS (OR = 8.7, 95% CI 1.9-39.4, P = 0.05)</p> <p>3) Women under age 60 years who preferred side sleeping were still showed a significant association to CTS after BMI adjustment (OR = 8.0, 95% CI 1.7-37.7, P = 0.016)</p> <p>*The association between CTS and lateral side sleeping remained significant with change of women age to 63 years and below</p> <p><i>Non-significant findings</i></p> <p>1) There were no significant showed between presence of CTS and BMI in men</p> <p><i>Other findings</i></p> <p><i>Control Populations</i></p> <p>1) Patients with no nocturnal paresthesia who preferred side sleeping (59.7%) were significantly less than</p>	<p><i>score</i> (revised by Atroshi et al., 2007)</p>
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		3) Had selected preferred sleeping position from previous survey (2010)	patients with nighttime paresthesia who preferred side sleeping (75.7%) *The lateral side sleeping had a strong association with presence of CTS especially in men and women under age 60 years old		
McCabe and Xue (2010)	Cross-sectional survey	<i>Participants</i> N = 247	<i>Significant findings</i> 1) Women showed higher significant in sleeping on lateral side with unadjusted OR 2.7 (P<0.001) 2) Women had significantly strong association between age and sleeping position compared to men (P<0.001)	<i>Insomnia Severity Index</i>	<i>Study Limitation</i> 1) Insufficient sample size 2) Inefficient in measuring sleep position 3) Limited in association
Evaluation of Sleep Position as a Potential Cause of Carpal Tunnel Syndrome: Preferred Sleep Position on the Side is Associated with Age and Gender.	78%	<i>Inclusion Criteria</i> 1) Primary care setting's patients (used as control group for further case-control study)	<i>Non-significant findings</i> 1) Age in men and sleeping position showed no significant association 2) No significant association showed between sleeping position and BMI 3) Lateral side sleeping and		

insomnia score had no
significant association

***Note. BMI= Body Mass Index; OR= Odd Ratio; CI= Confidence Interval*

Table 4.2 Crowe Critical Appraisal Tool (CCAT) summary

Author/Year	CCAT Category								Total score, n (%)
	Preliminaries	Introduction	Design	Sampling	Data Collection	Ethical Matters	Results	Discussions	
Betlach et al. (2019)	5	5	3	4	5	3	5	5	36 (88%)
Iranmanesh et al. (2015)	4	5	3	4	5	3	5	5	34 (85%)
McCabe et al. (2011)	4	5	4	5	4	2	5	5	34 (85%)
McCabe & Xue (2010)	3	5	3	5	4	2	4	5	31 (78%)

BIAS ASSESSMENT

This systematic review used CCAT to assess the risk of bias on the four selected articles and the scores were summarized in (Table 4.2). Most of the data that has been evaluated met the requirement in all categories in CCAT. Among all the categories, the evaluation on the Ethical Matters was the lowest average score because most of the studies do not mention providing the informed consent from the participants which secure the privacy and confidentiality of the participant, funding and conflict(s) of interest in their studies. However, all articles do obtain the ethical approval in the researcher ethics for their studies.

The Design category was the second lowest average score because it evaluated the risk of bias of the studies. Nevertheless, it is recorded that the highest average score among all the categories were both Introduction and Discussion. Generally, only one study scored the total percentage of 78% (McCabe and Xue, 2010) while the other three studies scored above 80% of the total percentage. McCabe and Xue had the lowest score in the preliminaries compared to the other articles which affect the total percentage of their articles. This is because they did not provide informative details regarding their study in the abstract evaluation in the preliminaries category. However, according to the CCAT user guidelines, the total percentage score is to prevent papers that do well overall but poorly in one or more categories from being mixed in with papers that performed well across the board.

RESULTS

This systematic review included four studies that studied the association between sleeping positions in CTS patients. According to the data that has been summarized in the (Table 4.1), it showed that mostly the studies shared the same methods of study whereby, cross-sectional study and only one study used case-control study as the study design. Based on the data collection that has been made, it can be said that the selected participants were mostly patients with CTS from young adults to the elderly and healthy participants were selected as the control group.

The outcome measure that has been used as the measuring tools varies in every article. Only two studies by Betlach et al. (2019) and McCabe & Xue. (2010) were reported to use the same outcome measure which is *Insomnia Severity Index* in their studies in measuring participants' quality of sleep. The finding also noted that most of the studies shared the same limitation whereby they had difficulty in obtaining large sample size, lack of association with possible risk factors and limited evidence explaining sleeping positions and nerve compression.

Based on the findings from the first article which is written by Betlach et al. (2019), lateral side sleeping is the most common preferred sleeping position reported in the study as it is believed that the sleeping position reduced the nighttime paresthesia that was experienced by the participants. According to the demographic data of the study, it showed a significant difference between participants that frequently experienced nighttime paresthesia with increasing age. It can be concluded that as the age increases, the frequency of the individual experiencing nighttime paresthesia increases. It also noted that the more frequent the individual experiencing nocturnal paresthesia, the more likely the clinical insomnia will present.

According to the logistic regression analysis in the articles, participants who frequently reported to experience nighttime paresthesia were significantly associated with BMI and CTS diagnosis compared to participants who reported to have less occurrence of the symptoms. Besides, in the study it is noted that the symptoms had a significant association with wrist flexion during sleeping and that it is reported to decline significantly associated with lateral side sleeping. Hence it can be concluded that sleeping with the wrist in flexion position can provoke the symptoms, while the symptoms are reduced with sleeping in lateral position.

In addition, according to the subgroup analysis in the article, the findings demonstrate that nocturnal paresthesia can affect young adults above age 21 without CTS diagnosis and with higher BMI. The study also illustrated that the symptoms had less significant association in young adults below age 21 that are also preferred sleeping with straight wrist position. Besides, it is reported to have a significantly less frequent association between sleeping with the wrist in a straight position and nocturnal paresthesia. There were no further associations recorded between the preference of sleeping position, nocturnal paresthesia, gender and BMI in the study. Hence the main report that can be concluded from the findings is, as the age increased in the study population, the preference in sleep specifically on the lateral position increased.

In the study by Iranmanesh et al. (2015) that conducted a cross sectional study, it observed two groups of participants which divide the patients with CTS and healthy participants as the control group. The findings illustrated the frequency of sleeping position in patients was less significant compared to the control group. It is also demonstrated that patients with right side CTS were more likely to be affected with sleeping positions compared to the left side CTS. The study reported no significant difference in age and gender between the two groups and the sleeping position does not affect the severity of CTS. Iranmanesh et al. (2015) also highlighted in the study that lateral side sleeping showed a significant association with the prevalence of CTS.

McCabe et al. (2011) is the only study in this review that reported to conduct a case control study that include two group of participants whereby the participants for the case group are the new patients that is reported with CTS and the control group was selected from the patients that previously reported of having no history of nighttime paresthesia from the previous survey that was conducted by McCabe and Xue (2010). Compared to other sleeping positions, lateral side sleeping has been reported to be the most preferred sleeping position by CTS patients that is severalized by both age and gender in this study. The study demonstrated a significant difference in male CTS patients where they were more preferred side sleeping compared to control population.

Besides, it is reported that female CTS patients under the age of 60 were significantly associated with side sleeping compared to the participants without CTS. It is also noted that the preference of side sleeping in women under the age of 60 remained to be significantly associated with CTS even after BMI adjustment. With the change of women's age to 63 years and below, the association between lateral side sleeping and CTS also remained significant. However, the results illustrated the contrast in men where it is noted to have no significant association between the presence of CTS and BMI. In short, the study highlighted that presence of CTS especially in men and women under age 60 years old that also experience nocturnal paresthesia had a strong association with lateral side sleeping.

Finally, according to the findings by McCabe and Xue (2010) that conducted a cross-

sectional survey study illustrated that women had a higher significant association in the lateral side sleeping and age compared to men. The non-significant findings that were presented in the study are men had no significant association with sleeping position and sleeping position had no relationship with BMI. It is also noted that lateral side sleeping had no significant association with insomnia score. To conclude, the study demonstrated that women CTS patients was more preferred sleeping in side lying and were influenced by their age compared to men.

DISCUSSION AND CONCLUSION

The findings describe the most common sleeping position in patients with CTS that also showed a significant association with age, gender and BMI of the participants. Basically, the median nerve compression in the carpal tunnel that is called CTS is the most common neuro compression in the upper extremity (Patel et al., 2014; Meyer et al., 2018). Many factors and risk factors can result in CTS. The most reported cases were noted to be mainly associated with female gender with increasing age as the common risk factor of CTS (Assmus et al., 2015; Hussain & Winterton, 2016).

The symptoms of the neuropathic pain, numbness and tingling sensation in the wrist were initially treated through conservative management to control the pain and if the symptoms worsen, it will then refer to proceed with surgical management. However, the noted symptoms of nighttime paresthesia were usually managed by wearing a night wrist splint to ease the pain and were rarely to be managed through sleeping position alteration despite the common complaint of the symptom (Wahab et al., 2017). Through the review that has been made, the findings also showed the limitation in the previous study obtaining research papers that studied in this field.

All four research papers that have been included in the systematic review specifically discussed the association of sleeping position in the CTS patients that includes other possible risk factors that may affect the symptoms and mostly was conducted through cross sectional study and only one article that conducted case-control study. Since nocturnal paresthesia has been characterized as the common symptoms of CTS, the criteria were included as the inclusion criteria in all four articles. However, only research by McCabe et al. (2011) and Betlach et al. (2019) presented in detail regarding the association between nighttime paresthesia and sleeping position.

Yet, the findings were noted to be contrast in the both articles. According to McCabe et al. (2011), patients who preferred side sleeping are more likely to report that the position provokes the symptom, while Betlach et al. (2019) presented in their findings side sleeping position was reported to reduce the symptom at night. Besides, Betlach et al. (2019) also believed in their study that the symptoms presented in young participants is due to the variables of lifestyle, ergonomics and posture. The study also hypothesized that the pressure of the median nerve in the carpal tunnel is increased with certain hand position, for instance hand-fisted position during sleeping triggered the CTS symptom.

All of the four studies showed that lateral side sleeping is the most preferred sleeping position especially as it is increased in age. However, the findings presented in the four studies had different arguments but agreed that side sleeping position is closely related with nighttime paresthesia and CTS. Three studies reported by Iranmanesh et al. (2015), McCabe et al. (2011)

and McCabe and Xue (2010) discussed the contribution of the lateral side sleeping in provoking the symptoms of CTS at night. This goes with the theory discussed by Iranmanesh et al. (2015) their study whereby, extension and flexion of the wrist increased in lateral side sleeping which then caused the compression of the median nerve in the carpal tunnel and lead to the increase of the prevalence of the cases. This is supported by McCabe et al. (2011) which also had an almost similar theory where they believed the possibility of the wrist to deviate and positioned in wrist flexion and extension when sleeping on the lateral side would eventually increase the pressure in the carpal tunnel and provoke the pain.

In contrast, Betlach et al. (2019) argued in their study that lateral side sleeping with neutral hand position resulted in less frequent event of nocturnal paresthesia but agreed that with the theory that describe wrist in flexed position during sleeping resulted in frequent nocturnal paresthesia. Furthermore, Iranmanesh et al. (2015) also noted that the severity of CTS with sleeping position had no significant association. They just conclude that sleeping position can be the possible causative factor of CTS and the theory is supported by McCabe et al. (2011) and McCabe and Xue (2010).

According to the findings from the article review, it can be synthesized that lateral side sleeping is more likely to be associated with the women population compared to male. Only studies by McCabe et al. (2011) and McCabe and Xue (2010) provide detailed description findings of the association between sleeping position and gender with the variation of age. The study by Betlach et al. (2019) reported having no relationship between preferred sleeping position and gender, while the study from Iranmanesh et al. (2015) presented, age and gender between both groups in their study had no relationship associated.

McCabe et al. (2011) discussed in their article, the occurrence of CTS cases was most likely in men and women under age 60 years old with preference of lateral side sleeping. They noted in their study, the significant association between lateral side sleeping and CTS cases with the change of women's age to 63 and below was maintained. However, they also discussed in their study that women with CTS were less preferred in lateral side sleeping compared to the control populations in the study.

In contrast, the result from the previous study by McCabe and Xue (2010) reported only women patients showed a significant difference in lateral side sleeping and had a strong influence of age in sleeping position compared to men patients. They also reported having no significant association between men and sleeping position. Nevertheless, it can be concluded that CTS patients in both genders showed the preference of sleeping on the side as the age increases despite the occurrence of the symptom nocturnal paresthesia at night. This can be theorized that lateral side sleeping as the possible factor that provoke the symptom at night

In the literature by Betlach et al. (2019), participants aged 40 years and in young adults above age 21 years without diagnosis of CTS and with increase of the BMI were reported to experience nighttime paresthesia more frequently compared to the age of 21 years and below. The possible theory that can be concluded for the young adult aged 21 years and below that experienced the symptoms was due to the occurrence of different nerve entrapment in the upper extremity that may be caused by malposition of the arm and hand at night.

From the overall review, three articles were noted to include BMI measurement as the possible variable in their studies. However, the findings were presented with different results in every

studies. Based on the previous study by McCabe and Xue (2010), the findings showed no significant difference between BMI and sleeping position. In contrast, in the study by McCabe et al. (2011) found that with BMI adjustment, women under age 60 years who preferred sleeping on the lateral side had a significant association with CTS. Betlach et al. (2019) also agreed that the symptom of nighttime paresthesia was influenced by BMI and was associated with patients with diagnosis of CTS and young adults above age 21 without diagnosis of CTS. In short, BMI may contribute as the possible variable causing the nerve entrapment in the upper extremity.

This review strongly concludes that sleeping position mainly in lateral side sleeping had a contribution in triggering CTS symptoms at night even though according to recent study by Betlach et al. (2019) lateral side sleeping is shown to ease the pain at night. However, from the overall review, it can be strongly concluded that lateral side sleeping was noted to be the most preferred sleeping position in patients with CTS either it triggered or ease the symptoms at night. Thus, this systematic review demonstrates the importance of recognizing sleeping positions as one of the possible risk factor or management to either provoke the symptoms or ease the pain in CTS patients as it is significantly associated with the symptoms of nocturnal paresthesia that has been recognized by most of the researchers as one of the common CTS symptoms (Mansuripur et al., 2013; Hussain & Winterton, 2016; Nicholls & Furness, 2019; Boyd et al., 2021).

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