

Carpal Tunnel Syndrome and Associated Factors Among Workers in Blacksmithing Industry in Java, Indonesia

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Abstract

Introduction: Carpal Tunnel Syndrome (CTS) is one of the most common work-related musculoskeletal disorders, particularly in the informal sector such as traditional blacksmithing industries.

Objective: This study aims to determine the prevalence and associated factors of CTS among blacksmith workers in Mekarmaju Village, Bandung Regency.

Methods: Using a cross-sectional design, data were collected from 100 male workers through questionnaires, work observations, and physical examinations (Phalen and Tinel tests).

Result: The results showed a CTS prevalence of 68%, with the majority of cases being bilateral. Bivariate analysis revealed several factors associated with CTS, including body mass index, age, dominant hand, and type of work. However, multivariate analysis identified only work duration (>3 years) as a significantly associated factor (aOR = 0.03; 95% CI: 0.01–0.92; p = 0.045), indicating that newer workers are more vulnerable to CTS.

Conclusion: These findings highlight the importance of early ergonomic interventions and health screening at the beginning of employment to prevent CTS in the informal labor sector.

Keywords: Carpal Tunnel Syndrome, blacksmith workers, work duration, occupational risk factors, ergonomics

Abstrak

Latar belakang: Sindrom Lorong Karpal adalah salah satu gangguan muskuloskeletal terkait pekerjaan yang paling umum, terutama di sektor informal seperti industri pandai besi tradisional.

Tujuan: Penelitian ini bertujuan untuk menentukan prevalensi dan faktor-faktor terkait STK di kalangan pekerja pandai besi di Desa Mekarmaju, Kabupaten Bandung.

Metode: Menggunakan desain cross-sectional, data dikumpulkan dari 100 pekerja laki-laki melalui kuesioner, observasi kerja, dan pemeriksaan fisik (tes Phalen dan Tinel). Sindrom ini menyebabkan kondisi mati rasa, kesemutan, nyeri, atau lemah di tangan akibat saraf median tertekan saat melintasi terowongan karpal.

Hasil: Prevalensi sindrom menunjukkan sebesar 68%, dengan mayoritas kasus bersifat bilateral. Analisis bivariat mengungkapkan beberapa faktor terkait, termasuk indeks massa tubuh, usia, tangan dominan, dan jenis pekerjaan. Namun, analisis multivariat hanya mengidentifikasi durasi kerja (>3 tahun) sebagai faktor yang terkait secara signifikan (aOR = 0,03; 95% CI: 0,01–0,92; p = 0,045), menunjukkan bahwa pekerja yang lebih baru lebih rentan terhadap sindrom ini.

Kesimpulan: Temuan ini menyoroti pentingnya intervensi ergonomis dini dan pemeriksaan kesehatan di awal masa kerja untuk mencegah sindrom ini di sektor pekerja informal.

Kata kunci: Sindrom Lorong Karpal, pekerja pandai besi, durasi kerja, faktor risiko pekerjaan, ergonomi

Introduction

Occupational diseases are one of the major issues in occupational health, significantly impacting workers, companies, and the state.^{1,2} These conditions arise as a result of exposure to various risk factors present in the workplace, such as non-ergonomic working postures, exposure to chemicals, vibrations, or prolonged repetitive activities.^{3,4,5} The International Labour Organization (ILO) also reports that there are 160 million non-fatal work-related disease cases occurring annually. Occupational diseases also cause enormous economic losses, including lost working hours, decreased productivity, and increased healthcare costs. The ILO estimates that the total economic loss caused by occupational diseases and workplace accidents can reach around 4% of the global Gross Domestic Product (GDP) each year.⁶⁻⁸

Typical symptoms of CTS include tingling, numbness, pain, and weakness in the thumb, index finger, middle finger, and part of the ring finger. ILO data from 2013 reported a CTS prevalence of 9% among female workers and 6% among male workers in Europe (International Labour Organization, 2013).⁹ In Asia, a study conducted in South Korea from 2008 to 2015 using National Health and Employment Insurance data revealed that foundry and blacksmith workers had a CTS incidence rate of 8,362 per 100,000 workers.¹⁰ In Indonesia, local studies have reported CTS prevalence rates of 82% among food packers in Karanganyar, 77% among garment workers in Denpasar, and 64.1% among stone breakers in Southeast Sulawesi.^{11,12}

Mekarmaju Village, Bandung Regency, is known as a center for traditional blacksmithing that produces various agricultural tools and metal equipment. The work processes in this village are still performed manually, with workers engaging in heavy physical activities such as forging, grinding, and assembling tool handles repetitively in non-ergonomic body positions. A lack of attention to occupational health and the unavailability of proper personal protective equipment further compound the work risks in this informal sector.

A preliminary survey conducted between August and September 2024 among 309 blacksmith workers in Mekarmaju Village found that 57.6% reported wrist pain and tingling after work, indicating potential CTS symptoms. A follow-up study using the Boston

Carpal Tunnel Questionnaire (BCTQ) on 30 selected respondents showed that 70% experienced mild CTS, 16% moderate CTS, and 14% exhibited no symptoms. These results highlight the need for further investigation into specific risk factors within the work environment.

Limited oversight in terms of regulations and occupational health in informal sectors like this increases the risk of workers suffering from persistent musculoskeletal disorders. Therefore, this study aims to determine the prevalence of CTS and identify individual and occupational factors associated with CTS among blacksmith workers in Mekarmaju Village. The results of this study are expected to form the basis for ergonomic interventions and preventive policy recommendations to improve occupational health in the informal sector.

Methods

This study employed an observational analytic design with a cross-sectional approach, conducted in Mekarmaju Village, Bandung Regency, from November 2024 to April 2025. The study subjects were 100 male blacksmith workers who had been actively employed for at least 12 months and had no history of hand injuries or degenerative diseases. The sample was selected purposively based on inclusion and exclusion criteria. The inclusion criteria consisted of active blacksmiths currently working during the study period, with a minimum of 12 months of work experience in the field, male gender, and willingness to participate and provide the required data. Exclusion criteria included blacksmiths with a history of hand injuries, degenerative diseases such as osteoarthritis, rheumatoid arthritis, or diabetes mellitus, as well as those with indications of other peripheral nerve disorders, including cubital tunnel syndrome, ulnar nerve compression, or non-CTS peripheral neuropathy. Data were collected through structured questionnaires, direct observation of work activities, and physical and neurological examinations using the Phalen and Tinel tests to diagnose Carpal Tunnel Syndrome (CTS).

The variables examined included individual characteristics (age, BMI, education, dominant hand, smoking and exercise habits) and occupational factors (type of work, years of service, daily working hours, rest duration, production frequency, and ergonomic risks).

The dominant hand can be determined by asking participants which hand they mainly use for daily tasks and observing their work activities. Smoking habits are assessed through questions on smoking status, frequency, and duration, classifying participants as non-smokers, former smokers, or active smokers. Exercise habits are evaluated by asking about the type, frequency, and duration of physical activities, noting whether they involve repetitive upper limb movements or general fitness that supports muscle strength and posture. These data are primarily collected through self-reported questionnaires and interviews.

Observation instruments included the ART tool to assess repetitive movements and the BRIEF survey for wrist posture.¹³ Data analysis was performed using SPSS version 29, employing bivariate tests (Chi-Square or Fisher's Exact Test), followed by multivariate logistic regression to determine independent risk factors for CTS. This study received ethical approval from the FKUI-RSCM Ethics Committee.

Results

This study involved 100 male respondents working as blacksmiths in Mekarmaju Village, Bandung Regency. All participants met the inclusion criteria: actively working for at least 12 months and having no history of hand injuries or degenerative diseases such as diabetes mellitus, osteoarthritis, or rheumatoid arthritis. Various data collection methods were used, including structured questionnaire interviews, ergonomic observation of work activities, and physical examination using the Tinel and Phalen provocation tests to diagnose Carpal Tunnel Syndrome (CTS).

From the clinical examinations and collected data, it was found that 68 workers (68%) were diagnosed

with CTS. These findings indicate a high prevalence of CTS among informal sector workers, particularly in traditional industries that rely heavily on manual hand strength without ergonomic work principles. The 68% prevalence not only reflects high physical workload but also highlights the lack of preventive interventions such as posture training or the use of personal protective equipment.

The majority of cases of this study being bilateral, in addition to measuring prevalence, this study identified the types of CTS symptoms experienced by the respondents. The most common symptom was pain in both thumbs (35%), followed by pain radiating to the index finger (17%) and pain accompanied by tingling in fingers innervated by the median nerve. Other specific symptoms included right wrist pain extending to the thumb, and unilateral tingling in either the right or left hand. These symptoms are consistent with median nerve involvement related to the workers' repetitive movements and non-neutral wrist positions.¹⁴⁻¹⁶

Bivariate analysis was conducted to assess the relationship between independent variables and CTS occurrence. The results showed statistically significant associations for several factors, including body mass index (BMI), dominant hand, age, job type, and work duration. Workers who were overweight, right-

Table 1. Prevalence of Carpal Tunnel Syndrome (CTS)

CTS status	Frequency	Percentage (%)
Positive	68	68.0
Negative	32	32.0
Affected hand side		
Both hands (bilateral)	49	72.0
Right hand only	15	22.0
Left hand only	4	6.0

Table 2. Distribution of respondents' symptoms

Symptom	Frequency	Percentage (%)
Pain in both thumbs	35	35.0
Pain from both thumbs to index fingers	17	17.0
Pain from wrist to thumb on both hands	12	12.0
Pain in both thumbs with tingling	11	11.0
Pain from right wrist to right thumb	11	11.0
Pain in both thumbs with tingling to index fingers	10	10.0
Pain and tingling in right thumb only	4	4.0

hand dominant, or who operated grinding machines had higher risks of developing CTS. Age also showed a similar trend, with respondents over 24 years old more frequently affected than younger ones. Interestingly, those who had been working for more than three years had a higher prevalence of CTS, although a contrasting pattern appeared in multivariate analysis.

In the multivariate logistic regression analysis, only one variable maintained a statistically significant association with CTS: work duration. Workers with more than 3 years of experience had an adjusted odds

ratio (aOR) of 0.03 (95% CI: 0.01–0.92; p = 0.045), indicating that those with shorter work duration (≤ 3 years) were more vulnerable to CTS. This phenomenon may be explained by biomechanical adaptation and technique—newer workers may lack proper motor skills, are unfamiliar with correct postures, and tend to perform compensatory movements that increase pressure on the median nerve. The lack of ergonomic training for new workers is also suspected as a key contributing factor.

Table 3. Multivariate analysis results

Variable	Carpal Tunnel Syndrome		P value bivariate	OR (CI 95%)	P value multivariate	aOR (CI 95%)
	Yes	No				
BMI						
Overweight	24	5	0,043	2,95	0,060	3,51
Normal	44	27		(1,00 – 8,64)		(0,9-13,0)
Dominant hand used for work						
Right hand	41	9	0,003	0,26	0,130	0,50
Both hand	27	23		(0,10 – 0,64)		(0,29-0,86)
Ages						
> 24 year	67	26	0,002	0,065	0,748	1,75
≤ 24 year	1	6		(0,007 – 0,564)		(0,05-53,7)
Educational status						
Elementary	49	19	0,063	-	0,817	-
Junior high school	17	8				
Senior high school	2	5				
Type of job						
Grinder	26	18	0,005	7.615	0,056	2,24
Sheath and handle maker	22	2		(1,58-36,50)		(0,97-5,13)
Metal forger	20	12				
Year of service						
> 3 years	67	25	0,001	0,053	0,045	0,032
≤ 3 years	1	7		(0,006 – 0,455)		(0,01-0,92)
Repetitive motion right hand						
High	42	15	0,161	1,83	0,362	0,50
Low-medium	26	17		(0,78 – 4,28)		(0,11-2,19)
Repetitive motion left hand						
High	30	8	0,066	2,37	0,208	2,63
Low-medium	38	24				(0,58-11,8)
Non-neutral position of the right wrist						
High risk	24	6	0,092	2,36	0,379	1,74
Low-medium Risk	44	26		(0,85 – 6,54)		(0,50-5,1)

Although other variables such as BMI, job type, dominant hand, and age were statistically significant in the bivariate analysis, they did not remain significant in the regression model. This suggests that their effects may be confounded by or dependent on another variable, namely work duration. Therefore, work duration emerged as the dominant and independent factor contributing to CTS in this population.

On the other hand, work activity observations showed that most workers were in the high ergonomic risk category. Around 57% had high repetitive motion scores on the right hand, and 38% on the left. Non-neutral wrist positions were observed in 30% (right) and 38% (left). However, these ergonomic factors did not show statistically significant associations with CTS in the final model, although they remain physiologically relevant.

Overall, these findings underscore the importance of work duration as a key risk indicator for CTS. Newer workers are particularly vulnerable and require targeted interventions including ergonomic education, proper technique training, and routine health monitoring. The study also highlights the urgent need for structural interventions from business

owners and occupational health institutions to create safe and biomechanically supportive work environments in informal sectors such as blacksmithing.

Discussion

The results of this study show that the prevalence of Carpal Tunnel Syndrome (CTS) among blacksmith workers in Mekarmaju Village reached a relatively high rate of 68%. This figure indicates that more than half of the workers in the study experienced sensory and/or motor disturbances consistent with CTS symptoms. This prevalence is even higher compared to several previous studies, such as among stone breakers in Southeast Sulawesi (64.1%).¹⁷ The high prevalence is likely due to intense biomechanical exposure in the informal worker group, especially in forging and grinding activities that require hand strength, repetitive hand movements, and non-ergonomic working postures.

One of the key findings of this study was the identification of work duration as the only statistically significant factor associated with CTS in the multivariate analysis. Interestingly, the result showed

that workers with ≤ 3 years of experience were more vulnerable to CTS than those who had been working for more than three years. While this may seem contrary to literature stating that cumulative exposure over time increases the risk of soft tissue injury and nerve compression, a deeper analysis reveals that this may be explained by biomechanical adaptation and work experience. Newer workers tend to lack efficient motor skills and ergonomic techniques, making them more prone to muscle strain and poor working posture. Additionally, they may strive to be highly productive in a short time without understanding the importance of movement variation or adequate rest.

Other factors such as body mass index (BMI), although not significant in the multivariate analysis, still showed clinically relevant trends. Overweight workers had a higher likelihood of developing CTS compared to those with normal body weight. Excess adipose tissue around the wrist may reduce space in the carpal tunnel and increase pressure on the median nerve.^{18,19} Furthermore, obesity is linked to low-grade chronic systemic inflammation, which can worsen tissue responses to mechanical stress.^{20,21} Previous studies, including Musolin study have supported these findings, reporting that workers with a BMI ≥ 30 are more susceptible to compressive neuropathies.²³

Job type also contributed to the risk of CTS. Grinding machine operators appeared to have a higher proportion of CTS cases compared to hammerers or sheath and handle makers. This may be due to the nature of grinding work, which heavily relies on grip strength and prolonged non-neutral wrist positions. These activities are usually repetitive with little movement variation, potentially causing chronic biomechanical stress on wrist structures. Although this variable did not show statistical significance in the final analysis, its clinical relevance remains important in preventive efforts.

Age also showed a significant relationship in the bivariate analysis, with respondents over 24 years old more likely to experience CTS. Age is often associated with reduced soft tissue elasticity, microcirculatory function, and degeneration of tendon and nerve structures. However, in the multivariate analysis, age lost its significance, suggesting its effect may be mediated by other variables such as work duration or job type. This emphasizes the importance of analytic approaches that account for confounding variables in interpreting causal relationships.

Several ergonomic variables, such as repetitive motion and non-neutral wrist posture, did not show statistically significant relationships in either bivariate or multivariate analyses. Nevertheless, from a physiological and literature-based standpoint, repetitive motion and extreme working postures are still recognized as major risk factors in CTS pathogenesis. Therefore, these findings do not negate the importance of modifying ergonomic factors in blacksmithing workplaces but rather suggest the need for more precise and longitudinal measurements to uncover their cumulative effects.

Overall, this study confirms that although CTS is a multifactorial disorder, short work duration is a significant risk indicator among informal workers such as blacksmiths. Newer workers lacking sufficient experience or understanding of ergonomic principles are the most vulnerable group. Occupational health interventions should thus focus on providing ergonomic training, proper technique adaptation from the start of employment, and routine health screenings. Additionally, workshop owners and related institutions must be involved in creating safer work environments through the provision of ergonomic tools, scheduled breaks, and task rotations.

The findings of this study offer valuable contributions to the understanding of CTS risk factors in the informal sector and provide a solid basis for the development of more targeted prevention strategies. However, this study has several limitations that should be considered when interpreting the findings. One of the limitations lies in the sample collection process, which faced technical challenges in the field. During data collection, scheduling conflicts often occurred, making it difficult to coordinate physical examinations and direct interviews. This may have limited the number of respondents who could be thoroughly assessed at a given time. In addition, the use of subjective instruments such as the Visual Analog Scale (VAS) to assess pain intensity presents another limitation. Differences in individual pain perception thresholds can lead to considerable variability in pain scoring, potentially resulting in measurements that do not fully reflect the same objective condition.

Conclusion

This study demonstrates that Carpal Tunnel Syndrome (CTS) is a significant occupational health issue

among blacksmith workers in Mekarmaju Village, with a prevalence of 68%. This high figure reflects the considerable biomechanical burden and lack of ergonomic risk control in the informal sector. Although several individual and occupational factors showed statistically significant associations in the bivariate analysis, only one variable—work duration—remained significant in the multivariate analysis. This finding indicates that newer workers with ≤ 3 years of experience are actually more vulnerable to CTS, most likely due to inadequate physical adaptation, suboptimal work techniques, and limited understanding of proper working posture. The implications of these findings are crucial in the context of primary prevention of musculoskeletal disorders. Occupational health interventions should focus on the early employment phase, providing ergonomic training, risk awareness regarding posture, and early screening for CTS symptoms.

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