Course of symptoms and median nerve conduction values in workers performing repetitive jobs at risk for carpal tunnel syndrome

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Background Carpal tunnel syndrome (CTS) is a common occupational disorder associated with repetitive manual work. Little information exists about the possible relation between the variation of biomechanical hand/wrist exposure and the development of symptoms and median nerve conduction values.

Aims To investigate the prevalence of CTS in a group of workers exposed to intensive use of the hands and the course of symptoms and median nerve conduction values after a period of reduced exposure to biomechanical risk factors.

Methods CTS was assessed in assembly and non-assembly line workers by means of clinical examinations and median nerve conduction studies (NCS). Ergonomic analysis was conducted for each assembly line workstation.

Results Prevalence of CTS was significantly higher in assembly line workers compared to non-assembly line workers but there was a high prevalence of median nerve conduction abnormalities in both groups (60/102 hands and 40/110 hands, respectively). In a sizable proportion of both groups there was no relationship between symptoms and electrodiagnostic findings (45 hands and 48 hands in assembly and non-assembly line workers, respectively). When assembly line workers were re-examined after 2 years following a period of reduced work schedule, a significant proportion reported resolution of symptoms or had reverted to having normal NCS.

Conclusions In our study, repetitive work was associated with a higher level of CTS and abnormal NCS. These findings appeared to be reversible following a period of less repetitive work. Overall, there was generally poor correlation between symptoms and electrodiagnostic findings.

Key words Biomechanical risk factors; carpal tunnel syndrome; nerve conduction abnormalities; reversibility of symptoms; work-related nerve disorders.

Introduction

Carpal tunnel syndrome (CTS) is a common occupational disorder. There is evidence that it can be caused by exposure to biomechanical risk factors such as repetition, force and vibration (especially when combined together) [1–4]. Its prevalence is usually much higher in occupations involving repetitive and/or forceful hand and wrist activities than in the general population [5,6].

In a consensus report, Rempel et al. [7] underlined the need to diagnose CTS on the basis of a combination of symptoms and median nerve conduction studies (NCS).

Although much information exists on the relevance of NCS in the diagnosis of CTS, less is known about the course of symptoms and median nerve conduction values in workers whose exposure changes over time. We conducted this study in order to

(i) assess the prevalence of CTS in a group of at-risk workers using a case definition which included both subjective symptoms and NCS and

(ii) assess the course of symptoms and median nerve conduction values after a period of reduced exposure to biomechanical risk factors.

Methods

Workers employed in the production department of a company producing electric-powered tools (drillers, grinders and others) were asked to participate in the...
study. They were divided into two groups according to the intensity of hand use: those working on the assembly line and a group of other workers (turners, storekeepers, maintenance operators and some clerical workers) engaged in light manual work and office duties. All the workers gave their informed consent.

Exposure was assessed by means of workplace walk throughs assisted by videotape recording. Videotapes were reviewed, checked and metered by a panel including one of the authors, the company physician and a doctor from the Occupational Health and Safety Service of the local health authority.

The assembly work was organized in one line for each tool. Each line was divided into workstations where the worker, handling some tools, repeated simple tasks according to a fixed sequence. Typical duties consisted of assembling some parts of the tools (mostly using a pinch grip and working with both hands) using small screws and an air-powered screwdriver to fasten them.

The regular day shift was 8 h, with two 10-min breaks (one in the morning, one in the afternoon) and a 60-min break for lunch.

The ergonomic analysis covered the three assembly lines working when the study was being carried out. Workers rotated on all three assembly lines, according to the needs of the production schedule.

Repetitiveness, awkward posture of the hand and wrist, static and dynamic manual exertion and local mechanical contact stress were evaluated according to the check-list developed by Keyserling et al. [8]. Work cycle duration and the number of motions/exertions were measured on the videotape. The average number of movements per second was 1.6 for the ‘angle grinder’ assembly line, 1.1 for the ‘cropper’ assembly line and 1.3 for the ‘circular saw’ assembly line. Jobs were characterized by awkward upper extremity posture (wrist flexion and extension, forearm pronation and supination, pinch grip), forceful exertion and frequent local mechanical stress.

Hand–arm vibration originating from the air-powered screwdrivers was measured, according to the ISO 5349/86 and ISO 8662-1/88 guidelines [9,10]. Eight machines were sampled: their weighted values, two axes, ranged between 2.67 and 10.89 m/s², except for one screwdriver (13.54 m/s²) which exceeded the threshold limit value of 12 m/s² for daily exposure up to 1 h [11]. However, since all the screwdrivers were used for <1 h a day, hand–arm vibration in the workers examined could be considered within acceptable limits.

The non-assembly line group included both production workers and clerical workers. Production workers (turners, storekeepers, maintenance operators) performed multitask jobs, characterized by low repetitiveness, occasional local mechanical stress, low forceful hand exertions (using light manual tools such as wrenches and screwdrivers) and sometimes awkward postures (wrist deviation and pinch grip) with no exposure to hand–arm vibration. Other tasks included checking the correct functioning of machine tools. Office workers performed light manual duties and were not exposed to intensive use of video display terminals. The non-assembly line group followed the same daily schedule.

Medical examination of each worker included clinical assessment and bilateral median NCS. All the workers were examined within the first 2 h of the beginning of the work shift.

Clinical assessment included a structured interview to collect data about personal and working history. There were no already treated cases of CTS. Presence of relevant current (or present during the previous week) sensory symptoms was defined as nocturnal and/or diurnal numbness/tingling involving at least one of the first three fingers.

Median NCS were performed at the workplace by means of Nicolet Compass equipment and were carried out by an experienced electrodiagnostic tester, who was blinded to the clinician. The tests were conducted bilaterally using the segmental palmar technique described by Kimura [12], latencies being measured in milliseconds and conduction velocities in metres per second. All latencies were measured from the stimulus artifact to the onset of the sensory/motor action potential. Surface electrodes with conduction gel were used for recording. The sensory responses were obtained antidromically by applying supramaximal stimulations at the palm, wrist and elbow, and recording from the index finger. The motor responses were obtained orthodromically by applying supramaximal stimulations at the palm, wrist and elbow, and recording from the abductor pollicis brevis muscle.

Since NCS are affected by body temperature, both hands were warmed by immersion in warm water until they reached a palmar temperature of ~32°C [13]. All NCS were performed in a warm room (22–25°C). Before applying the electrodes, the skin was cleansed with alcohol. Values falling within the appropriate upper/lower 99% confidence limit of the electrodiagnostic reference values described by Kimura [14] were considered ‘normal’: 43.8 m/s for sensory conduction velocity from wrist to palm (SCV-WP), 37.8 m/s for motor conduction velocity from wrist to palm (MCV-WP) and 4.3 ms for wrist motor latency (WML).

Doctors performing the electrodiagnostic study did not know whether the worker under examination belonged to the assembly or to the non-assembly line group.

All the workers were informed by the factory physician about the results of clinical and electrodiagnostic assessment.

Two years after the first study, a group of assembly line workers were re-examined. For the 5 months preceding the follow-up, the assembly line had been running on a reduced schedule (2 weeks/month) while daily production, work shift duration, scheduled breaks and number of
The workers underwent clinical examinations and median NCS following the same criteria employed in the previous investigation.

Before performing the study, CTS was defined as sensory symptoms plus slowing of SCV-WP or plus slowing of MCV-WP associated with a prolonged WML.

Data were analysed using STATA 7 software (Stata Corporation, College Station, TX, USA). The difference in proportions was evaluated by the Pearson’s chi-square ($\chi^2$) test with Yates correction or by the Fisher’s exact test. $P$-values <0.05 were considered significant. The differences in the presence of symptoms and NCS abnormalities between first investigation and follow-up were evaluated using the McNemar test. $P$-values <0.05 were considered significant.

Results

One hundred and twenty-one workers were employed in the production department. Out of the 60 assembly line workers, four refused to participate and five were excluded because they had been performing the job for <1 year. Out of the 61 subjects belonging to the non-assembly line group, six were excluded because they had been employed in the assembly line for the past 10 years.

The final population consisted of 106 subjects, 51 assembly line workers (32 males, 19 females; mean age 36.3 ± 11.4 years; mean body mass index (BMI) 23.6 ± 3.1) and 55 non-assembly line workers (41 males, 14 females; mean age 39.1 ± 10.3 years; mean BMI 24.6 ± 2.8).

The mean duration of employment in the current job was 7.7 ± 8.6 years for the assembly line workers and 12.1 ± 11 years for the non-assembly line workers. The right hand was the dominant hand in both groups.

The prevalence of CTS was 43% (22/51 subjects) in the assembly line group and 9% in the non-assembly line group (5/55 subjects) ($P < 0.01$, $\chi^2$ test, Yates correction). Among assembly line workers, the distribution of cases according to hand affected showed a greater involvement of the dominant hand (14 subjects), whereas no cases were registered involving the non-dominant hand only. Both hands were affected in eight cases. Among non-assembly line workers, two cases were registered both for the dominant and the non-dominant hand. Both hands were affected in one case.

In both groups, the number of hands with abnormal NCS findings exceeded the number of symptomatic hands: assembly line workers reported symptoms in 45 hands and presented NCS abnormalities in 60 hands; in non-assembly line workers the values were 20 and 40, respectively. If compared to symptomatic non-assembly line workers (6/20 hands), symptomatic assembly line workers showed a significantly higher proportion of median NCS abnormalities (30/45 hands) ($P = 0.013$, RR 2.2, CI 1.1–4.5). No significant differences ($P = 0.11$) were found for median NCS abnormalities in asymptomatic assembly line (30/57 hands) and non-assembly line workers (34/90 hands), the relative risk being 1.39 (CI 0.97–2.0). The relationship between reported symptoms and NCS findings is reported in Table 1.

Forty workers were examined after 2 years. Only 32 of them had participated in the first study, while the others had been hired, or assigned a different job according to the company’s needs. We only found four CTS cases instead of the 14 cases recorded at the first examination (three unchanged cases affecting the dominant hand, one new non-dominant hand case). At the end of the first examination, some of the workers had been recommended conservative treatment (wrist splinting), whose compliance could not be later verified. Between the first examination and follow-up, none of the workers had undergone surgical treatment for CTS. Mean BMI at follow-up did not significantly differ from mean BMI at first examination and no relevant individual variation occurred.

The majority of hands without symptoms at the first examination remained asymptomatic, while a large proportion of symptomatic hands became asymptomatic. When these changes occurred, there was a statistically significant reduction of symptoms both in the dominant and in the non-dominant hand ($P < 0.05$) (Table 2).

As for symptoms, the majority of NCS parameters tended to remain normal. Among changes, a statistically significant proportion of hands presenting NCS abnormalities at the first examination showed normal NCS parameters ($P < 0.05$ in the dominant hands and $P > 0.05$ in the non-dominant hands, see Table 3). Diversely, analysing the group of asymptomatic hands in which nerve conduction values remained abnormal, we observed that only one of the five hands with abnormal motor nerve conduction at the first examination had developed symptoms. Of the two asymptomatic hands

<table>
<thead>
<tr>
<th>Table 1. Relationship between symptomatic and asymptomatic hands and median NCS findings in assembly and non-assembly line workers</th>
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<tbody>
<tr>
<td>Assembly line (102 hands)</td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Abnormal NCS</td>
</tr>
<tr>
<td>Symptomatic hands (45)</td>
</tr>
<tr>
<td>Asymptomatic hands (57)</td>
</tr>
<tr>
<td>Non-assembly line (110 hands)</td>
</tr>
<tr>
<td>Symptomatic hands (20)</td>
</tr>
<tr>
<td>Asymptomatic hands (90)</td>
</tr>
</tbody>
</table>
with abnormal sensory nerve conduction values, one had developed symptoms.

**Discussion**

Our study found a higher prevalence of CTS among assembly line workers (43%) compared to non-assembly line workers (9%). Assembly line workers were more likely to have involvement of the dominant hand. We found a high prevalence of median nerve conduction abnormalities in both assembly line workers (60/102 hands) and non-assembly line workers (40/110 hands). In both groups, the most frequent abnormality was a combined slowing of motor and sensory conduction (41 hands in assembly line workers and 24 in non-assembly line workers). In a sizable proportion of both groups there was no relationship between symptoms and electrodiagnostic findings (45 hands and 48 hands in assembly and non-assembly line workers, respectively).

Poor overlap between reported CTS symptoms and median NCS has already been reported both in the general population and in manual workers [15–20]. Significantly reduced mean sensory amplitudes and prolonged motor and sensory distal latencies of the median nerve have been found in asymptomatic hands of industrial workers [21]. In a study on a group of applicants for industrial jobs, Bingham et al. [17] found abnormal median nerve conduction values in 17.5% of subjects, 90% of whom were asymptomatic. In both cases, the population examined included subjects exposed to different levels of occupational hand/wrist risk factors. Franzblau et al. found that ~25% of active workers had a slowing of median nerve sensory conduction in one or both hands and that about half of these subjects did not report any symptoms consistent with CTS in wrist, hand or fingers [22]. A case-control study was performed to determine whether an abnormal sensory NCS in asymptomatic workers was predictive of future complaints suggestive of CTS. After 17 months, no significant differences in reported symptoms were found between previously asymptomatic workers with and without median nerve conduction abnormalities. Seventy months later, results indicated that asymptomatic workers with a history of prolonged latency in sensory responses of the median nerve were more likely to develop symptoms consistent with CTS, although the vast majority remained asymptomatic [23,24]. The authors hypothesized that

<table>
<thead>
<tr>
<th>CTS symptoms (first examination → follow-up)</th>
<th>Number of hands</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Dominant hand</td>
</tr>
<tr>
<td>No symptoms → unchanged</td>
<td>13/32</td>
</tr>
<tr>
<td>No symptoms → symptoms</td>
<td>2/32</td>
</tr>
<tr>
<td>Symptoms → unchanged</td>
<td>6/32</td>
</tr>
<tr>
<td>Symptoms → no symptoms</td>
<td>11/32</td>
</tr>
<tr>
<td>P-value (McNemar test)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Table 2.** Change in symptoms recorded at the follow-up for dominant and non-dominant hands in the 32 assembly line workers

<table>
<thead>
<tr>
<th>NCS parameters (first examination → follow-up)</th>
<th>Number of hands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant hand</td>
</tr>
<tr>
<td>Motor NCS normal → unchanged</td>
<td>6/32</td>
</tr>
<tr>
<td>Motor NCS normal → abnormal</td>
<td>2/32</td>
</tr>
<tr>
<td>Motor NCS abnormal → unchanged</td>
<td>6/32</td>
</tr>
<tr>
<td>Motor NCS abnormal → normal</td>
<td>18/32</td>
</tr>
<tr>
<td>P-value (McNemar test)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sensory NCS normal → unchanged</td>
<td>13/31*</td>
</tr>
<tr>
<td>Sensory NCS normal → abnormal</td>
<td>0/31*</td>
</tr>
<tr>
<td>Sensory NCS abnormal → unchanged</td>
<td>5/31*</td>
</tr>
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</tr>
<tr>
<td>P-value (McNemar test)</td>
<td>&lt;0.001</td>
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</table>

*One hand not examined.
normative ‘hospital-based’ data are ‘supernormal’ and cannot be applied to the working population. They furthermore suggested that repetitive manual work can produce a very slow progressive injury to the median nerve due to cumulative trauma and localized ischaemia, with consequent prolongation of the action potential of the median sensory nerve without the sensory symptoms that typify CTS.

On the other hand, cases of symptomatic subjects with normal median nerve conduction values have been also reported [20,25]. It could be argued that these subjects represent ‘false-negative’ cases due to the fact that a small number of fast conducting nerve fibres can still give a ‘normal’ conduction velocity even when the slower fibres are affected. However, previous studies on the pathogenesis of CTS have shown that both mechanical and ischaemic events first produce structural abnormalities in large calibre (fast conducting) myelinated fibres [26].

The observed dissociation between symptoms and median nerve conduction abnormalities may be explained by their different pathophysiological mechanism, with symptoms being produced by the ectopic impulse following altered post-ischaemic membrane excitability and the slowing of nerve conduction being produced by disruption of myelin sheets or axonal damage [20,26].

Our data support the hypothesis that manual work produces an impairment of the median nerve at the wrist level (which produces symptoms and/or conduction slowing) and that such effect proportionally increases according to the intensity of hand use.

Although assembly line workers performing highly repetitive tasks are known to be at risk of CTS, the prevalence of CTS in this study is actually significantly higher if compared to previously published research in subjects performing repetitive manual work [27–29].

The case definition adopted might be a possible reason for this. It was actually based on CTS symptoms and slowing of median nerve conduction across the wrist using normative population-based NCS data. A recent study in meat industry workers applied different case definitions to describe the prevalence of CTS; lower CTS prevalence was found when applying reference NCS values recorded in asymptomatic at-risk workers instead of hospital-based data [30].

Another explanation could be the inclusion of subjects with transient symptoms or transient NCS abnormalities. This possibility is suggested by the changes which occurred after 2 years in the 32 assembly line workers.

In the case definition adopted, no cut-off concerning duration of symptoms was used. Symptoms were recorded if present, regardless of the duration, and this might have led to the inclusion of subjects with CTS symptoms that might have later disappeared. Moreover, a non-restrictive criterion has been adopted, corresponding to the definition of ‘possible CTS’ according to Rempel’s consensus criteria [7]. Follow-up data showed that only two out of 35 asymptomatic hands developed symptoms, whereas out of 29 symptomatic hands 10 remained unchanged and 19 returned to normal.

Manual repetitive work exposing median nerve to repetitive local compression at the wrist level could be responsible for subsequent thinning of the myelin sheath without conduction block and with or without related symptoms of CTS. A repairing process after significant reduction of local mechanical stress could be hypothesized. At the follow-up, the subjects were working on a reduced schedule which allowed them to have prolonged recovery time from repetitive work. It is therefore reasonable to assume that repetitive manual work can produce transient modification of median nerve conduction which could later develop into nerve conduction block or return to normal. The relationship between hand/wrist overuse and mechanical stress to the median nerve seems to be also supported by the higher amount of median NCS abnormalities in assembly line workers than in non-assembly line ones.

Like other clinical epidemiological surveys on a working population, this study has some limitations which must be taken into account. The population studied is small. Limited variations may therefore produce a larger proportional effect and only 60% of the subjects could be re-examined at the follow-up. Nevertheless, in order to achieve careful control of the variables (exposure assessment, clinical examination, diagnostic procedures), a field study becomes as complex as a laboratory investigation, where it is difficult to examine a large number of subjects. Despite these limitations, this study has, in our opinion, some distinctive findings which deserve to be commented on.

Median NCS abnormalities in asymptomatic at-risk workers need to be better understood as a possible consequence of repetitive manual work, especially in relation to the selection of normative values for NCS in the working population (which could be different from the values used for clinical patients).

In a longitudinal study, where industrial workers were followed for 11 years, the trend tended to increase for nerve conduction abnormalities and tended instead to decrease and fluctuate widely for symptoms. Besides, previously present median nerve conduction changes tended to persist and did not necessarily lead to symptoms and CTS. Authors concluded that nerve impairment might be imputable to age rather than to work activity [31].

On the contrary, our follow-up data show a decreasing trend both for symptoms and nerve conduction abnormalities. These also show that some ‘CTS cases’ found during the first examination could be related to hand/wrist symptoms or median NCS abnormalities, due to intensive hand use during work activity, that, in a substantial proportion of cases, returned to normal after a significantly reduced exposure to repetitive manual work.
If this is true, it could be useful to collect more data about symptoms, such as duration and frequency, and to plan follow-ups for electrodiagnostic studies. A case definition of CTS including not only the presence of symptoms and nerve conduction abnormalities but also their persistence over a definite period of time could be considered for epidemiological purposes in working populations.

Only through longitudinal studies can the development of symptoms and nerve conduction abnormalities related to CTS in an at-risk working population be better understood in order to establish the most accurate case definition and to understand whether a pattern of symptoms or nerve conduction abnormalities exist that can be considered reversible.

Conflicts of interest
None declared.

References


