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OCCUPATIONAL RISK FACTORS OF CARPAL TUNNEL SYNDROME ON WORKERS: A LITERATURE REVIEW

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ABSTRACT
The median nerve at the wrist becomes crushed in a condition known as carpal tunnel syndrome (CTS), which causes pain, numbness, and tingling in the worker's hand's palm. Risk elements for CTS include things like uncomfortable body posture at work, repetitive hand motions, and vibration exposure. Reviewing prior research on the connection between CTS and potential risk factors such worker hand posture, exposure to hand-arm vibrations, and repetitive hand movements is the goal of this study. The research approach involves searching for relevant articles using the terms carpal tunnel syndrome AND (occupational risk factors OR uncomfortable posture OR hand-arm vibrations OR repeated hand movements) in databases like ScienceDirect, PubMed, ResearchGate, and Scopus. The study indicates that Carpal Tunnel Syndrome is related to repetitive hand movements, hand-arm vibrations, and awkward hand posture during work. This research implies the importance of awareness about occupational safety. Additionally, the study suggests that job designs considering repetitive hand movements, vibrations, and incorrect posture can reduce the risk of Carpal Tunnel Syndrome. Therefore, it is hoped that organizations and workers can collaborate to create a safer, healthier, and more productive work environment.

Keywords: carpal tunnel syndrome, occupational risk factors, workers.

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INTRODUCTION

Carpal Tunnel Syndrome is a syndrome with pain or tingling (paresthesia) or numbness on the hand due to pressure conditions by the wrist flexor ligament tendons due to repetitive trauma to the median nerve in the carpal tunnel (Suma'mur, 2013). The hallmark of classic CTS is pain or paresthesia (numbness and tingling) in a distribution that includes the median nerve involving the first three fingers and the lateral half of the fourth finger (Kothari, 2022).

In essence, Carpal Tunnel Syndrome (CTS) develops due to a combination of compression and pulling mechanisms. Compression leads to increased pressure cycles, hindering venous outflow and causing local swelling. This pressure compromises the microcirculation of the median nerve. Consequently, the nerves are damaged, leading to dysfunctional myelin sheaths and axons, as well as inflammation in the surrounding tissue, diminishing their protective functions. Repetitive wrist movements worsen the condition, causing further nerve damage. Additionally, inflammation in any of the nine flexor tendons within the carpal tunnel can exert pressure on the median nerve. Typically, sensory fibers are affected before motor fibers, and even autonomic nerve fibers within the median nerve can be impacted (Sevy et al., 2022).

There are several risk factors associated with CTS. In working conditions, work using tools with great power or pressure, excessively flexed and extended hand positions and under prolonged conditions, repetitive use of flexor muscles, and exposure to vibration are some of the factors that have been reported. CTS can also result from various conditions, including inflammatory or non-inflammatory arthropathy, trauma or wrist fracture, diabetes mellitus, obesity, hypothyroidism, pregnancy, and genetic factors. (Franklin & Friedman, 2015).

As CTS progresses, symptoms may also be felt while awake, especially during activities that require sustained arm positioning or repetitive movements. In some cases, there is progression from intermittent to persistent sensory complaints and from paresthesia to sensory loss in the hands. Permanent sensory loss is usually a late finding characterized by a characteristic clinical pattern that can be felt by the pain of the fingers connected to the median nerve, pain in the hand or arm, especially at night or when working, weakness and wasting of the thenar eminence muscles, loss of sensation in hand in the median nerve, which runs from your forearm into the palm, tingling in the palms that are distributed to the median nerve, this condition is often bilateral (Ginsberg, 2010; Kothari, 2022; Salawati & Syahrul, 2014).

Therefore, this systematic review aimed to review the existing literature to determine the role of occupational risk factors and summarize the available data on risk factors to know how the risk could contribute to CTS based on the newest research.

METHOD

The journal databases used are ScienceDirect, PubMed, ResearchGate, and Scopus. The keywords used in the search are occupational risk factors and carpal tunnel syndrome. Reviewers select research based on the title, abstract, and article. The inclusion criteria in the literature review conducted were: 1) Scientific articles written in English; 2) Articles published in journals and proceedings; 3) Articles published in 2019-2023; 4) The eligibility of articles will also be determined if they contain any or all of the variables: awkward posture of the hand, repetitive hand movements, and vibration from the machine used by the hand; 4) The research was conducted using cross-sectional, cohort, case-control, and experimental studies on work-related risk factors that can cause Carpal Tunnel Syndrome.

Exclusion criteria include: 1) Not fully accessible; 2) in the form of a literature review; 3) If the variable of occupational risk factors for CTS is intervened with other variables besides the risk factors previously mentioned and exposure time while working. Suppose the keyword occupational risk factors used is not found in the journal on the portal used. In that case, the keywords will be assisted with awkward posture, hand-arm vibration, OR repetitive hand movements.

Articles taken based on the conditions met, among deviation) study period, the year of publication, the research design and research method, the research area, and the association between occupational risk factors (repetitive movement, vibration exposure, hand posture (flexion, extension, radial or ulnar deviation)), and CTS. The entire review was carried out in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines statements. The relevant PRISMA flowchart, which summarizes the outcomes of this methodology, is shown in Figure 1.

RESULTS AND DISCUSSION

The research included in this study included nine articles from The United States, Sweden, France, Denmark, Botswana, Pakistan, and Finland with different types of work. Initially, we reviewed the titles and abstracts of articles featured in each database used for this review; duplicate papers in the database were identified, and selection criteria were established with the following criteria: 1) Throughout the review of titles and abstracts, we retained papers regarding CTS and risk factors of interest, such as repetitive hand movements, exposure to hand-arm vibrations, and awkward hand postures. 2) Articles written in languages other than English will be rejected. After we selected works that met the predetermined criteria, we carried out a full review of each work. We classified them based on risk factors based on the work on CTS and then included them in this study. Figure 1 shows the flowchart of this literature review screening steps.

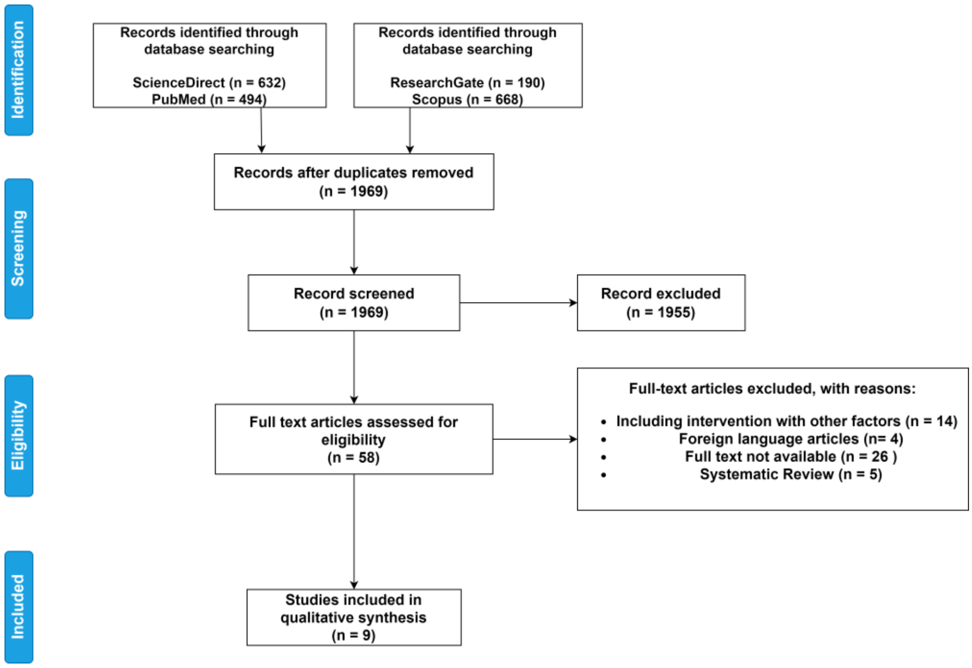

Figure 1. Systematic Review Flowchart

Based on a bibliographical search using the ScienceDirect, PubMed, ResearchGate, and Scopus databases, 632, 494, 190, and 668 articles were found for a total of 1984 research papers. Furthermore, 15 articles were identified as duplicates, bringing the total to 1969 articles after duplicates were removed. We thoroughly reviewed the remaining 58 articles following the previously described criteria. According to the criteria, we rejected 14 articles because they were related to CTS factors other than those examined in this study, for example, the Body Mass Index, hypertension, smoking, socio-demographic, and psychosocial. Furthermore, there are four articles with full text in a foreign language, 26 cannot be accessed for the full text, and five are systematic reviews. Lastly, nine articles were eligible for the literature review.

Table 1. List of selected Studies

Author (Years)	Study Design	Population	Method	Result
(Harris Adamson et al., 2022)	Prospective cohort study	372 workers with a prevalence or incidence of CTS were followed for up to 6.4 years	Exposure was assessed by observation and measurement of force using Borg CR-10, repetition using Hand Activity Level scale, hand posture using % time =30° wrist flexion and extension, and 2018 ACGIH TLV for hand activity. Hazard Ratios were estimated using Cox models.	In the upper tertile of the Hand Activity Level Scale, there was a nearly doubling of the risk for job change (HR 2.17; 95% CI 1.17-4.01), a total hand repetition rate of 1.75 (95% CI 1.02-3.02), a percentage of time spent in all hand exertions of 2.20 (95% CI 1.21-4.01), and a sixfold increase for high job strain.
(Vihlborg et al., 2022)	Case-control study	Four thousand three hundred ninety-six cases of CTS were obtained from the National Outpatient Register of Sweden.	For each employment, the daily 8-hour equivalent vibration level (A(8)) for hand-arm vibration exposure was determined. Logistic regression was used to examine the data.	HAV exposure raised the likelihood of CTS by 1.61 OR (95% CI: 1.46-1.77). With a mean year exposure above 2.5 m/s2, the risk increased to OR 1.84 (95% CI 1.38-2.46).
(Roquelaure, Jégo, et al., 2020)	Prospective Study	1367 workers as participants (804 men and 563 women)	With Borg's rating of perceived exertion, wrist bending, pinching, and hand-transmitted vibrations, biomechanical risk factors are evaluated. To investigate the connections between incident CTS cases, use structural equation modeling (SEM).	Symptomatic CTS risk was directly increased by biomechanical factors (exertion, wrist bending, pinching, and hand-transmitted vibration) (standardized coefficient = 0.19; P=0.011).
(Maghsoudipour et al., 2021)	cross-sectional study	106 dentists from dental schools in Tehran	The amount of vibration exposure (hour/day) was measured. To confirm the diagnosis of CTS, a nerve conduction velocity (NCV) test	Vibration exposure greater than two hours per day (OR: 2.5) was a significant

Author (Years)	Study Design	Population	Method	Result
			was performed. Using an independent T-test and logistic regressions, the analysis was carried out.	risk factor for CTS among dentists.
(Ijaz et al., 2023)	cross-sectional study	150 workers a subject	The self-designed questionnaire was used to know the subject's demographic, working hours and experience, and type of work (e.g., drilling, cutting, vibration, and carrying loads).	Types of work (p-value = 0.04) and type of activity (p-value = < 0.01) showed a significant association with CTS prevalence in workers.
(Erick et al., 2021)	cross-sectional study	184 hairstylists randomly selected hair salons in Gaborone, Botswana	The participant's psychosocial and physical work demands on hairstylists and awkward postures, such as prolonged and repetitive wrist flexion, extension, radial and ulnar deviation, abnormal patterns of wrist movements, firm grasping, repetitive use of the hand, use of handheld tools that vibrate, or positions that put pressure on the wrist, were assessed using an anonymous self-administered questionnaire. Then, Chi-Square and logistic regression models were used to analyze the data.	Awkward CTS symptoms were associated with posture (OR 2.52, 95% CI: 1.03–6.19) and great muscular effort when performing a task (OR 2.39, 95% CI: 1.01–5.72).
Lund et al.,(2019)	Cohort study	Employees who experienced hand vibrations (with a hazard ratio of 2.29 and a 95% confidence interval of 1.48–3.54) and individuals engaged in physically demanding occupations (with a hazard ratio of 1.71 and a	Thirty different jobs, including office work, childcare, laundry work, and slaughterhouse work, had their wrist movements measured electrogoniometrically. We calculated the mean power frequency (MPF), range of motion (ROM), and wrist angular velocity. The risk of CTS by quintiles of preceding exposure levels was assessed by adjusted incidence rate ratios (IRR^{adj}) using Poisson regression models.	Exposure–response association between wrist angular velocity and CTS with an IRR^{adj} of 2.31 (95% CI 2.09 to 2.56) when exposed to the highest level compared with the lowest. MPF also showed an exposure–response pattern, although less clear, with an IRR^{adj} of 1.83 (1.68

Author (Years)	Study Design	Population	Method	Result
		confidence interval of 1.06–2.76) faced a higher likelihood of being hospitalized due to Carpal Tunnel Syndrome (CTS).		to 1.98) for the highest compared with the lowest exposure level.
(Hulkkonen et al., 2020)	Cohort study	6326 workers as respondents from the Northern Finland Birth Cohort of 1966 who attended the 31-year follow-up in 1997	The study evaluated the relationship between background characteristics, occupational and physical factors, and hospitalization for Carpal Tunnel Syndrome (CTS) using the univariable Cox proportional hazards regression model. Subsequently, variables that remained significant in sex-specific analyses or analyses combining both sexes and were adjusted for sex were incorporated into the multivariable Cox proportional hazards regression models.	Employees who experienced hand vibrations (with a hazard ratio of 2.29 and a 95% confidence interval of 1.48–3.54) and individuals engaged in physically demanding occupations (with a hazard ratio of 1.71 and a confidence interval of 1.06–2.76) faced a higher likelihood of being hospitalized due to Carpal Tunnel Syndrome (CTS).
(Roquelaure, Jégo, et al., 2020)	Cross-sectional	Seven hundred eleven men aged 30-65 years old and working as either farmers or agricultural workers in 2009-2010 within a cohort covered by the French Agricultural Workers' and Farmers' Mutual Benefit Fund.	Using a self-administered questionnaire, CTS and exposure to chemical and physical wrist stressors were evaluated. Using multivariate logistic regression models, associations between CTS and personal/medical factors, exposure to physical wrist stressors, exposure to chemicals, and co-exposure to physical wrist stressors and chemicals were investigated.	CTS was associated with exposure to physical wrist stressors [OR = 2.6 (1.1-5.9)].

Finally, nine articles were grouped according to the factors stipulated for this review, i.e., hand repetitive movement, hand-arm vibration, and awkward hand posture. Several articles address occupational risk factors together (i.e., biomechanical factors and wrist angular velocity) and have results related to CTS also included. Based on the study reviewed, Table 1 shows two kinds of literature have significant results for hand repetitive movement association with CTS; five kinds of literature have found an association between hand tools vibration and CTS, and four kinds of literature found an association between awkward hand posture when working with CTS.

Hand Repetitive Movement

In the studies that have been reviewed, repetitive hand movements are associated with the appearance of CTS complaints in workers (Harris Adamson et al., 2022). Repetitive or repetitive movements are a series of movements that have little variation and are performed every few seconds, which can result in muscle fatigue and tension (Sekarsari et al., 2017). Jobs that include highly repetitive motions are hairdressers, which were discussed in the research conducted by Erick et al. One of the occupational groups that may be more susceptible to CTS is hairdressers. A hairdresser's duties may also occasionally include planting, twisting, and styling dreadlocks. Other duties include braiding, washing, and drying the client's hair. These tasks entail jerky or repetitive hand motions (Erick et al., 2021).

Repeated wrist movements will cause friction on the tissues in the wrist, which can cause injury. This wound can become scar tissue (scar tissue) as part of the tissue healing process on the wrist. The volume of scar tissue increases at the wrist and can compress the median nerve (Daniels, 2014). Thick scar tissue will form around the median nerve, which can result in nerve pulling (Aboonq, 2015). Inflammatory thickening of the synovial tissue increases tissue volume, increasing fluid pressure within the carpal tunnel. The increased carpal tunnel pressure will, in turn, put pressure on the median nerve, leading to poor blood circulation. Over time, ischemia eventually leads to long-term effects such as irreversible damage to flexor synovial cells and median nerve synovial thickening, with further severity of median nerve fibrosis and demyelination and can lead to CTS (Riccò & Signorelli, 2017).

Hand-Arm Vibration

Exposure to hand vibration is a risk factor for CTS. Direct vibration of the hand or the use of a vibrating handheld device will impact increasing muscle contractions. Vibration can also cause mechanical abrasion of the tendon sheaths neurological and circulatory disorders. Vibration can directly injure peripheral nerves, nerve endings, and mechanical receptors and cause symptoms of numbness, tingling, pain, and loss of sensitivity. The vibrations can immediately affect the digital arteries (Mallapiang & Wahyudi, 2015). Research on dentists conducted by Maghsoudipour et al. (Maghsoudipour et al., 2021) shows that the risk of CTS increases the longer a person is exposed to the vibration of the machine used or what is commonly called Hand Arm Vibration. According to previous studies, carpal tunnel syndrome is the most common self-reported musculoskeletal disorder among dentists (de Jesus Júnior et al., 2018).

The review also found other articles that stated that hand-arm vibration also increased the prevalence of CTS among workers in Sweden (Vihlborg et al., 2022). This cohort study found that Exposure to HAV increased the risk of CTS with an OR of 1.61 (95% CI 1.46–1.77). The risk increased with a mean year exposure above 2.5 m/s^2 to OR 1.84 (95% CI 1.38– 2.46). Vibration above 2.5 m/s^2 based on regulations includes Exposure action value, which means the level of daily vibration exposure to HAV for a worker above which steps should be taken to minimize exposure (The Control of Vibration at Work Regulations, 2005). Workers exposed to vibration in Northern Finland also had complaints of CTS (HR 2.29, 95% CI 1.48–3.54). Furthermore, research conducted by (Ijaz et al., 2023) found that workers in marble factories who use drilling cutting tools and other vibrating hand tools and carry out high-force activities significantly correlate with the incidence of CTS. These types of work can cause compression of the median nerve and can cause complaints of CTS. Exposure to HAV is also associated with concomitant exposure to various ergonomic factors, such as static load and high force grip on tools, which themselves increase the risk of CTS (Aroori & Spence, 2008)(van Rijn et al., 2009). Van Rijn et al. discovered similar research, claiming that repetitive work (cycle time 50% of cycle time performing the same movements) and hand-arm vibration daily 8-hour energy-equivalent frequency-weighted acceleration of 3.9 m/s2 compared to the action value of 2.5 m/s2 described in the ACGIH on hand-arm vibration are all associated with CTS (ACGIH, 2021).

Awkward Hand Posture

Farmers and agricultural workers who are respondents to research conducted by Roquelaure et al. (Roquelaure, Jégo, et al., 2020) are subjected to a variety of physical wrist stressors at work, such as awkward wrist postures, repetitive motions, and manual handling of loads, which increases the pressure in the carpal tunnel. The position of the wrist and the pressure experienced when doing work or using equipment are co-factors contributing to CTS's emergence. The longer the wrist position is awkward, the higher the risk of developing CTS (Sekarsari et al., 2017). Research on other subjects also conducted by Roquelaure et al. (Roquelaure, Garlantézec, et al., 2020) showed that exposure to biomechanical risk factors, such as high perceived workload, hand-transmitted vibration, and repetitive/sustained wrist bending and pinching directly increased the risk of CTS.

The same result was found in research conducted by Erick et al. (2021), which claims that hairstylists adopt awkward postures while performing these tasks, particularly when using a lot of movement. When performing a task, awkward posture and fluid movements were positively linked to a higher risk of developing CTS. However, most patients reported mild symptoms of CTS and its mild interference with daily activities. Other factors that were discovered to contribute to the development of CTS symptoms included hair washing, an awkward posture, a great deal of muscular effort when performing a task, and stressful work.

The results of these studies can be supported by the research conducted by Keir et al. (1997, 1998), who reported that extreme wrist extension or flexion can put a lot of pressure on the carpal tunnel, damaging the median nerve. This physiological evidence backs up the theory that persistent awkward wrist postures in workers can cause CTS. High repetition of a hand doing flexion or extension increased the occurrence of CTS (van Rijn et al., 2009).

CONCLUSION

Various professions in this world come with risk factors associated with their tasks. Especially those arising from exposure to work activities that can lead to occupational diseases, one of which is Carpal Tunnel Syndrome. Research indicates that Carpal Tunnel Syndrome is linked to repetitive hand movements, hand-arm vibrations, and awkward hand postures during work. The exposure in this context involves repetitive hand motions, prolonged awkward body postures, and the use of vibrating tools, all of which are associated with an increased risk of CTS in workers. Monitoring the handheld vibrating tools used by workers and evaluating hand postures and the intensity of repetitive movements during working hours is necessary to reduce pain complaints and maintain workers' productivity.

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