

Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome

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HAGBERG M, MORGENSTERN H, KELSH M. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. *Scand J Work Environ Health* 1992;18:337-45. In this investigation reported epidemiologic studies on carpal tunnel syndrome (CTS) (15 cross-sectional studies involving 32 occupational or exposure groups and six case-referent studies) were reviewed. The prevalence of CTS in the different occupational groups varied between 0.6 and 61%. The highest prevalence was noted for grinders, butchers, grocery store workers, frozen food factory workers, platers, and workers with high-force, high-repetitive manual movements. Odds ratios greater than 10 were reported for exposed groups in three studies. On the basis of epidemiologic and other evidence, it was concluded that exposure to physical work load factors, such as repetitive and forceful gripping, is probably a major risk factor for CTS in several types of worker populations. At least 50%, and as much as 90%, of all of the CTS cases in these exposed populations appeared to be attributable to physical work load.

Key terms: entrapment, epidemiology, ergonomic, hand, nerve, neuropathy, occupational health, work load, wrist.

The association between occupational activities and carpal tunnel syndrome (CTS) has been addressed by several investigators. Despite the reported association between occupation or occupational exposure and CTS, a causal relationship between usage and CTS has been refuted. Recently an editorial in the *Journal of Occupational Medicine* claimed that "CTS is not a cumulative trauma disorder [p 39]." In the Newsletter, *Occupational Problems In Medical Practice* the same author claimed that "I am convinced that some forms of usage can exacerbate the symptoms of some regional musculoskeletal illness, but not all — for example, not CTS [p 7]" (2). On the other hand Gerr et al (3), in a review of upper-extremity musculoskeletal disorders of occupational origin, concluded that "carpal tunnel syndrome is etiologic related to occupational exposures [p 562]." Evidence for a causal relationship between workplace ergonomic factors and nerve entrapment of the median nerve at the wrist was recently reported in a meta-analysis by Stock (4). To infer a causal relationship between occupational exposure and CTS, epidemiologic studies would have to show a statistical association between occupation and CTS that is not due entirely to estimation errors (chance or bias).

The aim of the present investigation was to review

the epidemiologic literature for the possible effect of occupation, specifically physical work load, on the occurrence of CTS and to consider the overall evidence for a causal relationship.

Materials and methods

A survey of the Medlars documentation system was performed for the years 1966 to 1990 (November); 164 references were obtained with the use of the key words carpal tunnel syndrome, CTS, occupation, incidence, and prevalence. Most of the articles dealt with case descriptions, diagnosis, or treatment (60% of the references). Reviews or educational articles came second (20% of the references). Only 15% of the articles were population-based studies of CTS in occupational groups. Furthermore, we studied the reference lists of these articles to assess all the literature of interest for epidemiologic aspects of CTS. Only articles or official reports in which CTS was defined by both symptoms and signs were considered. These signs included an electrodiagnostic test of median nerve block, a positive Phalen's test, or a positive Tinel test. Surgical release of the median nerve at the wrist was also accepted as CTS, since both symptoms and signs are a general requirement for carpal tunnel surgery (5). Furthermore we included a study of occupational groups in which only nerve conduction was measured (6). Prevalence odds ratios with 95% confidence intervals were estimated for the different exposures or occupational groups in the studies in which the authors did not perform these computations (7). The prevalence odds ratio approximates the incidence rate ratio if the mean duration of the disease is the same for the exposed and the unexposed and no other sources of bias are present (8, 9).

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The impact of the exposure (occupational group or job title) was estimated by the attributable fraction in the exposed population — ie, the proportion of exposed cases that would not have developed the disease in the absence of exposure. In the reviewed studies the reference group had a different occupation or job task than the study group. The reference groups could not be regarded as unexposed but rather as less exposed than the study groups. Therefore the preferred terminology is reference group and not control group since exposure was not under control. The attributable fraction was estimated by $(OR-1)/OR$, where OR was the estimated odds ratio (8). The confidence limits for the attributable fraction were calculated from the upper and lower limits of the odds ratio.

In one case-referent study, the authors presented differences in mean exposures between the cases and referents. These differences were converted to odds ratios by the method of Greenland (10).

Results

In our survey of the literature, there were 21 articles and reports that met the established criteria: 15 cross-sectional studies in which 32 occupational or exposure groups had been studied (table 1) (6, 11–24) and six case-referent studies (table 2) (25–30). All of these studies involved prevalent cases of CTS.

The prevalence of CTS in the different occupational groups varied between 0.6 and 61% (table 1). The lowest prevalences were noted for industrial workers

with low-force, low-repetitive jobs (0.6%) and slaughterhouse workers (1%) (table 1). The highest prevalences in the cross-sectional studies were noted for grinders, butchers, grocery workers and frozen food factory workers with high-force, high-repetitive gripping jobs, and platers. The estimated effects on CTS in the cross-sectional studies were high for industrial workers with high force and high repetition in their jobs with an odds ratio of 16 and for platers with an odds ratio of 11.0 (table 2). In the case-referent studies (table 3) the highest odds ratios were observed for exposures defined as high-level or long-lasting vibration exposure, three different studies showed odds ratios greater than 4 (table 4). An exposure-response relationship for vibration exposure was indicated in both cross-sectional and case-referent studies (11, 25). Other occupational factors related to CTS were wrist flexion and extension postures and keying work (table 4).

The impact of occupation or occupationally related exposure on CTS was substantial (table 5). High-force, high-repetition vibration exposure or manual work or both indicated attributable fractions of 80% or higher in the exposed populations (table 5). Keying had an attributable fraction of 74% among women working at least 20 h a week with a keyboard (table 5).

Discussion

There are numerous sources of estimation error (bias) in epidemiologic studies. In the following discussion

Table 1. Characteristics of the occupational or exposure groups in the included 15 cross-sectional studies. (CTS = carpal tunnel syndrome; NA = data not available)

Job title, occupational tasks and study base characteristics	Gender	N	Mean age (years)	Mean employment time (years)	CTS prevalence (%)	CTS criteria	Study
1. Platers: stainless steel welding, grinding, chip-hammering, from employer's list of 112 platers working as a plater and younger than 55 years of age	Male	89	36.7	10.1	14	Paresthesia in hand with median nerve distribution and a positive Phalen's or Tinel test	Nilsson et al, 1990 (11)
2. As 1, but platers currently exposed to vibration	Male	71	32.4	12.2	13	Same as 1	Nilsson et al, 1990 (11)
3. Office workers: engineering construction, supervision and selling; randomly selected from employer's list of 500 office workers younger than 55 years of age	Male	61	39.4	—	2.2	Same as 1	Nilsson et al, 1990 (11)
4. As 3, but office workers with no previous vibration exposure	Male	45	36.7	—	1.7	Same as 1	Nilsson et al, 1990 (11)
5. Workers at seven different industrial sites; 39 different jobs classified according to repetition and force requirements for the hands, high force and high repetition	Male/ female	157	38.0	8.3	5.6	Median nerve paresthesia, nocturnal exacerbation, symptoms more than 20 times or lasting more than a week during previous year, onset of symptoms since beginning of current job, and job-positive Phalen's or Tinel test with exclusion of thoracic outlet, cervical root, pronator teres syndrome, rheumatoid arthritis and trauma	Silverstein et al, 1987 (12)
6. Same as 5, but job demands of hands low force and high repetition	Male/ female	143	40.7	8.1	2.1	Same as 5	Silverstein et al, 1987 (12)
7. Same as 6, but job demands of the hands high force and low repetition	Male/ female	195	38.9	7.5	1.0	Same as 5	Silverstein et al, 1987 (12)
8. Same as 7, but job demands of the hands low force and low repetition	Male/ female	157	40.2	7.0	0.6	Same as 5	Silverstein et al, 1987 (12)

(continued)

Table 1. Continued.

Job title, occupational tasks and study base characteristics	Gender	N	Mean age (years)	Mean employment time (years)	CTS prevalence (%)	CTS criteria	Study
9. Forestry workers: chain-saw operators randomly selected from 186 that had >500 h of exposure, the total number of employed operators was 217	Male	79	45.3	—	25	Clinical picture of CTS with distal latency and motor conduction velocity pathology	Färkkilä et al, 1988 (13)
10. Butchers working with beef and pork from two slaughter houses (N = 19); 17 participated; meat cutters not included	Male	17	38.8	15.3	53	Median nerve distributed numbness and nerve conduction signs of median block	Falck & Aarnio, 1983 (14)
11. Same as 10	Male	17	38.8	15.3	12	Median nerve distributed numbness and Phalen's test positive	Falck & Aarnio, 1983 (14)
12. Electricians: work with light- or medium-weight tools (pliers, screw-drivers, hammers power tools and cable cutters); all members of one shop	Male	14	49	15	43	Symptoms of paresthesia and nerve conduction block	Bleeker et al, 1985 (15)
13. Employees at a meat cutting plant: bi-manual work involving repetitive grasping and pulling, in cutting areas room temperature 50°F (11°C) with a meat temperature of 38°F (3°C)	Male	733	35.5	9.1	15	CTS surgery	Masear et al, 1986 (16)
14. Same as 13	Female	55	34.3	9.1	20	Same as 13	Masear et al, 1986 (16)
15. All subjects at three workstations at a poultry-processing company; retrieving a bird in one position and placing it in a designated area for further preparation; temperature 55 to 60°F (13 to 16°C); work categorized as low force high repetition	Female	35	NA	NA	20	At least three of following six symptoms and signs: positive Tinel sign, positive Phalen sign, subjective report of morning swelling of hands, three-jaw chuck pinch reduced from published norms, a squared wrist dimension, elevated vibrometer readings compared with the contralateral side in the median nerve distribution	Muffy-Else & Flinn-Wagner, 1987 (17)
16. Slaughterhouse workers in a slaughterhouse with a total of 119 butchers, meat cutters and meat by-product workers (82 men, 31 women); cutters, butchers meat by-product workers; meat temperature 0–7°C; workplace temperature 10°C	Male/ female	113	31.8	5.5	1	Nocturnal paresthesia, positive Tinel's test, and positive Phalen test	Viikari-Juntura, 1983 (18)
17. Garment workers selected from 214 people in a garment shop: women's jackets were produced, stitcher (sewing machine operator), finisher (sewing and trimming by hand), under-presser (ironing by hand), floor work (carrying bundles), shipping, operation of a facing machine	Female	162	43	11	6.8	Symptoms and positive Tinel test or Phalen's test	Punnett et al, 1985 (19)
18. Hospital workers in chronic care	Female	73	41	5	5.5	Symptoms and positive Tinel test or Phalen's test	Punnett, 1987 (20)
19. Ski-manufacturing workers in a ski-manufacturing shop, repetitive jobs	Male/ female	106	35	5	34	Electrodiagnostics	Barnhart et al, 1991 (21)
20. Ski-manufacturing workers in a ski-manufacturing shop, nonrepetitive jobs	Male/ female	67	41	10	19	Same as 19	Barnhart et al, 1991 (21)
21. Grocery store workers in a large supermarket with a cluster of reported CTS; high exposure category	Male/ female	16	35	5.2	44	Symptoms and Tinel test or Phalen's test or median sensory deficit of the hand or thenar atrophy	Osorio et al, 1989 (22)
22. Same as 21; medium exposure category	Male/ female	30	28	3.1	10	Same as 21	Osorio et al, 1989 (22)
23. Postal workers: letter sorting	Male/ female	79	38.4	6.6	22	Symptoms and median sensory deficit of the hand or a positive Tinel or Phalen's sign	California Occupational Health Program, 1990 (23)
24. Postal workers: optical character reader operators	Male/ female	34	34.6	2.2	15	Same as 23	California Occupational Health Program, 1990 (23)
25. Frozen food factory employees: low exposure to cold and low repetitive movements	Male/ female	49	39.9	7.3	4	Symptoms and positive Tinel sign or Phalen's test	Chiang et al, 1990 (24)
26. Frozen food factory employees: no exposure to cold but a high degree of repetitiveness	Male/ female	37	38.0	5.5	46	Same as 25	Chiang et al, 1990 (24)
27. Frozen food factory employees: exposed to cold and a high degree of repetitiveness	Male/ female	121	41.5	5.2	47	Same as 25	Chiang et al, 1990 (24)
28. Grinders (group V)	Male/ female	23	NA	NA	61	Maximum latency difference of 0.4 ms or greater for eight sensory latencies assessed in consecutive 1-cm segments of the median nerve	Nathan et al, 1988 (6)
29. Assembly workers (group III)	Male/ female	164	NA	NA	47	Same as 28	Nathan et al, 1988 (6)
30. Keyboard operators (group II)	Male/ female	22	NA	NA	27	Same as 28	Nathan et al, 1988 (6)
31. Administrative and clerical workers (group I)	Male/ female	147	NA	NA	28	Same as 28	Nathan et al, 1988 (6)
32. General plant (group IV)	Male/ female	115	NA	NA	38	Same as 28	Nathan et al, 1988 (6)

Table 2. Case-referent studies included in the review. (NA = data not available, CTS = carpal tunnel syndrome)

Case and referent definition	Gender	N	Mean age	Mean employment time	Exposure assessment/ exposure studied	Controlling	Study
I. Men aged 20–66 years who were operated on at one hospital during 1975–1980; clinical diagnosis and electrodiagnostic test	Male	34	NA	NA	Telephone interview; use of handheld tools < 1 year, 1–20 years, or > 20 years	Gender, age	Wieslander et al, 1989 (25)
Men from surgical register with one gallbladder operation for each case and one varicose veins operation; general population referents, two for each case	Male	143	NA	NA	Repetitive wrist movements < 1 year, 1–20 years, or > 20 years; work causing great load on wrist < 1 year, 1–20 year, or > 20 year		
II. Persons who had received workers' compensation benefits for wrist-arm-hand 1977–1979, 16 persons CTS; medical department diagnosis 1977–1979, 14 people identified; total 3 men and 27 women	Male/ female	30	43.2	5.5	Questionnaire; use of vibrating hand tools; performance of repetitive motion task; years on the job	Gender, use of vibrating hand tools, history of gynecologic surgery, years on the job, performance of repetitive motion	Cannon et al, 1981 (26)
Three referents per subject were randomly selected from persons employed at the same plant	Male/ female	90	44.8	11.7			
III. Female sewing machine operators; medical histories review; "disease" cases excluded; sewing seat covers	Female	18	33.2	NA	Hand force, hand position, wrist position, pinch force	Gender, plant	Armstrong & Chaffin 1979 (27)
Female sewing machine operators, no CTS	Female	18	34.0	NA			
IV. CTS surgery register, Örebro county	Female	112	NA	NA	Repetitive, manual, knitting, piece work	Age, gender	deLaval et al, 1985 (28)
General population	Female	199	NA	NA	Typist keyboard		
V. CTS surgery register	Male	18	NA	NA	Vibration exposure	Age, gender, manual work	Voog et al, 1985 (29)
General population	Male	238	NA	NA			
VI. 128 consecutive carpal tunnel syndrome patients from a hospital and an additional 28 from a population survey	Male/ female	25/ 131	NA	NA	Activities with flexed wrist 0–5 years ago; activities with extended wrist (hours); activities with extended and flexed wrist in combination; pinch, grasp, typing	Gender, age	De Krom et al, 1990 (30)
Random population sample	Male/ female	163/ 310	NA	NA			

Table 3. Estimated prevalence of carpal tunnel syndrome and odds ratios for cross-sectional studies with referents. (95% CI = 95% confidence interval, NA = data not available)

Job title or exposure	Referents	Prevalence (%)			95% CI	Adjustment	Study
		Exposed	Unexposed	Odds ratio			
High force and high repetitiveness	Low force and low repetitiveness	5.6	0.6	16	1.7–142	Age, gender, plant years on the job	Silverstein et al, 1987 (12)
Platers	Office workers	14	1.7	11	2.0–62	Age	Nilsson et al, 1990 (11)
Frozen food factory workers exposed to cold and repetition	Frozen food factory workers	47	4.3	9.4	2.4–37	Gender, age employment time	Chiang et al, 1990 (24)
Platers with active vibration exposure	Office	13	2.2	7.7	1.2–50	Age	Nilsson et al, 1990 (11)
Grocery workers: high exposure category	Grocery workers: low or medium exposure category	44	10	7.0	1.5–33	None	Osorio et al, 1989 (22)
Vibration	Nonvibration	NA	NA	5.3	NA	None	Silverstein et al, 1987 (12)
Grinders	Administrative and clerical workers	61	28	4.0	1.6–9.9	None	Nathan et al, 1988 (6)
Low force and high repetitiveness	Low force and low repetitive	2.1	0.6	2.7	0.3–28	Age, gender, plant, years on the job	Silverstein et al, 1987 (12)
Assembly workers	Administrative and clerical workers	47	28	2.3	1.4–3.7	None	Nathan et al, 1988 (6)
Ski-manufacturing workers with repetitive jobs	Ski-manufacturing workers with nonrepetitive jobs	34	19	2.3	1.1–4.8	None	Barnhart et al, 1991 (21)
Frozen food factory workers exposed to repetition, no cold	Frozen food factory workers	41	4.3	2.2	0.2–21	Gender, age, employment time	Chiang et al, 1990 (24)

(continued)

Table 3. Continued.

Job title or exposure	Referents	Prevalence (%)			95% CI	Adjustment	Study
		Ex-posed	Unex-posed	Odds ratio			
Vibration	Nonvibratory exposure	NA	NA	1.9	NA	Force and repetition	Silverstein et al, 1987 (12)
High force and low repetitiveness	Low force and low repetitiveness	1.9	0.6	1.8	0.2–21	Age, gender, plant years on the job	Silverstein et al, 1987 (12)
Garment workers	Hospital employees	6.8	5.5	1.3	0.4–4.1	None	Punnett et al, 1985 (19)
Keyboard operators	Administrative and clerical workers	27	28	1.0	0.3–2.6	None	Nathan et al, 1988 (6)

Table 4. Estimated odds ratios for carpal tunnel syndrome in the case-referent studies. (95% CI = 95 percent confidence interval)

Exposures	Odds ratio	95% CI	Adjustment	Study
High-level vibration exposure >10 h/week	14	5.5–35	Gender, age	Voog et al, 1985 (29)
Activities with flexed wrist 20–40 h/week	8.7	3.1–24	Gender, age	De Krom et al, 1990 (30)
Use of vibrating hand tools	7.0	3.0–17	Gynecologic surgery, years on the job, repetitive work task	Cannon et al, 1981 (26)
Activities with extended wrist 20–40 h/week	5.4	1.1–27	Gender, age	De Krom et al, 1990 (30)
Manual work and vibration	5.2	2.7–9.8	Gender	Voog et al, 1985 (29)
Vibration exposure >20 years	4.8	1.5–16	Gender, age	Wieslander et al, 1989 (25)
Repetitive movement of wrist >20 years	4.6	1.8–12	Gender, age	Wieslander et al, 1989 (25)
High-level vibration exposure 1–10 h/week or medium-level exposure >10 h/week	4.1	1.9–8.7	Gender, age	Voog et al, 1985 (29)
Typist keyboard	3.8	1.3–11	Gender, age	de Laval et al, 1985 (28)
Vibration exposure, medium level 1–10 h/week	3.2	1.2–8.2	Gender, age	Voog et al, 1985 (29)
Activities with flexed wrist 8–19 h/week	3.0	1.8–4.9	Gender, age	De Krom et al, 1990 (30)
Activities with extended wrist 8–19 h/week	2.3	1.0–5.2	Gender, age	De Krom et al, 1990 (30)
Repetitive work task	2.2	1.3–3.6	Gender, age	de Laval et al, 1985 (28)
Repetitive motion tasks	2.1	0.86–5.3	Gynecologic surgery, vibrating tools, years on the job	Cannon et al, 1981 (26)
Pinch force	2.0 ^a	1.6–2.5 ^a	None	Armstrong & Chaffin, 1979 (27)
Manual work	1.9	1.0–3.5	Gender, age	Voog et al, 1985 (29)
Repetitive movement of wrist 1–20 years	1.5	0.5–4.4	Gender, age	Wieslander et al, 1989 (25)
Activities with flexed wrist 1–7 h/week	1.5	1.3–1.9	Gender, age	De Krom et al, 1990 (30)
Activities with extended wrist 1–7 h/week	1.4	1.0–1.9	Gender, age	De Krom et al, 1990 (30)
Repetitive manual tasks, 50–65 years of age	1.4	0.6–3.2	Gender, age	de Laval et al, 1985 (28)
Activities with extended and flexed wrist 20–40 h/week	1.4	0.7–2.9	Gender, age	De Krom et al, 1990 (30)
Activities with extended and flexed wrist 8–19 h/week	1.2	0.8–1.7	Gender, age	De Krom et al, 1990 (30)
Activities with extended and flexed wrist 1–7 h/week	1.1	0.9–1.2	Gender, age	De Krom et al, 1990 (30)
Hand force	1.05 ^a	0.95–1.15 ^a	None	Armstrong & Chaffin, 1979 (27)
Pinch grasp 1–7 h/week	0.9	0.8–1.1	Gender, age	De Krom et al, 1990 (30)
Typing 1–7 h/week	0.9	0.6–1.4	Gender, age	De Krom et al, 1990 (30)
Years on the job	0.89	0.81–0.97	Gynecologic surgery, vibrating tools, repetitive work task	Cannon et al, 1981 (26)
Pinch grasp 8–19 h/week	0.8	0.5–1.3	Gender, age	De Krom et al, 1990 (30)
Typing 8–19 h/week	0.8	0.3–2.5	Gender, age	De Krom et al, 1990 (30)
Pinch grasp 20–40 h/week	0.7	0.3–1.6	Gender, age	De Krom et al, 1990 (30)
Typing 20–40 h/week	0.7	0.1–6.0	Gender, age	De Krom et al, 1990 (30)

^a Computed from mean values and standard deviation according to Greenland (10).

we evaluate the relevant CTS literature in terms of the following four major threats to (internal) validity: (i) selection bias and temporal ambiguity, (ii) problems of case definition and identification, (iii) problems of exposure definition and measurement, (iv) and con-

founding. In addition, we consider several other criteria that reflect our ability to make scientific generalizations about causal associations (8, 31–34). Although we recognize the limitations in defining any set of causal criteria (31), we discuss the five criteria that

Table 5. Attributable fractions in the exposed population (AFE) for exposures and job titles above 0.50 in the diagnosis of carpal tunnel syndrome (95% CI = 95% confidence interval, NA = data not available)

Exposures/job titles	AFE	95% CI	Study
High force and high repetitiveness	0.94	0.41–0.99	Silverstein et al, 1987 (12)
High level vibration exposure > 10 h/week	0.93	0.82–0.97	Voog et al, 1985 (29)
Platers	0.91	0.50–0.98	Nilsson et al, 1990 (11)
Frozen food factory workers exposed to cold and repetition	0.89	0.58–0.97	Chiang et al, 1990 (24)
Activities with flexed wrist 20–40 h/week	0.89	0.68–0.96	De Krom et al, 1990 (30)
Grocery workers high exposure category	0.86	0.33–0.97	Osorio et al, 1989 (22)
Use of vibrating hand tools	0.86	0.67–0.94	Cannon et al, 1981 (26)
Vibration exposure	0.81	NA	Silverstein et al, 1987 (12)
Manual work and vibration	0.81	0.63–0.90	Voog et al, 1985 (29)
Activities with extended wrist 20–40 h/week	0.81	0.09–0.96	De Krom et al, 1990 (30)
Vibration exposure > 20 years	0.79	0.33–0.94	Wieslander et al, 1989 (25)
Repetitive movement of wrist	0.78	0.44–0.92	Wieslander et al, 1989 (25)
High-level vibration exposure 1–10 h/week or medium-level exposure > 10 h/week	0.77	0.47–0.89	Voog et al, 1985 (29)
Grinders	0.75	0.38–0.90	Nathan et al, 1988 (6)
Typist, keyboard	0.74	0.23–0.91	Voog et al, 1985 (29)
Medium-level vibration exposure 1–10 h/week	0.69	0.17–0.88	Voog et al, 1985 (29)
Activities with flexed wrist 8–19 h/week	0.67	0.44–0.80	De Krom et al, 1990 (29)
Assembly work	0.57	0.29–0.73	Nathan et al, 1988 (6)
Low force and high repetitiveness	0.63	0.70–0.96	Silverstein et al, 1987 (12)
Ski-manufacturing workers with repetitive jobs	0.57	0.09–0.79	Barnhart et al, 1991 (21)
Activities with extended wrist 8–19 h/week	0.57	0–0.81	De Krom et al, 1990 (30)
Repetitive work task	0.55	0.23–0.72	de Laval et al, 1985 (28)
Frozen food factory workers exposed repetition	0.55	0.80–0.95	Chiang et al, 1990 (24)
Repetitive motion task	0.52	0.17–0.81	Cannon et al, 1981 (26)
Pinch force	0.50	0.38–0.60	Armstrong & Chaffin, 1979 (27)

we believe are the most relevant to generalizing about the possible effect of physical work exposure on the occurrence of CTS: strength of association, consistency of results, coherence of evidence, experimental and laboratory support, and literature availability.

Selection bias and temporal ambiguity

A potential limitation of prevalence studies is that the time of disease onset among study cases is usually not known. Consequently, we cannot be sure that the exposure preceded disease occurrence, especially when the exposure is measured at the same time the disease status is observed. Even retrospective measurement of the exposure may not rectify this problem of "temporal ambiguity," since we seldom know the exact time of disease or symptom onset.

The problem of temporal ambiguity is the most likely to threaten the validity of a prevalence study when the disease or related symptoms can affect exposure status or when the disease can affect subject selection differentially through exposure status. In occupational studies, the latter phenomenon is a secondary form of the well-known "healthy-worker effect"; that is, exposed workers who develop symptoms of CTS or other conditions (in part because they are exposed) leave their jobs and are not selected for future studies of working populations. This type of selection problem, there-

fore, will probably lead to a negative bias in the estimation of the effect of physical work exposures on CTS. Thus prevalence findings are likely to underestimate the true exposure effect.

Problems of case definition and identification

In all of the studies selected for this review, the diagnostic criteria for CTS included both symptoms and signs. In most of the studies it was not clear what quality of symptoms or combination of symptoms was required to meet the case criteria. Median nerve distribution of symptoms was a case criterion used by most of the studies. The criteria for intensity and duration of hand symptoms to meet the case criteria may have differed among the reviewed studies. In studies in which the sign was a positive Phalen's or Tinel test, however, there may have been undetected cases in comparison with studies in which nerve conduction measurements were performed, and the sign was defined as median nerve conduction block. It has been reported that the sensitivity of the Phalen's or Tinel test is only 60–67% in comparison with electrophysiological nerve conduction block as the "gold standard" (35). De Krom et al (36) claimed that provocative tests do not distinguish between CTS and other causes of nocturnal hand complaints. This possibility could explain some of the variability between similar occupational

groups. We would urge scientists to use electrodiagnostic tests for CTS for case definition in future studies of CTS.

Problems of exposure definition and measurement

In the cross-sectional studies, exposure was defined by job title according to the employer's records. In the case-referent studies, the exposure was usually obtained by questionnaire or interview. There was no study in which direct exposure measurements were performed in the workplace for all of the study persons. Job titles and questionnaire data are crude indicators of exposure (37, 38). The variability of exposure definition (eg, job title criteria, posture and movement criteria) is probably great across different studies.

Confounding and individual susceptibility

Individual risk factors (individual indicators of susceptibility) can act as confounders of exposure effects. The most important confounders are age, gender, anthropometry, and other diseases.

The stress capacity of different tissues decreases with age, causing a shift of the stress-strain curve. The normal reparative and wound healing process is also slower with age. The duration of exposure is related to age. There is yet no study that has shown age as a risk factor for CTS when the duration of exposure is controlled.

The incidence rate of CTS is related to gender. A male-to-female ratio of 1:3 was described in a population study (39). There is yet no evidence for an increased female susceptibility for work-related CTS when exposure is controlled for. In a population-based incidence study of occupational CTS, the male-to-female ratio was 1.2:1 (40). In the study, by Silverstein et al (12), of CTS among industrial workers, no difference was observed between genders when exposure factors were controlled.

Carpal canal size is a controversial risk factor for CTS. There are different studies linking CTS with both small and large areas (15, 41). Other disorders associated with CTS are diabetes mellitus, myxedema, acromegaly, amyloidosis, fracture of the forearm, and the like. There is one report of a CTS prevalence of 11% for diabetes mellitus patients (42). For pregnant women an incidence of CTS of up to 25% has been reported (43, 44).

Most of these studies have taken into account possible confounding by age and gender. Would the other individual risk factors influence the inference of occupation and job tasks as risk factors for CTS? For example, Juntunen et al (45) questioned the association between vibration exposure and CTS, claiming that patients with neuropathic diatheses, who are at greater risk for CTS, tend to be selected into groups of patients with vibration syndrome. This phenomenon could be due to a detection problem (ie, workers with vibration exposure are likely to get more medi-

cal attention because of white fingers than unexposed workers do). If so, the frequency of CTS would be higher among exposed workers because of earlier diagnosis or detection in this group. However, this detection bias was not present in the cross-sectional studies in which the same diagnostic procedures were used for both the study and reference groups. Nevertheless, it is not likely that workers with neuropathic diatheses would be exposed to physical work load such as repetitive forceful gripping and vibration to a greater extent than would workers without this susceptibility. It is more likely, we believe, that the most susceptible workers would seek jobs with less physical workload exposure. Although exposure to physical workload factors can result in CTS as an early manifestation of a neurologic disorder in some workers (46), the frequency of such disorders is probably very low in worker populations (17, 47, 48).

Strength of association

The strength of association in the reviewed studies was generally high. There were three different studies reporting odds ratios greater than 10 for (i) high repetition and high force in the hands, (ii) vibration exposure, and (iii) occupation as a plater. Such large effects cannot be easily explained by any sources of bias (eg, a confounder), especially biases that were not evident to the investigators. Nevertheless it should be noted that even strong observed associations are not incompatible with spurious results.

Consistency of results

There was a surprising consistency of observed effects across the different cross-sectional studies, as well as between the case-referent studies and the cross-sectional studies. Occupational tasks or job titles associated with vibration exposure, repetitive hand movements, and forceful grips were reported in both the cross-sectional and case-referent studies as risk factors for CTS. Vibration exposure is probably an indicator of exposure to forceful repetitive gripping. In the study by Silverstein et al (12), the crude odds ratio for exposure to vibration was 5.3, but the odds ratio adjusted for high force and high repetition was only 1.9 (table 3). One inconsistency was noted, however. Butchers were reported to have a CTS prevalence of 53% in the study by Falck & Aarnio (14), but the 113 slaughterhouse workers (including 38 butchers) studied by Viikari-Juntura (18) had a reported prevalence of only 1% (one case with the job title cutter). One explanation for this inconsistency is that CTS was defined by symptoms and nerve conduction measurements, which may be a more sensitive indicator of CTS, in the Falck & Aarnio study. If one considers only symptoms and a positive Phalen's test in the Falck & Aarnio study, the prevalence would drop from 53 to 12% (exact 95% confidence interval 1–36) (14). Furthermore, the secondary healthy worker selection may have been

stronger in the Helsinki area, it being a metropolitan area with more job opportunities than in the smaller town of Pori where Falck & Aarnio performed their study. Thus the inconsistency could have been due to different diagnostic criteria, sociodemographic factors, or chance.

The issue of temporality, which means that the exposure precedes the onset of the disorder, was not demonstrated in all of the studies. In the investigation by Nilsson et al (11) the observed latency (duration between onset of exposure and symptoms) for CTS was reported. In the study by Silverstein et al (12), only disorders that developed after the onset of exposure were considered. In most of the other studies it was not clear whether all registered exposure preceded the onset of symptoms. In future studies of CTS we would urge investigators to explore the temporality of CTS and to establish exposure-latency time relationships.

Coherence of evidence

An exposure-response relationship was reported in several studies. For example, Silverstein et al (12) found that both repetition and force were predictors of CTS and, if both exposure factors were present, the risk of CTS was even greater. Repetition and force can be regarded as two components of biomechanical stress exposure. In the study comparing platers with office workers, the risk of CTS increased with the number of years exposed to vibration (11). In the case-referent study of Wieslander et al (25), there were progressive trends in the odds ratios with the number of years of use of handheld vibrating tools and repetitive movements of the wrist. In the studies of Silverstein et al (12), Cannon et al (26), and Chiang et al (24), however, the number of years on the job was not a predictor of CTS. One explanation for this inconsistency may be that only certain individuals are at risk of developing CTS and the latency for these individuals is relatively short when they are exposed to hazardous physical work load. Thus cumulative exposure may not be an important predictor of CTS.

Experimental and laboratory support

There are experimental studies on humans that support the causal relationship between ergonomic factors and CTS. Exposures are likely to affect the median nerve both directly through mechanical stress (eg, stretching and compression) and indirectly through ischemia causing paresthesia or a nerve conduction block. A localized pressure greater than 50 mm Hg (≈ 6666 Pa) in the carpal tunnel or a tourniquet with a pressure higher than systolic around the upper arm will cause a conduction block in the median nerve at the wrist (44). Extreme flexing or extension of the wrist causes an increase in pressure in the carpal tunnel that can affect the blood perfusion of the median nerve (49, 50). The histopathology of CTS shows coherence with the epidemiologic evidence for physical work load as

a risk factor. Microscopic studies of tissues in the carpal tunnel in wrist specimens reveal changes (eg, an increase in epineurium density) suggesting that repeated exertions with a flexed or extended wrist are involved in the etiology of CTS (51). These changes relate to mechanical pressure and perfusion of the median nerve.

Literature availability

Most of the studies considered in this review were cross-sectional investigations. All of the case-referent studies dealt with prevalent cases. There were no prospective cohort investigations. Furthermore, a review of the association between occupation and CTS is likely to be distorted by the fact that there is a tendency to publish positive findings rather than negative or equivocal ones. However, since data concerning the epidemiology of work-related musculoskeletal disorders is sparse, reports of negative or equivocal findings of CTS epidemiology are probably welcome in the journals. An example of an equivocal report is the study of slaughterhouse workers by Viikari-Juntura (18), who found only one case of CTS among 117 workers.

Concluding remarks

On the basis of epidemiologic and other evidence, we conclude that exposure to physical workload factors such as repetitive and forceful gripping is probably a major risk factor for CTS in several types of worker populations. At least 50%, and as high as 90%, of all CTS cases in these exposed populations appear to be attributable to physical work load.

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