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Quantitative magnetic resonance imaging and the electrophysiology of the carpal tunnel region in floor cleaners

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Objectives The purpose of this study was to evaluate possible structural changes of the wrist and subclinical damage in the median nerves of healthy floor cleaners.

Methods Twenty-four cleaners and 19 referents (noncleaners), all women, underwent bilateral magnetic resonance (MR) wrist examination and nerve conduction studies. They were all randomly selected from an occupational health service. From MR images the volumes of the wrist, carpal tunnel, and thenar and hypothenar muscles were calculated, as well as the signal intensity of the median nerve, bilaterally.

Results No significant difference in the volume of the carpal tunnel was found in the two groups. The relative signal intensity of the median nerve was 0.55 for the cleaners and 0.48 for the referents ($P = 0.05$). The mean nerve conduction velocity values were $55.2 \text{ m} \cdot \text{s}^{-1}$ for the right median nerve of the cleaners and $57.4 \text{ m} \cdot \text{s}^{-1}$ for the right median nerve of the referents ($P = 0.03$). The median nerve of the cleaners had a mean sensory amplitude of $128.2 \text{ } \mu\text{V}$ compared with $162.8 \text{ } \mu\text{V}$ for the referents ($P = 0.01$). There was a tendency towards a longer distal latency of the median nerve in the cleaner group.

Conclusions This study revealed subclinical intrinsic damage to the median nerve, as demonstrated by MR, and poorer electrophysiological nerve function among workers at high risk (cleaners) compared with workers at lower risk (noncleaners).

Key terms floor cleaners, handworkers, neurophysiology.

Median nerve neuropathy is a common work-related disease (1). Persons who work with their hands are mostly affected (2, 3). Apart from its well-described relationship with vibration, the disease can also occur as a result of repetitive wrist motion (3). Other reported occupational factors associated with carpal tunnel syndrome are forceful motions and awkward postures of the wrist (4, 5). Repetitiveness and high force represent a higher risk in the development of median neuropathy compared with low force plus low repetitive jobs (6). To our knowledge, a study comparing quantitative magnetic resonance imaging (MRI) data and electrophysiological parameters of the median nerve has not been completed before. Our main objective was to search for structural changes in the carpal tunnel and subclinical damage to the median nerve in this professional group.

Subjects and methods

Twenty-four professional floor cleaners considered to be at high risk for cumulative trauma disorder and 19 referents considered to be at lower risk were included in the study. All were women, with a mean age of 44.0 (range 26–59) years for the cleaners and 39.5 (range 25–44) years for the referents. The mean number of years at work was 10.4 years for the cleaners and 13.6 years for the referents. The cleaners worked 29.1 (range 24.7–35) h a week, while all the referents worked 37.5 h a week.

Both the cleaners and the referents were recruited from the same occupational health service. They were all selected from a list of workers visiting the health center for a routine physical examination. For inclusion it was

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required that the work time for the cleaners be more than three consecutive years and at least 19 h a week. Their cleaning duty required heavy hand motions in mop twisting with repetitive flexion-extension and circumflexion of the wrists. The work analysis was qualitatively evaluated by one doctor working at the occupational health center (SIB). All the cleaners used a dry or wet mop during the day except when cleaning small rooms or stairs. In contrast the selected referents were exposed to minimal repetitive hand movements like typing, key board operation, and regular writing. Exclusion criteria for both groups were systemic diseases and psychiatric disorders including alcoholism. Alcohol consumption was evaluated using a validated screening method (CAGE) by means of a questionnaire with a score from 1 to 4 (7). All the participants had a score which varied between 0 and 1, reflecting a low risk of alcoholism. At the time of the study none of the participants had a history of wrist pain.

All the subjects underwent bilateral MR wrist examination by means of a fast imaging technique (fast field echo). Axial images were obtained and transferred to a computerized device for quantitative analysis. The areas and volumes of both the carpal tunnels and the wrists were calculated from the radio-carpal joint (carpal inlet) to the base of the metacarpals (tunnel outlet) (figures 1—4). The area of the carpal tunnel was measured by drawing a line along the internal border of the carpal bones and over the flexor retinaculum (figures 1 and 3). The same method was used for all consecutive slices from the inlet to the outlet. The cross-sectional area of the wrist was also calculated on the same slices (figures 2 and 4). The wrist volume : tunnel volume ratio was then calculated bilaterally for both groups. On the assumption of a cone shape, the volumes were calculated by means of the following geometric formula for cones: $V = \pi h/3(R^2 + Rr + r^2)$. We also calculated the relative signal intensity of the median nerve in both groups using

Figure 1. Bilateral magnetic resonance axial images of the wrists, showing the measurements of the cross-sectional area of the carpal tunnel proximally.

Figure 3. Bilateral magnetic resonance axial slice through the distal carpal row, displaying the measurement of the cross-sectional area of the carpal tunnel.

Figure 2. Same level as the measurement of the cross-sectional area of the wrist, proximally, in figure 1.

Figure 4. Same level as the measurement of the cross-sectional area of the wrist, distally, in figure 3.

the fat tissue as the standard reference. The formula used was as follows (8):

$$\Delta SI = 1/SIn [SIf/SIn \times \Delta SIn + \Delta SIf],$$

where ΔSI = the relative signal intensity of the nerve calculated with fat as the reference, SIn = signal intensity of the median nerve, SIf = signal intensity of fat, ΔSIn = standard deviation of the signal intensity of the nerve, and ΔSIf = standard deviation of the signal intensity of fat.

The cross-sectional area of the thenar and hypothenar eminences were measured in both groups bilaterally at the level of the hamate, where the muscle groups were better defined (figures 5 and 6). For comparison purposes the signal intensity of the thenar eminence was analyzed from an identically selected region of interest in all the subjects. A total of 86 wrists were quantitatively evaluated. The MR examinations were performed by the same physician (CPJ) without previous knowledge of clinical and neurophysiological findings in the study groups.

Neurophysiological studies of the median nerve were performed on the right arm in both groups. We measured the compound motor unit potential amplitude, motor conduction velocity, median sensory amplitude, and distal latency in both the motor and sensory branches of the nerve. Standard techniques of supramaximal percutaneous stimulation with surface electrode recordings were used for all the participants (9). Plastic-molded surface electrodes with a 20-mm interelectrode distance were used. Median nerve potentials were recorded from the right thenar and the elbow with a distance of 8 cm between the electrodes. Since temperature has a marked effect on conduction velocity (10), we measured skin temperature on the dorsum of the index fingers, as well as the axillar temperature, in both groups.

The statistical analysis of the MR and neurophysiological measurements were performed using Student's t-test and 95% confidence intervals (95% CI). The level of significance was set at $P < 0.05$. Multiple regression analysis and the correlation factor were used to describe associations between variables and to account for other variables, such as the age and height of the subjects. For the MR parameters, the number of wrists was compared statistically in the two groups, while the electrophysiological values were obtained only from the right arm in both groups. No cut-off limit of pathological cases was defined in this study because the study population was presumably healthy.

Results

The calculated volumes of the carpal tunnel were almost similar in both groups (table 1). The smallest mean

Figure 5. Bilateral images at the level of the hamate, which demonstrate the measurement of the cross-sectional area of the thenar eminence.

Figure 6. Same level of bilateral images as in figure 5 at the level of the hamate, which demonstrate the measurement of the cross-sectional area of the hypothenar eminence.

volume found was 872 (SD 102) mm³ for the cleaners and 820 (SD 123) mm³ for the referents ($P = 0.03$). The mean value for the biggest volume was 1253 (SD 168) mm³ for the former group and 1198 (SD 187) mm³ for the latter ($P = 0.16$). In all the subjects the tunnel inlet (mean 1080 mm³) was larger than the outlet (mean 951 mm³); this finding confirmed the cone configuration of the tunnel. The mean cross-sectional area of the thenar eminences was 293 mm² for the cleaners and 298 mm² for the referents ($P = 0.86$). The cross-sectional area of the hypothenar eminences was larger for the cleaner group [mean 221 (SD 61) mm²] than for the referents [188 (SD 42) mm²] ($P = 0.007$). The mean relative signal intensity of the thenar eminence was 0.24 (SD 0.10) for the cleaners and 0.23 (SD 0.09) for the referents ($P = 0.57$). The calculated signal intensity of the median nerve was higher among the cleaners than among the referents although the difference was not clearly significant (table 1).

The mean skin temperature of the index finger was 29.0°C for the cleaners and 29.1°C for the referents. The axillar temperature had a mean value of 37.0°C for both groups. The nerve conduction studies revealed a signifi-

Table 1. Bilateral quantitative magnetic resonance (MR) measurements made for the cleaners and referents. (95% CI = 95% confidence interval)

	Carpal tunnel cleaners ^a (N = 46)		Carpal tunnel referents ^b (N = 38)		95% CI	P-value
	Mean	SD	Mean	SD		
Carpal tunnel volume (mm ³)	7801	1065	7556	1357	-2316—2806	0.35
Wrist volume (mm ³)	71540	10883	68229	13448	-1989—8611	0.21
Carpal tunnel:wrist volume ratio	0.11	0.11	0.11	0.11	-0.04—0.05	0.52
Relative signal intensity of the median nerve	0.55	0.19	0.48	0.12	0—0.14	0.05

^a Number of wrists = 46.^b Number of wrists = 38.**Table 2.** Hand grip strength and nerve conduction studies for the right median nerve in cleaners and referents. (95% CI = 95% confidence interval)

	Cleaners		Referents		95% CI	P-value
	Mean	SD	Mean	SD		
Right hand grip (mm Hg) ^a	412.6	121.0	448.4	81.5	-8.3—79.9	0.28
Median motor nerve (right)						
Amplitude (mV)	8.6	2.1	8.2	3.0	-0.75—1.55	0.63
Conduction velocity (m · s ⁻¹)	55.2	3.0	57.4	3.3	0.81—3.59	0.03
Distal latency (ms)	3.5	0.7	3.3	0.4	-0.04—0.44	0.19
Median sensory nerve (right)						
Amplitude (μV)	128.2	44.2	162.8	37.8	16.8—52.4	0.01
Distal latency (ms)	1.5	0.4	1.3	0.2	0.07—0.33	0.16

^a 1 mm Hg ≈ 133.333 Pa.

cantly lower motor nerve conduction velocity of the right median nerve for the cleaners (table 2). In both the motor and sensory branches of the median nerve, there was a tendency towards longer distal latency for the cleaners (table 2). The sensory amplitude also appeared to be lower for the cleaners (table 2). In the cleaner group we found a positive association between the hand grip and the area of the hypothenar eminence. No significant differences were found for the other nerve physiology parameters. A simple regression analysis considering the number of years at work as the independent variable and the median motor conduction velocity as the dependent variable was not significant ($\beta = -0.7$, SE 0.19, $P = 0.71$). A multiple regression analysis incorporating the age and height of the subjects was also nonsignificant. Neither were there any significant results from the regression analysis using the amplitude of sensory nerves as the dependent variable with age and height as independent variables. Work-related factors and age were not related to the MRI parameters. No significant associations between the nerve physiology and the MR parameters were detected.

Discussion

In this study we found both morphological and electrophysiological subclinical damage to the median nerve in women working as professional floor cleaners when they

were compared with noncleaners. Despite the lack of association between time at work and these findings, this study confirms previous reports regarding the role of the workplace in the incidence of median nerve neuropathy.

We hypothesized that floor cleaners are at risk of carpal tunnel syndrome because of repeated flexion and extension of the wrist when using a mop. Repeated flexion and extension is one documented occupational factor in the etiopathology of this syndrome. Among the reported occupations at risk are female grocery checkers (11), poultry processors (12), and sewers and meat packers (8). Most of the studies producing these results were uncontrolled cross-sectional or retrospective studies; therefore the problem of cause and effect is raised. One of the main problems in this controlled study was the work analysis. No attempt was made to quantify wrist motion or evaluate the moping technique. However, as the mopping technique is well known, we assumed that the operation involved a repetition of the same movement more than 50% of a total cycle of 30 s that would be consistent with the definition of highly repetitive jobs proposed by Silverstein et al (6). Whether floor moping is categorized as a high- or low-force job was not estimated in our study. This nonquantitative evaluation of the work procedure made it impossible for us to calculate consistent dose-response relationships between job exposure and median nerve changes.

There have been reports on changes in carpal tunnel size (eg, carpal stenosis) (13) and shape (eg, bulging of

the retinaculum) in patients with median neuropathy (14). In this study, the carpal tunnel was found to have an identical cone configuration in both study groups. The intracanal pressure may increase in some patients with median nerve neuropathy. The pressure can go up to 90 mm Hg (12 kPa) in symptomatic patients, especially in repetitive wrist flexion and extension (15, 16). We do not have sufficient evidence to attribute the neurophysiological findings of the floor cleaners to a mechanical etiology, despite the frequency of flexion-extension of the wrist in their daily work activities. The lack of association between the MR findings and neurophysiology parameters indicates that the quantitative MRI technique used may have a different sensitivity than nerve conduction analysis in diagnosing median neuropathy.

In conclusion, the results of this study are in accordance with those of previous reports confirming the predisposition of handworkers to median neuropathy, as subclinical changes were detected for both MR and neurophysiological parameters. There is increasing evidence that cumulative trauma plays a major role in the incidence of occupational disorders. The lack of association between canal size and median nerve changes indicates that other mechanisms, such as an intermittent increase in intracanal pressure, are important in the pathogenesis of median neuropathy among floor cleaners.

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