Worksite and Personal Factors Associated with Carpal Tunnel Syndrome in an Egyptian Electronics Assembly Factory

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The study objective was to identify personal and work-related risk factors associated with carpal tunnel syndrome (CTS) in electronics assembly operators relative to clerical workers in the same factory. Of 422 workers in a television assembly factory located in Ismailia, Suez Canal Area, Egypt, 198 (46.9%) participated. The electronics assembly workers were more likely to report CTS (odds ratio = 11.41, 95% CI = 3.6–40.26) than were the clerical workers. The significant risk factors were longer work years (odds ratio = 1.11, 95% CI = 1.03–1.20) and precision-type hand grip (odds ratio = 6.5, 95% CI = 1.08–39.23). The results suggest an association between electronics assembly and CTS. Work years and precision grip are possible risk factors for CTS and should be studied more thoroughly. Tools to reduce the need for precision grip may help reduce CTS.
Key words: carpal tunnel syndrome; electronics assembly; prevalence; risk factors.

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Chronic repetitive injury is increasingly recognized as a cause of a variety of musculoskeletal and neurologic disorders, including carpal tunnel syndrome (CTS). Prevention of CTS depends on identifying the risk factors for it and, as appropriate, modifying the work tasks or work environment to decrease the frequency and extent of workers' hand–wrist movements.[1]

Some physically demanding work situations, such as work that involves twisted or bent body positions, static or repetitive work, and a fast work pace, have been associated with various musculoskeletal symptoms and disorders.[2] Ekberg and associates,[2] found that the economic cost of these disorders is high due to the frequency of sick leave, rehabilitation expenses, costs for compensation and insurance benefits, and individual costs. The same researchers also identified risk factors for neck and shoulder symptoms in a cross-sectional study using the Nordic musculoskeletal survey questionnaire.[3] They found female gender, immigrant status, repetitive movements demanding precision, work pace, work content, and work role ambiguity to be risk factors for repetitive injury.

Silverstein et al.,[4] studied the prevalence of CTS among workers in jobs requiring hand force and repetitive motion. The prevalences of CTS ranged from 0.6% among workers in low-force–low-repetitive jobs to 5.6% among workers in high-force–high-repetitive jobs. After controlling for gender and awkward postures, the odds of CTS for those in the high-force–high-repetitive jobs was more than 15 times that of those in low-force–low-repetitive jobs.

In a study of 84 Egyptian adults with idiopathic CTS, Niazy and El-Shenawy[5] showed that 54.7% of the patients were engaged in occupations calling for repetitive movements of the fingers, and about 6% were exposed to hand-held vibrating tools such as pneumatic scissors.

This current study was designed to estimate the frequency of CTS in a large Egyptian electronics-assembly factory and to identify worksite and personal factors associated with CTS.

METHODS

The study site was an assembly factory established in the early 1960s. It is the only such factory in the Suez Canal area and one of five in Egypt. The workers in this factory assemble television sets and video and audio components. There were a total of 422 workers in this factory during the 1994 study period (Figures 1 and 2). Of this number, 235 worked in assembly-line tasks and 187 worked in clerical, administrative, or maintenance jobs.

Sample Plan

With an expected prevalence of CTS in jobs requiring repetitive motion of 25%,[6] prevalence of CTS in the reference group of 5%, a type I error of 5%, and a type II error of 10%, the derived sample size was 85 workers per group. An expected 10% non-response rate increased the sample size needed to 95 workers per group.[7]

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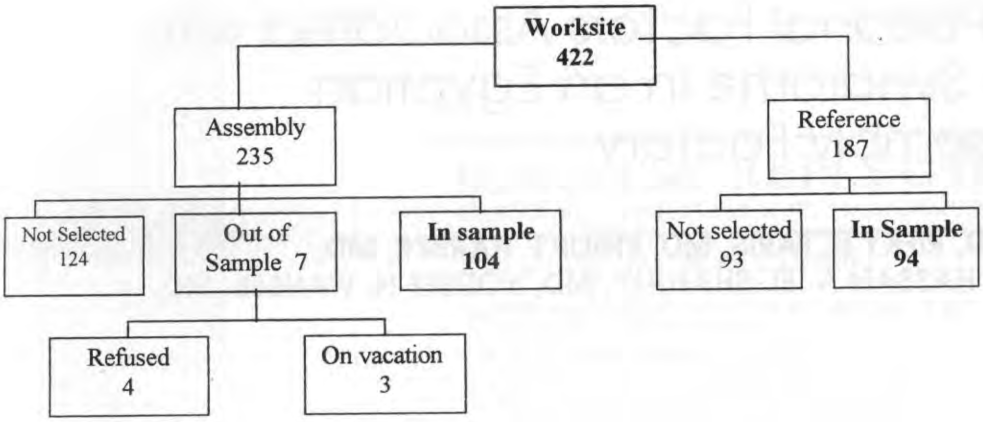

Figure 1—Sources of the subjects in the study: selection by systematic random sampling of subjects for the electronics assembly group (n = 104) and the reference group (n = 94).

The study objective and methods were explained to small groups of workers by the factory supervisor. Freedom to enrol (or not participate) and confidentiality of the information were assured, and signed informed consent was requested. Referral to a rheumatologist for medical diagnosis was available if requested.

Of 198 workers selected from the 422 workers at the factory, all agreed to participate except seven: four refused because they did not see a direct personal benefit from the study or were apprehensive about electromyography, and three were on vacation (Figure 1).

Work Setting

The electronics assembly group included 104 workers and included two job categories: components assembly and quality control. Assembly workers are responsible for placing components in the electronics boards. They do not use hand tools but handle small components such as transistors; this operation usually requires a precision grip. Quality control operators are responsible for testing and debugging the electronic boards; they often use vibrating hand tools. The reference group was composed of 94 clerical, administrative, and maintenance employees whose work did not involve repetitive or precision-grip tasks. Electronics assembly begins with assembly of lighter and smaller components, requiring frequent repetition but less force. At the end of the assembly line, there are fewer pieces, but they are larger and heavier, requiring less repetitive movements but more physical force. Biomechanical stress was evaluated by a trained industrial hygienist. Jobs were characterized by the following factors: weight lifted; work pace (number of pieces produced per hour); and predominant grip type, which was classified into: precision (e.g., pinch), intermediate (e.g., handling a cup), and power grip (e.g., holding a hammer).

Individual workstation layout was measured for each subject based on adjustability of the work platform height, platform level or tilt, posture of neck and arms, lighting and direction of airflow, back support, forearm support, mobile chair and adjustability of chair height.

Measurements

Each worker was interviewed, followed by a general physical examination. The interview asked about per-

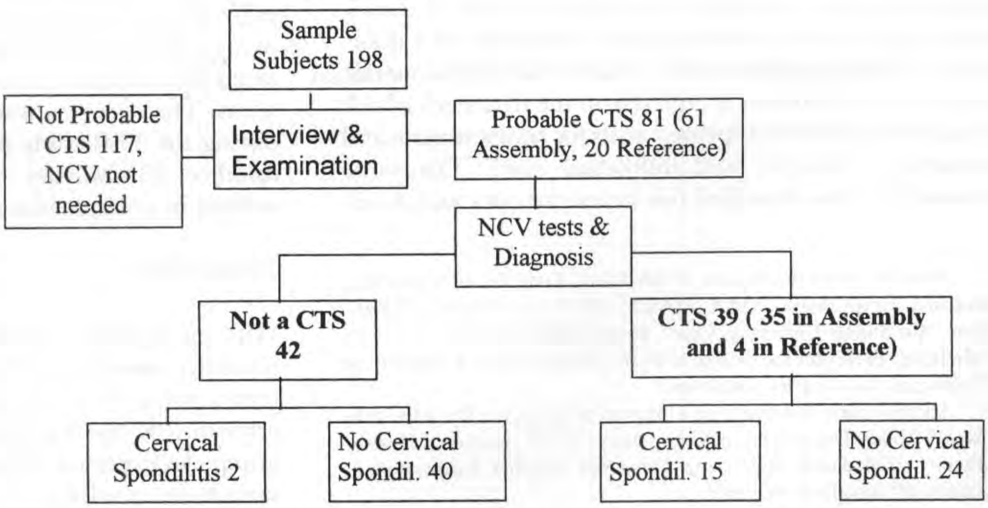

Figure 2—Flowchart of the subjects in the study: 81 subjects were considered likely to have carpal tunnel syndrome (CTS) based on history and clinical examination. There were 39 subjects whose CTS diagnoses confirmed by conduction-velocity tests.

sonal, work, and health status. The physical examination was performed by the lead author and included questions about pain or paresthesias in the neck, shoulder, or upper extremity. Subjects found to have "probable CTS" (n = 81) were investigated further with a computerized tomography scan to exclude other causes for pain or paresthesia. All 81 of these workers underwent nerve conduction velocity (NCV) testing.

The NCV test was conducted using computerized electromyography (TOENNIES, Multiliner). The TOENNIES system automatically adjusts for room temperature. The system was available in the rheumatology outpatient clinic at Suez Canal University Hospital. Rheumatology residents who had been trained to use the system performed the test. For motor function tests, the stimulating electrode was placed medial to the palmaris longus tendon and the recording electrode was placed 6.5 cm away on the bulk of the thenar muscle. Both hands were tested. For sensory function testing, the stimulating and the recording electrodes were placed on the proximal interphalyngeal joints of each index finger. The worker was assigned the diagnosis of CTS if he or she reported pain and/or paresthesias in the median nerve distribution in either hand and a decrease of NCV to less than 42 milliseconds with a normal f-test and/or a delay of more than 4.2 seconds. The final diagnosis of CTS was established by a senior faculty rheumatologist based on the reported clinical findings and NCV test data.

Statistical Analysis

Data were analyzed using Epi Info 6.0 public-domain software[8] for descriptive and comparative statistics. Comparison of the assembly-line workers with reference workers and comparison of the workers with CTS with the other workers in the assembly-line group were accomplished using Epi Info 6.0 software as univariate analysis, e.g., chi-square test and p value. The Statistical Package for Social Sciences[9] was used for logistic regression analysis to examine the prevalence odds ratio for independent risk factors in the presence of other possible confounding factors.

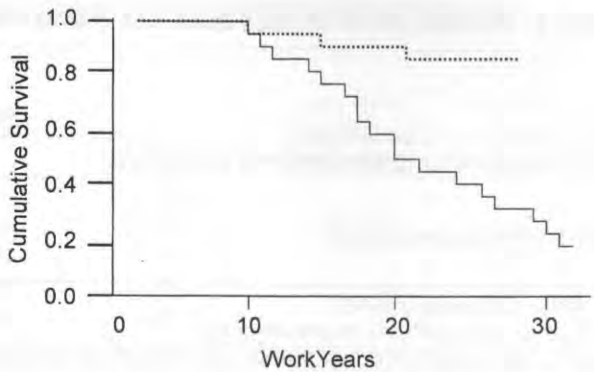

Figure 3—Probabilities of CTS (1 – predicted prevalence) for the electronic assembly workers (solid line) and the reference group (dotted line) using the Kaplan–Meier curve.

We used a logistic regression analysis model to analyze the data by calculating the probability of developing CTS by years of work. This model predicts prevalence of CTS according to work years in electronics assembly.

The logistic regression analysis model was used to calculate predicted prevalence of CTS among assembly workers as follows:

$$\text{Predicted prevalence of CTS} = 1/1+e^{(-3.70+1.8754 \cdot \text{precision grip} + 1.1066 \cdot \text{years of work})}$$

where precision grip = 1 or 0.

RESULTS

Description and Comparison of Assembly-line Workers with Reference Workers

Demographic characteristics of the study population are shown in Table 1. In all, 75.5% of the assembly workers

TABLE 1 Population Characteristics by Job Category

	Electronics Assembly Group (n = 104)	Reference Group (n = 94)	p Value of Difference
Gender female	95 (91.3%)	78 (83%)	0.07
Age, mean ± SD			
All	37.2 years ± 7.7	36.1 years ± 9.6	0.56
Females	36.4 years ± 7.1	34.8 years ± 9.5	0.51
Males	45.1 years ± 9.7	42.6 years ± 7.2	0.65
Marital status married	77 (75.5%)	78 (83.0%)	0.19
Work tenure, mean ± SD			
All	16.1 years ± 6.0	13.5 years ± 8.2	0.03
Females	15.9 years ± 5.7	12.3 years ± 7.8	0.02
Males	19.0 years ± 5.7	19.5 years ± 7.7	0.31

*The reference group consisted of clerical, administrative, and managerial workers.

TABLE 2 Prevalences of Cervical Spine Complaints and Carpal Tunnel Syndrome According to Job Category

	Electronics Assembly Group	Reference Group	Prevalence Odds Ratio (95% CI*)
Cervical spine or upper-extremity complaint	54 (51.9%)	27 (28.7%)	2.68T (1.43–5.05) $p = 0.0009$
Carpal tunnel syndrome‡	35 (33.7%)	4 (4.3%)	11.41† (3.60–40.20) $p = 0.0000002$

*95% confidence interval.
†Comparison with the reference group.
‡15 of 39 workers who had carpal tunnel syndrome also had cervical spondylosis.

group were married. Women represented 91.3% of the assembly worker group and 83.0% of the reference-worker group. The difference in proportions of genders was not statistically significant. Table 2 shows the frequencies of cumulative trauma disorders by job category. Fifty-four (51.9%) of the assembly workers reported having had cervical spine, hand, forearm, or shoulder (upper extremity) complaints during the 12 months before start of the study, while 27 (28.7%) of the reference workers reported the same complaints during the same period. The difference was statistically significant ($p < 0.05$). The frequency of cervical spine and/or upper extremity musculoskeletal complaints in the assembly workers was 2.68 times that found in the reference group. Thirty-five (33.7%) of the 104 workers in the assembly group had CTS (as defined earlier), whereas only four (3.8%) of the 94 workers in the reference group had CTS, for a prevelance odds ratio of 11.4 ($p < 0.001$).

TABLE 3 Characteristics of Assembly Workers with and without Carpal Tunnel Syndrome (CTS)

	CTS (n = 35)	No CTS (n = 69)	p Value of Difference*
Age (years)			0.20
20–	2	8	
30–	19	45	
40–	11	10	
50–	3	6	
Gender			0.25
Females	34	61	
Males	1	8	
Nerve conduction velocity, mean ± SD	36.1 ± 7.1	48.3 ± 6.0	0.02
Delay, mean ± S.D.	4.4 ± 0.8	3.8 ± 0.2	0.19
Work characteristics			
Weight of parts			0.16
0–	24	37	
100–	1	7	
200–	8	13	
300–	2	12	
Repetition			0.43
High	10	25	
Low	25	44	
Force			0.51
High	25	45	
Low	10	24	
Force/repetition			
High/high	1	8	
High/low	9	17	
Low/high	24	37	
Low/low	1	7	

*Difference between the CTS and non-CTS group among exposed workers.

Comparison of Workers with CTS with Workers Having No CTS Symptoms in the Assembly Group

Personal (age, gender, etc.) and work characteristics (repetitive motion, grip force, etc.) of the assembly workers are shown in Table 3. Those diagnosed as having CTS (cases) are compared with the rest of the assembly group (no CTS). Nerve conduction velocity was significantly lower in the CTS group than in the non-CTS group ($p < 0.05$). Age and gender distributions were not significantly different between the groups.

The weights of the electronic component parts were grouped at intervals of 100 grams. The distributions of the weight groups differed for workers with and without CTS. The weight of the component parts was heavier for the workers without CTS.

Work tasks requiring a lot of repetitive motion were more common in the non-CTS group of workers (36.2%) than in those with CTS (28.6%). However, tasks that required high energy force were more common in the CTS group of workers than in those workers with no CTS sign or symptom. With respect to both repetition and force, the differences in proportions were not statistically significant. When job categories requiring various combinations of high and low levels of repetitions and high and low force were examined, it was observed that the largest category for both the CTS group and the non-CTS group was low force and high level of repetitive work tasks. The difference (CTS 68.6% versus non-CTS 53.6%) was not significant.

We used logistic regression to identify and measure possible risk factors for CTS (Table 4). Work years and precision grip were related to CTS in the regression model. Using the date of diagnosis of CTS as an event date and

TABLE 4 Logistic Regression Analysis for Factors Associated with Carpal Tunnel Syndrome (CTS) among the Assembly Group

Variable	β Coefficient	Standard Error	Significance	Adjusted Prevalence Odds Ratio	95% Confidence Interval for POR
Grip type†			0.0203		
Precision grip	1.8754	0.9154	0.0405	6.5237	1.08–39.23
Intermediate grip	0.6827	0.9160	0.4561	1.9792	0.32–11.91
Work years	0.1066	0.0393	0.0067	1.1125	1.03–1.201
Constant	−3.7078	1.1939	0.0019		

*This model compared the risk factors for CTS among assembly workers with CTS versus non CTS. Variables included in the model:

Dependent variable:
Having CTS = 1, no CTS = 0

Independent variables:
Age in years (excluded to avoid collinearity with work years)
Job satisfaction, excellent = 1, good = 2, moderate = 3, 1 was reference
Marital status, married = 1, single = 0
Neck posture, flexion = 1, neutral = 0
Posture, bent forward = 1, neutral = 0
Amount of production/day, numeric variable
Weight of parts, numeric variables
Work years
Gender, female = 1, male = 0
Grip type

†Grip types 1 and 2 are compared with grip type 3, power grip.

TABLE 5 Predicted Prevalences of Carpal Tunnel Syndrome (CTS) According to Years of Work among the Assembly Group Using the Logistic Regression Model*

Years of Work	Probability of CTS among Assembly Workers with Precision Grip	Probability of CTS among Assembly Workers with Intermediate or Power Grip
0.1	0.1311	0.0467
0.2	0.1405	0.0472
0.5	0.1444	0.0487
1.0	0.1511	0.0512
5.0	0.2142	0.0764
10.0	0.3172	0.1235
15.0	0.4419	0.1937
20.0	0.5743	0.2904
25.0	0.6969	0.4109
30.0	0.7966	0.5431

*The logistic regression analysis model was used to calculate predicted prevalence of CTS among assembly workers as follows:

$$\text{Predicted prevalence of CTS} = 1/1 + e^{(-3.70 + 1.8754 \cdot \text{Precision grip} + 0.1066 \cdot \text{years of work})}$$

where precision grip = 1 or 0.

the hire date to define exposure time, we compared the assembly group with precision grip and the reference group using the Kaplan–Meier survival curve.[10] The two groups had comparable probabilities of CTS complaints up to ten years on the job, after which the assembly group had an increased probability of reporting CTS.

DISCUSSION

Cumulative trauma disorders are a significant problem in many working populations.[1,4,11,12] Although repetitive work is found in many industries, assembly of electronic components is of greater concern than other tasks because the work is characterized by high rates of repetitive motion; workers in the assembly line had a higher prevalence of CTS than did those in the clerical/administrative group. Other studies, as noted by Silverstein et al.,[4] have suggested the importance of repetition and force as risk factors for CTS. Our study showed that grip type is also a major determinant of risk of CTS, i.e., precision grip was associated with a high prevalence of CTS when adjusted for some confounding factors. This finding suggests that grip type should be added to force and repetition as a factor in assessing the ergonomic features of work.

Inasmuch as the prevalence of CTS increases markedly for workers with ten or more years on the job, it seems worthwhile to suggest that factory management require interviews or NVC surveillance of their employees.

Work involving precision grip appears to be important in the development of CTS and requires additional study in other, related, industries.

Since this study was based in a large Egyptian electronics assembly factory, and most workers had worked at this factory for many years, it provided a good opportunity to carefully assess many exposure factors for each participant. Thus, rather than relying on job titles, more specific task data were used to identify specific factors associated with the prevalence of CTS.

The findings from this study may be relevant to other factories in Egypt that employ workers to do assembly work. In addition, with the stable Egyptian economy and moderately high unemployment, most workers remain in the same jobs for many years. Thus, employers have an opportunity to institute possible preventive programs, including workstation redesign.

The prevalence survey design precluded study of a cause-and-effect association, but the findings nonetheless are consistent with other published epidemologic studies.[4,12,16]

CONCLUSION

This prevalence survey allowed assessment of the effects of different types of physical stress on the prevalence of CTS. Neither force nor repetition alone differentiated those with CTS from those without. Type of grip was found to be related to CTS prevalence. This finding has implications for prevention. For example, modifications of grip type by use of properly designed tools rather than direct physical handling of components may be a way to reduce CTS.

Other possible preventive factors that may be useful in reducing the occurrence of CTS include job rotation, workstation design change, and more frequent rest breaks. These factors unfortunately could not be evaluated in this factory. Findings identified in this study should be sought in other industries that require workers to use precision grip in assembly work.

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