An ergonomics study on the evaluation of carpal tunnel syndrome among Chikan embroidery workers of West Bengal, India

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Background: Chikan embroidery is a popular handicraft in India that involves hand-intensive stitching while seated in a static posture with the upper back curved and the head bent over the fabric. Women perform most Chikan embroidery.
Objectives: The aim of this study was to analyze the repetitive nature of this work among female Chikan embroiderers by measuring the prevalence of upper extremity discomfort and carpal tunnel syndrome (CTS).
Methods: The Nordic musculoskeletal questionnaire was used to analyze the extent of upper extremity pain symptomology. The repetitive nature of Chikan embroidery work was evaluated using the Assessment of Repetitive Tasks of the upper limbs tool (ART). Motor nerve conduction studies of median and ulnar nerves were performed with embroidery workers and a control group to determine the risk of CTS.
Results: Among embroidery workers, the prevalence of wrist pain was 68% and forearm pain was 60%. The embroiderers also commonly reported Tingling and numbness in the hands and fingertips. The ART analysis found that Chikan embroidery is a highly repetitive task and nerve conduction studies showed that the embroidery workers were more likely to experience CTS than women in the control group.
Conclusions: Chikan embroidery is a hand-intensive occupation involving repetitive use of hands and wrists and this study population is at risk of experiencing CTS. Future research should explore the potential benefits of ergonomics measures including incorporating breaks, stretching exercises, and the use of wrist splints to reduce repetitive strain and the probability of developing CTS.

Keywords: Carpal tunnel syndrome, Informal sector workers, Repetitive work, Nerve conduction, Upper extremity, India

Introduction

Chikan embroidery is one of the most ancient and popular art forms in India, commonly practiced by women living in rural areas in West Bengal. The embroidery process involves hand-intensive stitching typically performed while seated in a static posture with a curved upper back and the head bent over the fabric (Fig. 1), a posture that has been previously linked to musculoskeletal disorders. For example, Choobineh *et al.* found that static sitting postures, common among carpet weavers, were associated with a high rate of musculoskeletal problems in the back and shoulders.[1] It has long been recognized that workers with predominantly repetitive tasks, or those maintaining fixed postures for long periods of time, have an increased risk of developing work-related musculoskeletal illnesses.[2,3]

Chikan embroidery involves repetitive stitching using the hands and wrists. Repetitive fabrication jobs are often monotonous, boring, and demotivating, and can result in decreased worker productivity.[4] Carpal tunnel syndrome (CTS) results from persistent compression of the median nerve, while it passes through the rigid carpal tunnel in the wrist, and is one of the most common peripheral nerve entrapment syndromes characterized by pain, tingling, and numbness in the hands and forearms.[5–7] Therefore, manual labor involving repetitive wrist movement can increase the risk of developing CTS.[8] CTS occurs most often among people between 30 and 60 years old and is five times more common in women than men.[9] It is a leading cause of workers' compensation claims and results in significant lost time and productivity in manual workers.[10] Electrodiagnostic

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Figure 1 Chikan embroidery worker performing embroidery in a static sitting posture.

tests, particularly nerve conduction studies, are used to diagnose CTS and determine the severity of median neuropathy.[5]

In India, Chikan embroidery workers are part of the informal and unorganized occupational sector. They are typically women from rural areas and lower socioeconomic classes. Around one billion people worldwide are employed in the unorganized sector.[11,12] The National Commission for Enterprises in the Unorganized Sector, also known as the Arjun Sengupta Committee, reports that more than 93% of the total workforce of India belongs to the unorganized sector with women more likely than men to be informally employed.[13,14] While, there are no reliable approximations of the number of embroiderers worldwide, Wilkinson-Weber estimates that there are between 30 000 and 100 000 in India.[15]

Previous qualitative research with Chikan embroidery workers revealed that most women purchase their materials locally, work from home, and do not have a fixed monthly income — instead getting paid in piece-rates. Women spend a considerable amount of time embroidering *sarees* and *salwaar suits*. One piece can take up to 3 days and is typically sold for approximately 40 rupees (<$1 USD). In order to ensure a regular earning, women are required to work rigorously throughout the year. Furthermore, because Chikan embroidery work is often considered a leisure-time activity and therefore, unworthy of special consideration and appropriate wages, organization, and advocacy for improved working conditions is especially difficult.[16]

Biomechanical studies have shown that extraneural pressure in the carpal tunnel increases with hand loading and non-neutral wrist postures.[17] Little is known about the prevalence of CTS in embroiderers. While women are heavily involved in this handicraft production, their contribution is often masked by discourses that tend to ignore, marginalize, or portray their work as a leisure time activity. Overall, despite the large number of women employed in Chikan embroidery in India, no studies have been carried out to document the impact of occupational conditions on the health and safety of these workers.

This study is the first of its kind to assess CTS among Chikan embroidery workers in India. Our aims were (1) to document the working conditions of Chikan embroidery workers in West Bengal; (2) to examine the health conditions of these embroiderers based on questionnaires and physical examinations; and (3) to evaluate the risk factors and prevalence of CTS.

Methods

Study design and recruitment

This cross-sectional study was carried out between January and April of 2013 among female Chikan embroiderers of Babnan, Hooghly in West Bengal, India. Babnan is a traditional center of Chikan embroidery, with approximately 600 women engaged in the work. It is constituted of two villages: Mulgram and Dargapada. Two hundred female Chikan embroidery workers were selected using simple random sampling method from these villages. A lottery system was used and alternates house in each village were visited. Any women in the household performing Chikan embroidery were asked to participate in the study. Willing participants were given a small monetary compensation for their partcipation. To be eligible, women must have been working as Chikan embroiderers for at least 5 years. Women with a history of rheumatoid arthritis, diabetes mellitus, or who were more than 3 months pregnant were excluded from the study. The authors made multiple visits to the embroiderers to explain the aims of the study and informed consent was obtained before their participation in this study.

The control group was comprised of 200 postgraduate female students in the Department of Physiology at the University of Calcutta. They were matched by age to the embroiderers, with similar socio-economic backgrounds, and in some cases, they were distant relatives of the subjects (although not closer than second cousins). Simple random sampling, using a card draw lottery, was used to select eligible control group students.

Data collection

Interviews and direct observation were used to collect information about demographics, occupational history, salary, and health history. A research assistant spent approximately 60–90 minutes of interviewing

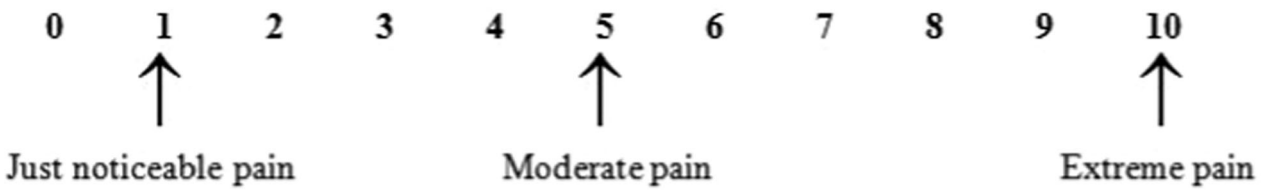

Figure 2 Body Part Discomfort scale.

and observing each embroiderer, while she was at work. On an average, three to four embroiderers were interviewed daily. All interviews were completed individually.

Height and weight were measured using Martin's Anthropometer and a Crown weighing machine (Mfg. by Raymon Surgical Co.). These data were used to compute body mass index (BMI).[18,19]

We collected information from embroiderers about their working conditions and body discomfort using the Nordic musculoskeletal questionnaire and the Body Part Discomfort (BPD) scale. The Nordic musculoskeletal questionnaire is a self-reported measure and contains a series of objective questions with multiple-choice responses.[20] The questions were arranged and grouped into the following major sections: demographic information, skill requirement, job autonomy, work organization and work behavior, and work stress. The BPD is a self-reported objective rating of pain feeling (Fig. 2) used to quantify the direct experience of discomfort in different body parts.[21]

Work repetitiveness

The Assessment of Repetitive Tasks of the upper limbs (ART) was used to study repetition of the work process and was only administered to the embroidery workers, since the control group was primarily engaged in educational activities and not repetitive tasks.[22] The ART assesses tasks that require repetitive movement of the upper limbs (arms and hands) and can be used to identify common risk factors in repetitive work that contribute to the development of Upper Limb Disorders. The ART assessment is divided into four stages: stage A is the assessment of frequency and repetition of movements; stage B is the assessment of force; stage C is the assessment of awkward postures; and stage D is the assessment of additional factors, such as work breaks, work pace, requirement of precise movements of the hand or fingers, how many times the hand is struck per hour, and task duration.

Nerve conduction study

Nerve conduction was used to evaluate the electrical conduction of the motor nerves in the embroiderers and control subjects. This test determines impairment in the median nerve function in the wrist. Median nerve conduction velocity and comparison of median with ulnar conduction is a sensitive electrodiagnostic test used to identify CTS.[23] The test involves electrical stimulation of median and ulnar nerves and recording the onset of the compound muscle action potential. The time necessary for the electrical impulse to travel from the stimulation to the recording site is referred to as latency and is measured in milliseconds (ms). Distal motor latency is the interval between the stimulus and the onset of the compound muscle action potential. The size of the response (amplitude) is measured in millivolts (mV). We stimulated at least two locations along the same nerve in order to calculate the nerve conduction velocities across different segments. Conduction velocity calculations were performed using the distance between the different stimulating electrodes and the difference in latencies.

The nerve conduction study was performed with the embroiderers and the control group using the RMS EMG EP Mark II (Fig. 3) and both median and ulnar nerve conduction velocities and their distal motor latencies were measured.

To measure the median nerve conduction velocity and distal motor latency, electrical stimulation was given at two points in the hands: S1 stimulation was placed at the wrist between the palmaris longus and the flexor carpi radialis; S2 stimulation was placed at the elbow crease, medial to the biceps tendon. The

Figure 3 Nerve conduction study on Chikan embroidery worker.

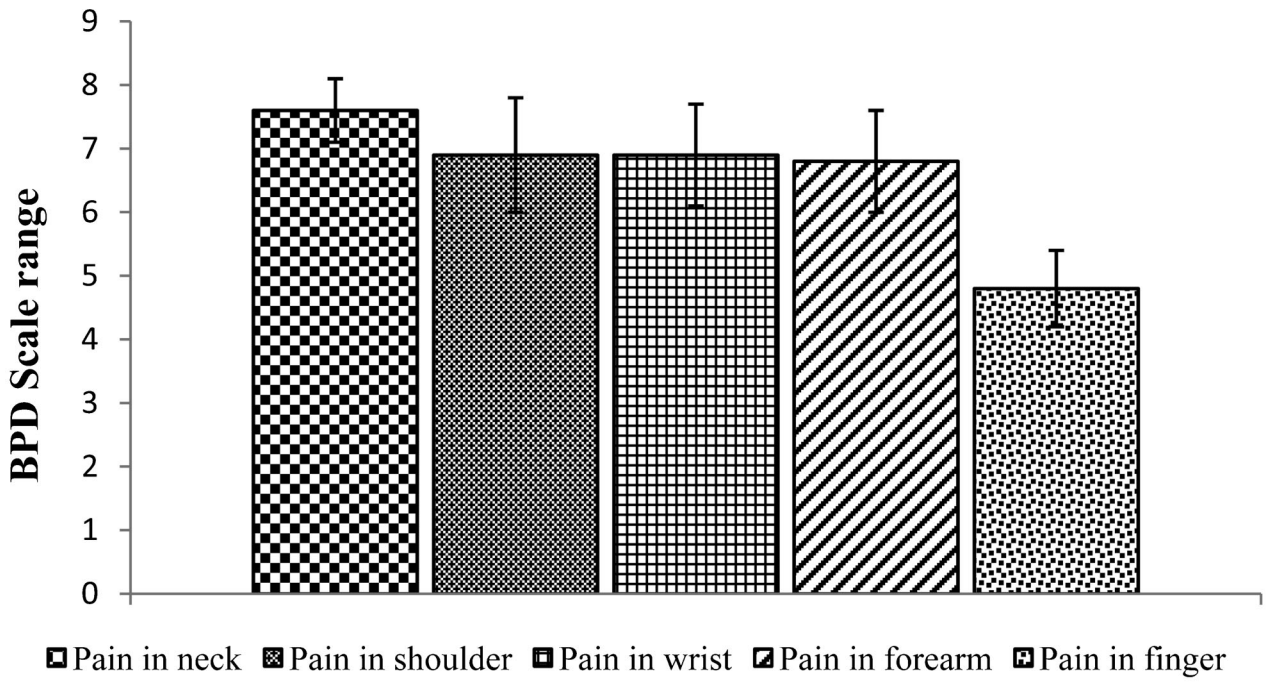

Figure 4 Body Part Discomfort scale analysis.

ground electrode was placed at the dorsum of the hand. The recording electrode was placed at the valley of the abductor pollicis brevis and the reference electrode was placed at the tendon of the abductor pollicis brevis.

For the measurement of ulnar nerve conduction velocity and distal motor latency, electrical stimulation also performed at two hand sites: S1 stimulation was placed at the wrist in the second distal most crease just medial/lateral to the flexor carpi ulnaris; S2 stimulation was placed slightly above the ulnar groove at the elbow. The ground electrode was placed at the dorsum of hand. The recording electrode was placed at the valley of the abductor digiti minimi and the reference electrode was placed distal to the active electrode.

The criteria for electrodiagnosis of CTS are that distal median motor latency should be more than 4.4 ms and the difference between the distal motor latency of the median and ulnar nerve should be more than 1.1 ms.[24]

Statistical analysis

Data were analyzed using SPSS v.20. The mean and standard deviation of physical parameters were calculated and the difference in age and BMI values between the embroiderers and the control group was analyzed by a Student's *t*-test. Pearson's correlation tested the association between pain intensity in the wrists and forearms with embroiderers' age, BMI, regular working hours, years of experience, and the ART score for repetitiveness. Multiple linear regression analysis (backward elimination method) was performed to quantify the strength of association. Regression models were constructed using a backward elimination procedure, where the probability of F to eliminate any predictor was ≥ 0.100. Student's *t*-test was performed to investigate any significant differences between the embroiderers and control group in respect to median nerve conduction velocity, distal motor latency of median nerve, and difference in distal motor latencies of the median and ulnar nerves.

Results

Demographics of the study population are presented in Table 1. No significant difference was found in age or BMI values between embroiderers and the control group.

Feelings of discomfort

Nordic questionnaire analysis found that the embroiderers experienced pain in multiple parts of their

Table 1 Demographics of the study population

Individual characteristics	Embroiderers (mean ± SD) (N=200)	Control group (mean ± SD) (N=200)
Age (years)	27.1 ± 2.8	26.9 ± 2.8
Height (cm)	151.4 ± 4.9	150.8 ± 4.7
Weight (kg)	51.8 ± 9.1	51.5 ± 8.7
BMI (kg/m^2)	22.6 ± 4.0	22.7 ± 3.9
Years of experience (years)	12.0 ± 2.8	…
Regular working hours	6.0 ± 1.9	…

Table 2 Correlations between Body Part Discomfort scale score in wrist and forearm, with subject characteristics and repetitiveness score

	BPD scale score (mean ± SD)	Age	BMI	Regular working hours	Years of experience	ART score for repetitiveness
		Pearson correlation coefficients (*p* value)				
Wrist pain	6.9 ± 0.8	0.77 (0.000)*	0.35 (0.000)*	0.12 (0.131)	0.75 (0.000)*	0.41 (0.000)*
Forearm pain	6.8 ± 0.8	0.63 (0.000)*	0.22 (0.002)*	0.04 (0.534)	0.68 (0.000)*	0.45 (0.000)*

Note: Correlations represent Pearson's *r*.
*Statistical significance: $p<0.05$.

body. Eighty percent of embroiderers reported suffering from some type of pain: 76% had neck pain, 74% had shoulder pain, 68% had wrist pain, and 60% reported forearm pain; 72% reported experiencing a tingling sensation in the hands in the past 12 months and 64% felt sensations of numbness in the fingertips in the last 12 months. Figure 4 shows the analysis of BPD scale, which supports the findings of the Nordic questionnaire analysis. The neck and shoulder pain values on the BPD scale ranged between 7 and 8 and wrist and forearm pain values ranged between 6 and 7.

Repetition

The ART instrument found a 26.2 ± 1.7 exposure score of repetitiveness. The ART allows for sub-scores to be calculated based on arm movements, hand repetition, neck and back posture, elbow and wrist posture, finger grip, and continuous use of the hand tool (needle). In all instances, these sub-scores indicated a "red" classification, reflecting a high level of risk and indicating a need for immediate intervention. Other tasks such as hand tool use with force and performing continuous tasks without a break were classified as "amber," implying a medium level of risk and recommending further study. The results indicate that Chikan embroidery is repetitive and constrained work.

Factors affecting pain in the wrist and forearm

Table 2 presents the results of the correlation between wrist and forearm pain intensity with age, BMI, regular working hours, years of experience, and job repetitiveness. Statistically significant correlations were observed between wrist and forearm pain intensity and age, BMI, years of experience, and job repetitiveness for embroidery workers. However, no significant correlation was found between wrist and forearm pain intensity and regular working hours. Stepwise multiple linear regression analyses showed that age, BMI, years of experience and job repetitiveness were the most significant predictors of wrist and forearm pain ($P<0.05$) (Table 3).

Nerve conduction analysis

Table 4 shows a decrease in median motor nerve conduction across the wrist. The median nerve conduction velocity among embroiderers (55.9 ± 6.7) was significantly lower than that of the control group (65.1 ± 8.6), suggestive of CTS. Among embroiderers, the distal latency of median nerve recorded from the abductor pollicis brevis was higher (3.2 ± 0.4) than among the control group (2.7 ± 0.4). This may also be indicative of CTS. The difference between the median and ulnar nerve latency measurement between embroiders and the control group is an important parameter of diagnostic value. However, this value was not significant.

Discussion

This study found that Chikan embroidery workers in India are engaged in a highly repetitive hand intensive job, which increases their susceptibility to CTS. This is the first study to investigate work exposures of the hands and wrists and prevalence of CTS among Chikan embroiderers in India. We carried out the

Table 3 Multiple linear regression models for the association between wrist and forearm pain with age, years of experience, BMI, ART score, and regular working hours

Models	Coefficients	*p* value	R^2
Wrist pain: dependent variable			
Model 1			0.720
Age (years)	0.109	0.000*	
BMI (kg/m^2)	0.039	0.000*	
Years of experience	0.104	0.000*	
Regular working hours	0.005	0.775	
ART score	0.093	0.000*	
Model 2			0.720
Age (years)	0.110	0.000*	
BMI (kg/m^2)	0.039	0.000*	
Years of experience	0.103	0.000*	
ART score	0.093	0.000*	
Forearm pain: dependent variable			
Model 1			0.562
Age (years)	0.051	0.023*	
BMI (kg/m^2)	0.020	0.050*	
Years of experience	0.133	0.000*	
Regular working hours	−0.009	0.680	
ART score	0.134	0.000*	
Model 2			0.562
Age (years)	0.050	0.025*	
BMI (kg/m^2)	0.020	0.050*	
Years of experience	0.134	0.000*	
ART score	0.135	0.000*	

Note: Backward elimination criterion: probability of *F*-to-remove ≥0.100.
*Statistically significant ($p<0.05$).

study of repetitiveness using the ART instrument on the embroiderers and the exposure score of repetitiveness was found to be 26.2±1.7. According to the ART tool, an exposure score greater than 22 implies that further investigation is urgently required for assessment of the task.[22] By performing nerve conduction analysis in the study population, we found a statistically significant reduction in median motor nerve conduction velocity across the wrist in the embroiderers when compared to the control group. A significant increase in the distal motor latency of median nerve was also found in the embroiderers (3.2±0.4) compared to the control group, indicating an increased risk of CTS for embroiderers. Specifically, for embroiderers, there was an increased risk of experiencing CTS among those who reported suffering from wrist and forearm pain. The regression model showed that the embroiderers' ages, BMI, years of experience, and job repetitiveness were able to explain 72% and 56.2% of the variance in wrist pain and forearm pain, respectively. The Nordic questionnaire and BPD scale analysis revealed that embroiderers reported pain mostly in the neck, followed by pain in the shoulders, wrists, forearms, and fingers. Given that women embroider while sitting in a static posture for prolonged periods, the pain is not surprising. Tingling and numbness in hands and fingertips were also widely reported, which are commonly associated with CTS. Previous studies with workers performing repetitive jobs have reported similar observations. In general, upper extremity musculoskeletal disorders are more prevalent among females than among males.[25] Motamedzade and Moghimbeigi in their study on carpet menders found that the most commonly affected upper extremity regions were shoulders, upper backs, necks and wrists.[26] It has been well established that industrial repetitive tasks are associated with musculoskeletal disorders in the upper extremities.[27] Cartwright *et al.* in their study on Latino poultry processing workers have established that the repetitive and strenuous nature of poultry processing work resulted in the increased CTS prevalence.[28] Katz *et al.*[29] and Franzblau *et al.*[30] have found numbness and tingling sensation to be classic symptoms of CTS. Both obesity and age have been recognized as risk factors for the initiation of CTS symptoms.[8,31]

We performed nerve conduction study on the embroiderers as they have reported considerable pain in wrist and forearm. Several electrophysiological studies confirmed the early diagnosis of CTS with a high degree of sensitivity.[32] The usefulness of median nerve conduction studies in the diagnosis of CTS was first described by Simpson in 1956.[33] We found a significant decrease in median motor nerve conduction velocity in the embroiderers. The slowing of median nerve conduction velocity was associated with prolongation of distal motor latency (3.2±0.4) in all the embroiderers. Slowing of median nerve conduction velocity in CTS is focal and localized to the segment of the median nerve in the carpal tunnel. These findings are in agreement with other studies.[9,34,35] According to Graham, motor terminal latency of less than 4.5 ms represents Grade 2 (or mild) CTS.[36] This suggests that these embroiderers have developed early symptoms of CTS.

Being an entirely hand intensive job, the findings from this study are critical for these embroiderers. The unorganized sector and small scale industries in particular are subjected to numerous occupational health hazards, especially among women who make up the majority of the informal sectors but are more likely to be overlooked.[11,37]

There were few limitations to this study, one of which was participant recruitment among the embroiderers. These women are part of a socioeconomic class that does not typically allow them to communicate with strangers. This made it challenging for us to convince them to participate in the study. We opted to use a combination of self-reported symptoms and nerve conduction studies to assess CTS. Owing to limited resources, only motor nerve conduction studies were performed with the embroiderers. The strengths of the study include the sample size, relevant comparison group, and systematic approach to CTS diagnosis. To date no studies have reported the occurrence of CTS in this vulnerable occupational group in India. Thus, the primary strength of this study is that it provides important baseline information for future research. The novel exploration of this study was the examination of

Table 4 Analysis of motor nerve conduction studies

Parameters	Control group (N=100) (mean±SD)	Embroiderers (N=100) (mean±SD)	t value	p value
NCV (m/s) of median nerve	65.1±8.6	55.9±6.7	8.4	0.000*
Distal motor latency (ms) of median nerve	2.7±0.4	3.2±0.4	8.8	0.000*
Diff. b/w distal motor latency of median and ulnar nerves (ms)	0.8±0.6	0.9±0.7	1.1	0.279

Note: *Statistically significant (p<0.05).
NCV, nerve conduction velocity; (m/s), meter/s; ms, milliseconds.

parity between self-reported symptoms and nerve conduction study results.

Median sensory nerve conduction studies and *F*-wave studies are also important in the diagnosis of CTS.[34,38,39] Future studies should consider incorporating sensory nerve conduction and *F*-wave for corroboration of CTS. Several studies have shown that a mixed model including interaction among different contributing factors was more accurate and had better predictive ability than the models with only personal or occupational risk factors for determination of CTS.[40,41] Therefore, future research should develop a predictive model for CTS including the interaction terms that were found to be significant for validation. It is also essential to investigate the prevalence and severity of CTS.

Although it is one of the most ancient handicrafts in India, the Chikan embroidery industry is still a much-neglected sector and deserves special attention. We recommend that future research work investigate not only occupational health problems, but also the potential benefits of positive ergonomics measures such as incorporating more frequent pauses during embroidering, performing stretching exercises for the hands and wrists, and the use of wrist splints to reduce the amount of repetitive strain and thereby reducing the probability of developing CTS.[42]

Disclaimer Statements

Contributors There are no contributors other than authors.

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Conflicts of interest There is no conflict of interest.

Ethics approval Necessary Ethical clearance was granted by the Institutional Ethical Committee.

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