

1 **INCIDENCE AND OPERATIONS OF CARPAL TUNNEL SYNDROME, ULNAR AND RADIAL**

2 **NEUROPATHIES IN FINLAND: NATIONWIDE REGISTER STUDY**^[A1]

3

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20

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32

33 **Abstract**

34

35 The aim of this study was to investigate the incidence rates and operations of carpal tunnel
36 syndrome, ulnar and radial neuropathies in the Finnish population. Patients diagnosed with
37 entrapment neuropathies of the upper extremity were identified from the Care Register for Health
38 Care, 2007–2016. There were 81,911 cases in 54,095,070 person-years. The total crude incidence
39 rates per 100,000 person-years among women and men were 196.5 and 104.8 for carpal tunnel
40 syndrome, 25.8 and 36.0 for ulnar neuropathies, and 5.7 and 8.5 for radial neuropathies,
41 respectively. Of these, carpal tunnel syndrome was operated on in 63% of women and 61% of
42 men, ulnar neuropathy in 43% of women and 47% of men, and radial neuropathy in 11% of
43 women and 7.7% of men. Incidence of carpal tunnel syndrome and ulnar neuropathies increased
44 up to late middle age, while radial neuropathies were less common.

45 Level of evidence: III.

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INTRODUCTION

50

51 Peripheral neuropathies of the upper extremity are common in the general population (Martyn
52 and Hughes, 1997), and their incidence rate peaks among the working-age population (Yves
53 Roquelaure et al., 2006). This might lead to loss of productivity at work (Martimo et al., 2009),
54 increased health care costs (Feuerstein et al., 1998; Juratli et al., 2010), work disability (Daniell et
55 al., 2009; Katz et al., 1998; Newington et al., 2018), and early retirement and disability pension
56 (Jensen et al., 2012).

57

58 More than half of carpal tunnel syndrome cases usually require surgical treatment (Verdugo et al.,
59 2008), and carpal tunnel release is one of the most common surgical procedures of the upper
60 extremity (Jain et al., 2014). If conservative treatment fails or the entrapment is moderate or
61 severe, surgery is needed in ulnar neuropathy too (Caliandro et al., 2016).

62

63 For carpal tunnel syndrome, previously published studies report an incidence rate of 233–376 per
64 100,000 person-years in the general population (Dieleman et al., 2008; Gelfman et al., 2009;
65 Mondelli et al., 2002; Nordstrom et al., 1998). The annual age-standardized rates per 100,000 [A2][A3]
66 new presentations of carpal tunnel syndrome in primary care were 87.8 among men and 192.8
67 among women based on the UK General Practice Research Database (Latinovic et al., 2006). A
68 recent study revealed that the incidence of first-time carpal tunnel syndrome per 100,000 person-
69 years was 104 among men and 232 among women in the general population in Sweden
70 (Tadgerbashi et al., 2019).

71

72 Ulnar neuropathy is the second most common entrapment neuropathy of the upper extremity,
73 with an incidence rate varying between 24.7 and 30.0 per 100,000 person-years (Mondelli et al.,
74 2005; Osei et al., 2017). Radial neuropathy is rare, with only very few studies reporting its
75 incidence rate in the general population. Based on the UK General Practice Research Database [A4][A5] the
76 annual age-standardized rates per 100,000 new presentations of radial neuropathy were 2.97
77 among men and 1.42 among women (Latinovic et al., 2006).

78

79 The aim of this study was to observe incidence rates of carpal tunnel syndrome, ulnar and radial
80 neuropathies in the whole population of Finland between 2007–2016, and to find out how often
81 they are operated on.

82

83

METHODS

84

85 **Study population**

86

87 The study population consisted of the whole population of Finland between 2007 and 2016. In
88 Finland, all citizens are assigned a personal identification code [A6] at birth or immigration by the
89 Population Register Centre. The personal identification code can be linked to other national
90 registers, including the Care Register for Health Care, which covers both public and private
91 hospitals in Finland. It identifies over 95% of hospital discharges and 80–99% of common
92 diagnoses (Sund, 2012). Healthcare in Finland is divided into health centers (primary care) and
93 hospitals (specialized care). In this study, we used hospital data covering both inpatient and
94 outpatient-based services in specialized care.

95

96 The diagnoses of entrapment neuropathies of the upper extremity are coded according to the
97 International Classification of Diagnoses (ICD), the ninth revision from 1987 to 1995 and the tenth
98 revision from 1996 onwards. The persons diagnosed with ICD tenth revision codes G56.0 for carpal
99 tunnel syndrome, G56.2 for ulnar neuropathy, and G56.3 for radial neuropathy and persons with
100 procedure codes ACC51 for carpal tunnel syndrome, ACC53 for ulnar nerve, and ACC52 for radial
101 nerve were identified; their gender, age, and year the diagnosis occurred for the first time, and
102 their age and year of the procedure were collected from 2007 to 2016. We only included new

103 incident cases. The Finnish population and population structure by age group were obtained from
104 Statistics Finland (OSF, 2008).

105

106 **Statistical analysis**

107

108 Incidences of carpal tunnel syndrome, ulnar and radial neuropathies were counted as cases per
109 100,000 person-years by dividing the number of new cases in each age group by the population of
110 that age group in Finland. Incidence rates were calculated for each year and both genders
111 separately. The mean incidence rates and the share of operations in 2007–2016 were calculated
112 by dividing the total number of diagnoses by the sum of the population in each age group
113 represented, separately for both genders and diagnoses. Risk ratios (RRs) between genders were
114 calculated. Age adjustment for the rates was carried out using the direct method with the
115 European Standard Population 2013 divided into 5-year age groups, stratified by gender as a
116 standard. The 95% confidence intervals (CIs) were estimated assuming the Poisson distribution of
117 the cases.

118

119

RESULTS

120

121 The annual crude and age-standardized incidence rates of carpal tunnel syndrome, ulnar
122 neuropathies, and radial neuropathies are shown in Table 1. Carpal tunnel syndrome was far more
123 common than ulnar or radial neuropathies, and more frequent among women compared to men
124 (RR=1.9). The total crude incident rate (in 2007–2016) of carpal tunnel syndrome was 196.5 per
125 100,000 person-years among women and 104.8 among men; the standardized incidence rates
126 were 197.2 and 107.9 per 100,000 person-years, respectively. Among both women and men, the

127 incidence rate increased up to the age of 50–59. Carpal tunnel syndrome was most frequent
128 among women aged 50–59 with an incidence rate of 418.0 per 100,000 person-years. Only in the
129 age group 90+ was the crude incidence rate almost equal among women and men.

130

131 Ulnar neuropathies were more frequent among men compared to women (RR=1.4). The total
132 crude and standardized incidence rates of ulnar neuropathies per 100,000 person-years were 36.0
133 and 36.1 among men, and 25.8 and 26.3 among women. The incidence of ulnar neuropathies
134 increased until the age of 50–59 years, and then decreased among both men and women. Ulnar
135 neuropathies were most frequent among men aged 50–59 years, with an incidence rate of 74.3
136 per 100,000 person-years.

137

138 Radial neuropathies were far less common. The total crude and standardized incidence rates of
139 radial neuropathies were 5.7 and 5.8 among women, and 8.5 and 8.6 among men per 100,000
140 person-years, respectively. They were more frequent among men compared to women (RR=1.5).

141 The peak incidence rate was found among 40–49-year-old men: 14.2 per 100,000 person-years.

142

143 The age- and gender-specific incidence rates and operations are shown in Table 2. A total of 65%
144 of the women diagnosed with carpal tunnel syndrome between 2007 and 2016 were operated.

145 Men reached nearly the same figure with an operation rate of 61%. Operations increased in the

146 older age groups among both genders, reaching a peak at the age group of 80–89 years among

147 women and the age group of over 90 years in men: 70% of women and 77% of men were

148 operated. In total, 47% of men and 43% of women diagnosed with ulnar neuropathies between

149 2007 and 2016 were operated. Operations increased up to late middle age in both genders. Half of

150 the women and men aged 50–59 and the men aged 60–69 years diagnosed with ulnar

151 neuropathies were operated. In total, 7.7% of men and 11% of women hospitalized for radial
152 neuropathies were operated. Operations in elderly patients were uncommon. Operations of radial
153 neuropathies were most frequent among women in the age group of 40–49 years with an
154 operation rate of 17%, while men of the same age had an operation rate of 13%.

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DISCUSSION

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161 Our study revealed that carpal tunnel syndrome is common in the Finnish general population. It is
162 more common among women. Among both men and women, the incidence of carpal tunnel
163 syndrome increases up to late middle age. A total of 65% of women and 61% of men diagnosed
164 with carpal tunnel syndrome were operated. Ulnar and radial neuropathies were less common.

165

166 Compared with previously published studies on the incidence rate of carpal tunnel syndrome, our
167 results were similar (Latinovic et al., 2006; Tadjerbashi et al., 2019). A recent study revealed that
168 the incidence of first-time carpal tunnel syndrome per 100,000 person-years was 232 among
169 women and 104 among men in the general population in Sweden (Tadjerbashi et al., 2019). Only a
170 few studies on the incidence of ulnar and radial neuropathies have been published, mostly limited
171 by small sample sizes or specific occupational groups (Jackson et al., 2019; Mondelli et al., 2006;
172 Pisquiy et al., 2019). In our study, the total crude incidence rate of ulnar neuropathies was 36.0
173 per 100,000 person-years among men and 25.8 among women. This finding is in line with those

174 reported in previous studies (Mondelli et al., 2005; Osei et al., 2017). Nearly half of the patients
175 diagnosed with ulnar neuropathies were operated (47% of men and 43% of women in total).

176

177 Our study reveals that the total crude incidence rate of radial neuropathies was 5.7 among
178 women and 8.5 among men. This is higher compared with a study from the UK, which reported
179 incidence rates based on diagnoses from primary care, also including patients with only mild
180 symptoms and those unwilling to visit a specialist at a hospital for any reason (Latinovic et al.,
181 2006). As radial neuropathies are challenging to diagnose even for hand surgeons, they might be
182 recognized better in our hospital-based data than in primary care data in which patients with such
183 rare conditions may be diagnosed with more unspecific codes. Even though they are more
184 common in the Finnish population, radial neuropathies were still rare, and the reliability of the
185 Care Register for Health Care diagnoses may not reach the excellent reliability and validity of
186 common diagnoses (Sund, 2012). In this register study it was not possible to identify Guyon's canal
187 syndrome and ulnar nerve entrapment at the elbow, and posterior interosseus nerve (PIN) or
188 sensory superficial branch (Wartenberg syndrome) as separate illnesses, since all the neuropathies
189 of the ulnar and radial nerves are coded under the same diagnosis codes. The incidence and
190 operation rates of these separate conditions remain unknown.

191

192 The proportion of operations due to carpal tunnel syndrome increased towards old age in this
193 study, while operations for ulnar neuropathies were the most common in working age. Operations
194 due to radial neuropathies were rare, and extremely uncommon among the elderly. As shown
195 before in another study from the UK, the severity of carpal tunnel syndrome may be greater
196 among the elderly than in younger patients (Bland and Rudolfer, 2003), and as surgery is needed
197 more often with more severe carpal tunnel syndrome (Verdugo et al., 2008), a higher proportion

198 of diagnosed cases of carpal tunnel syndrome may need surgery among elderly patients. The ulnar
199 nerve usually gets compressed at the elbow; one of the most common entrapment sites is the
200 proximal fascia of *m. flexor carpi ulnaris* (Andrews et al., 2018). As the peak incidence of ulnar
201 neuropathies is in working-age men with greater forearm muscle mass compared to women and
202 older men (Mondelli et al., 2005), ulnar neuropathies may cause more severe symptoms among
203 middle-aged men, especially those doing manual work (Fadel et al., 2017), and require surgical
204 treatment more often (Caliandro et al., 2016).

205

206 Our study included the whole population of Finland, including all age groups and all
207 socioeconomical groups. The Care Register for Health Care is a nationwide register covering all
208 healthcare in Finland, and has proven reliable, accurately recognizing 80–99% of the common
209 diagnoses (Sund, 2012). In primary care, suspected diagnoses are coded according to the same
210 codes as verified diagnoses, so we only used hospital data (specialized care). Thus, patients with
211 mild symptoms and those unwilling to seek specialized care may be unrecognized. In Finland,
212 diagnoses of carpal tunnel syndrome and ulnar neuropathies are usually based on both symptoms
213 and a neurophysiological examination, and a preoperative electrophysiological study has been
214 performed on all patients coming to a nerve entrapment operation. Thus, the diagnosis is based
215 on both ENMG and clinical findings, which should improve the diagnostic accuracy of hospital-
216 based data compared with primary care data.

217

218 Diagnosing radial neuropathies clinically can be challenging even for hand surgeons. Since we used
219 register data, errors in coding the diagnoses may lead to misclassification bias, especially with rare
220 diagnoses such as radial neuropathies, and reduce the epidemiological validity of our results.

221

222 The operations for entrapment neuropathies are coded as ACC51 for neurolysis of the median
223 nerve in carpal tunnel, ACC52 for any neurolysis of the radial nerve, and ACC53 for any neurolysis
224 of the ulnar nerve. These specific operation codes have been used in Finland since 2004, and
225 before that a non-specific code ACC59 for any neurolysis was used. During the first years after
226 introducing the specific codes for neurolyses, the non-specific code was used alongside them,
227 which may reduce the proportion of operations coded with the specific codes.

228

229

230 To conclude, this large register study of the whole population of Finland showed the incidence
231 rates and operations of carpal tunnel syndrome, ulnar and radial neuropathies over a ten-year
232 period.

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334 Table 1. Annual crude and age-standardized incidence rates per 100,000 person-years for carpal
 335 tunnel syndrome, ulnar and radial neuropathies by gender.

Year	Person-years	Carpal tunnel syndrome			Ulnar neuropathies			Radial neuropathies		
		Cases	Incidence rate		Cases	Incidence rate		Cases	Incidence rate	
			Crude	Standardized		Crude	Standardized		Crude	Standardized
Men										
2007	2,596,787	2,599	100.1	103.4	781	30.1	29.7	194	7.5	7.6
2008	2,611,653	2,697	103.3	106.7	875	33.5	33.5	200	7.7	7.7
2009	2,625,067	2,690	102.5	105.7	871	33.2	32.9	214	8.2	8.1
2010	2,638,416	2,760	104.6	108.6	950	36.0	36.1	232	8.8	8.8
2011	2,652,534	2,845	107.3	110.8	1,012	38.2	38.2	223	8.4	8.5
2012	2,666,622	2,782	104.3	107.6	931	34.9	35.3	214	8.0	8.1
2013	2,689,364	2,961	110.5	114.0	1,048	39.1	39.5	228	8.5	8.5
2014	2,691,863	2,868	106.5	109.7	1,061	39.4	40.0	252	9.4	9.5
2015	2,701,490	2,853	105.6	107.8	1,005	37.2	37.1	240	8.9	9.2
2016	2,712,327	2,794	103.0	105.3	1,022	37.7	37.7	268	9.9	10.0
Total	26,577,123	27,849	104.8	107.9	9,556	36.0	36.1	2,265	8.5	8.6
Women										
2007	2,703,697	5,183	191.7	191.3	556	20.6	20.6	125	4.6	4.7
2008	2,714,661	5,530	203.7	204.3	622	22.9	23.1	123	4.5	4.5
2009	2,726,360	5,414	198.6	199.1	581	21.3	21.5	146	5.4	5.4
2010	2,736,860	5,500	201.0	201.7	710	25.9	26.6	146	5.3	5.5
2011	2,748,733	5,213	189.7	190.2	664	24.2	24.8	147	5.3	5.3
2012	2,769,052	5,238	189.8	190.2	752	27.2	27.7	184	6.7	6.8
2013	2,770,906	5,618	202.7	204.6	809	29.2	30.0	161	5.8	6.0
2014	2,779,890	5,426	195.2	197.2	859	30.9	31.7	188	6.8	6.9

2015	2,785,818	5,422	194.6	196.0	787	28.2	29.0	171	6.1	6.3
2016	2,790,970	5,518	197.7	198.8	767	27.5	28.0	175	6.3	6.2
Total	27,517,947	54,062	196.5	197.2	7,107	25.8	26.3	1,566	5.7	5.8

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339 Table 2. Age- and gender-specific crude incidence rates (95% confidence intervals, CI) per 100,000
 340 person-years and proportion of operations for carpal tunnel syndrome, ulnar and radial
 341 neuropathies from 2007 to 2016.

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	Carpal tunnel syndrome		Ulnar neuropathies		Radial neuropathies	
	Incidence rate (95% CI)	Operations, %	Incidence rate (95% CI)	Operations, %	Incidence rate (95% CI)	Operations, %
Men						
0-19	2.3 (1.9-2.7)	30	2.9 (2.5-3.3)	23	1.2 (1.0-1.5)	6.5
20-29	41.1 (39.0-43.2)	52	19.1 (17.6-20.5)	40	7.3 (6.4-8.2)	4.7
30-39	99.8 (96.6-103.2)	59	35.8 (33.8-37.8)	44	10.4 (9.3-11.5)	11
40-49	162.8 (158.6-166.9)	59	60.8 (58.2-63.3)	47	14.2 (12.9-15.4)	13
50-59	208.7 (204.1-213.3)	61	74.3 (71.6-77.1)	50	13.3 (12.2-14.5)	7.7
60-69	137.2 (133.3-141.2)	65	47.8 (45.5-50.2)	52	10.0 (8.9-11.0)	2.4
70-79	175.9 (169.9-181.9)	67	37.8 (35.0-40.6)	47	8.6 (7.3-9.9)	2.5
80-89	147.5 (138.9-156.0)	70	21.4 (18.1-24.6)	45	7.9 (5.9-9.9)	0.0
90-	62.8 (45.9-79.8)	77	5.9 (1.9-13.8)	40	4.7 (1.5-11.1)	0.0
Total	104.8 (103.6-106.0)	61	36.0 (35.2-36.7)	47	8.5 (8.2-8.9)	7.7
Women						
0-19	5.4 (4.8-6.0)	29	2.5 (2.1-2.9)	26	0.6 (0.4-0.8)	11
20-29	81.2 (78.1-84.3)	52	16.7 (15.3-18.1)	29	3.8 (3.2-4.5)	11
30-39	198.0 (193.3-202.9)	60	30.7 (28.8-32.6)	40	7.1 (6.2-8.0)	16

40-49	311.2 (305.4-317.1)	64	47.9 (45.6-50.2)	45	10.1 (9.0-11.1)	17
50-59	418.0 (411.4-424.5)	66	50.0 (47.7-52.2)	47	9.4 (8.5-10.4)	14
60-69	217.3 (212.5-222.2)	66	27.8 (26.1-29.5)	46	5.4 (4.7-6.2)	4.1
70-79	271.9 (265.3-278.5)	68	25.8 (23.7-27.8)	43	5.8 (4.8-6.8)	2.2
80-89	230.0 (222.3-237.8)	70	14.0 (12.1-15.9)	42	7.5 (4.8-8.9)	0.9
90-	69.3 (59.9-78.8)	67	6.1 (3.6-9.6)	28	6.1 (0.9-2.3)	0.0
Total	196.5 (194.8-198.1)	65	25.8 (25.2-26.4)	43	5.7 (5.4-6.0)	11

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