Digital nerve injuries: Epidemiology, results, costs, and impact on daily life.

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Running title: Digital nerve injuries

Original paper

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Abstract

Epidemiology, results of treatment, impact on activity of daily living (ADL) and costs for treatment of digital nerve injuries have not been considered consistently. Case notes of patients 0-99 years of age living in Malmö municipality, Sweden that presented with a digital nerve injury and that were referred to the Department of Hand Surgery 1995-2005 were analyzed retrospectively. The incidence was 6.2 /100 000 inhabitants and year. Most commonly men (75%; median age 29 years) were injured. Isolated nerve injuries and concomitant tendon injuries were equally common. The direct costs (hospital stay, surgery, outpatient visits, visits to a nurse and/or a hand therapist) for a concomitant tendon injury was almost double compared to an isolated digital nerve injury [6136 EUR (range, 744-29689 EUR) vs 2653 EUR (range, 468-6949 EUR)]. More than 50 % of the patients who worked were injured at work and 79 % lost time from work [median 59 days (range 3-337)]. Permanent nerve dysfunction for the individual patient with ADL problems and subjective complaints of fumbleness, cold sensitivity and pain occur in the patients despite surgery. We conclude that digital nerve injuries, often considered as a minor injury and affect young people at productive age, cause costs and disability. Focus should be directed against prevention of the injury and to improve nerve regeneration from different aspects.

Key Words: Digital nerve, nerve repair, incidence, epidemiology, costs, outcome

Introduction

Digital nerves are the most frequently severed peripheral nerve [1] and a transection of a digital nerve deserves surgical attention. Though small in size they are of critical importance since they provide us with discriminatory touch from the finger pulps. Lack of sensation may dramatically reduce hand function and dexterity, but also exposes the fingers to a variety of lesions, such as burns and wounds. A non-sensate hand, if not guided by vision, is a "blind" hand.

Protective sensation does not return in affected skin if nerves are left unrepaired; in worst case a painful neuroma may occur. Evidence based on published results favors primary repair, with the exception of untidy and contaminated wounds or crush injuries where secondary repair is indicated [2]. Microsurgical repair of digital nerve has been reported to give "satisfactory results", since a normal or good two-point discrimination can be obtained in about half of cases, while sensation improves in the rest [3]. The age of the patient and the severity of the associated trauma are factors known to affect the quality of sensory recovery, where full recovery is to be expected only in children. Avulsion injuries always results in poor return of sensation. Patients older than 40 years have a significantly poorer recovery of sensibility than patients younger than 40 years [3-12]. In adults even a digital nerve injury, by definition a minor injury, may cause costs for society in terms of sick-leave. More importantly, the injury may have an impact on the patient's daily activities with a profound effect on leisure activities. However, the incidence, costs and impact on ADL of digital nerve injuries have not previously been studied sufficiently in a well defined population in a specific geographical area.

In this retrospective study, we aimed to analyze the epidemiological pattern of digital nerve injuries, factors that influence the risk of such an injury, costs for treatment and loss of production, i.e. sick leave, and results, eg. impact on ADL, in a specific geographical area in Sweden (Malmö municipality).

Material and Methods

Malmö is the third biggest city in Sweden with 274022 inhabitants (2006-2007). The working population is mainly engaged in private services (34 %), public services (30 %), trade and communications (24 %) or manufacturing industries (12 %) (www.malmo.se). Acute and elective hand surgery, with few exceptions, is performed at the city's only hospital. All patients living in Malmö at the time of the assessment of the injury, 1995-2005, with a clinical digital nerve injury that were referred to the Department of Hand Surgery, Malmö University Hospital, Sweden, were included in this retrospective study. All patients underwent end to end surgery with epineurial sutures. Patients were defined from the administrative system at the hospital using the ICD codes 833 (all letters), 955 F, G, H, W, 907 E, X 1987-1997 and S64.3, S64.4, S64.7, T92.4 1998-2005.

Exclusion criteria were digital nerve injuries occurring with fractures, amputation injuries and/or injury at the same occasion to proximal parts of the median, and/or ulnar nerves, since this type of injury was regarded to override the impact of the injured digital nerve. Case notes were collected and analyzed retrospectively. Information, i.e. age, gender, affected nerve, level, extension, type of injury, place for injury, handedness, employment, sick leave, operation time, ward days, number of outpatient visits and sessions of physiotherapy, was extracted from the patients case notes. Data regarding results, subjective and objective, were also collected from those patients where medical certificates were issued more than one year after the injury and repair.

Direct costs were calculated using the administrative prices paid by any referring hospital to the Department of Hand Surgery in year 2009. Costs are calculated based on the

average exchange rate of year 2009 (the Swedish Central Bank, www.riksbanken.se). The cost for one ward day was estimated to 744 EUR, for one outpatient visit to a doctor 167 EUR, and for one visit to a nurse or hand therapist 68 EUR. Costs for emergency surgery were 26 EUR/ operation minute and for elective surgery 13 EUR/operation minute. All mentioned costs are expressed as median (range) unless otherwise specified. The study was approved by the Ethical committee at Lund University.

Results

Demographic data

During the study period a total of 194 patients with a digital nerve injury were identified from the administrative hospital system. Eighteen case notes could not be found leaving 176 patients for analysis; 132 men and 44 women (Figure 1). The incidence of a digital nerve injury was calculated to 6.2 /100 000 inhabitants and year during the study period but with a slight variation from year to year. The median age at time of injury was 29 years (range, 1-80 years; Figure 2a).

Place and cause of injury

The patients were almost equally injured at home (n=59), during leisure time away from home (n=51), and at work (n=48) (data missing in 18 cases). The cause of injury was dominated by knife (n=70), followed by glass (n=54), other tools (n=22), others, i.e. “broomstick”, “fridge” (n=15), sheet metal (n=10) and dog bite (n=2) (data missing in 3 cases). Injury as a result of violent crime was reported in 15 cases for men and 2 for women. Information about patients under influence of alcohol at the time of the injury was found in 11 male cases and in one female.

Dominant hand, site, level and extension of injury

Ninety-nine patients were right-handed, 6 left-handed and 3 double-handed, while in 68 of the cases notes this information was not specified. The left hand was affected in 108 cases and the right in 68.

In patients, where information about dominant hand was found, the dominant hand was involved in 38 % of the injuries. The index finger was affected in 37 % of the patients, followed by the little finger in 23 % and the thumb in 22 % of the patients (Figure 2b). Two digits were affected in 12 cases. The most common level of injury was the basal phalanx in 44 % and distal to the basal phalanx in 44 %; the remaining twelve were located proximal to the mcp joint. The ulnar side was affected in 52 %, and the radial side was affected in 43 %. Both sides were affected in 5 %. Isolated nerve injuries (44 %) and concomitant flexor tendon injuries (45 %) were equally common. In eight (5 %) cases the nerve was not transected, but was classified as a contusion. In the remaining 6 % there was a mixture of extensor tendon and ligament injuries combined with a nerve injury.

In 126 cases the nerve was totally transected, with a concomitant injury to the artery in at least 24 cases. Eighteen patients had a partial nerve transection estimated to 50-99 % of the diameter of the nerve, while 32 patients had a partial injury less than 50%.

Surgical procedure, duration, patient's delay, ward days and outpatient visits

One hundred twenty-three patients were examined by a hand surgeon the same day as the injury had occurred and an additional 40 patients the day after. The remaining 13 patients were

examined later; 9 patients during the first month, 3 patients between 2 months and one year and one patient six years after injury.

Ninety four of the patients underwent surgery at the same day as the injury, and 62 patients the following day. In 2 patients the operating time was unknown. The remaining 20 patients underwent surgery later; 12 patients during the first month, 4 patients during the second and third month. Four outliers underwent surgery 12 months, 18 months, 5 years and 6 years after the injury. Seventeen patients underwent a second operation. Eight of those being children where their bandages were changed and the rest were patients with a concomitant tendon injury where the results were not satisfying. The duration of surgery was median 55 minutes when surgery was done within 24 hours (range 12-482 minutes), and, children excluded, 52 minutes when performed as elective surgery (range, 10-403 minutes). In all procedures that required nerve sutures an epineurial technique was used.

One hundred thirteen patients stayed at the ward, while 63 patients were only treated at an outpatient basis. The median stay at the hospital was two days (range 1-17). The median number of outpatient visits was 4 (range 1-21). One hundred patients visited a hand therapist for rehabilitation; median 4 times (range 1-25).

Occupation and length of sick leave

Seventy seven patients worked at the time of injury, 13 were retired, 16 were unemployed, 21 were students (upper secondary school or university) and 27 were children (defined as below the age of 15; Figure 2). In 20 cases the occupation was not specified. Among the 7 patients that were 16-18 years of age, 6 were students and one worked.

Seventy nine percent of the patients (n=70) who worked at the time of injury lost time from work. The median length of sick leave in the working group was 59 days (range 3-337 days). Among the unemployed, 50 % could not take a work immediately and had a median sick leave of 64 days (range 30-614 days). There was no difference (MW p=0.47) with respect to length of sick leave between those who worked (47% had a single digital nerve) and the unemployed (38% had a single digital nerve) patients. Generally, those with a concomitant tendon injury had a significantly (MW p=0.001) longer sick leave than those with a single digital nerve injury.

Forty-five out of fifty patients returned to the same workplace fulltime as before the injury (one working only 70 % of time). One patient had to change workplace due to the injury, and 4 patients did not return to work at all. In thirty eight case notes this was not specified (Figure 1).

Results of repair

Nineteen percent (n=34) of the patients received a certificate of invalidity requested by an insurance company. Ninety-one percent complained about reduced function at work although working fulltime. Seventy-one percent had an impact on their leisure time activities and problems with their activity of daily living (ADL). Seventy-nine percent was tormented with cold sensitivity and 97 % had trouble with fumbleness. Fifty-six percent complained about a constant mild to moderate pain. Five patients had no return of protective sensation at all. On the damaged side two point discrimination (2-PD) was on average 12 mm (range, 4->20), compared to 4 mm on the undamaged side (range, 3-10 mm). Grip strength (Jamar, kg) on the damaged side was on average 73 % of the healthy side.

Costs

The costs for the patients institutional care, i.e. ward days were 1892 EUR/patient (range 946-16079 EUR). The costs for outpatient visits were on average 672 EUR/patient (range 168-4537 EUR). Surgery performed within 24 hours cost 1415 EUR/patient (range 309-12404 EUR). Elective surgery cost 528 EUR/patient (range 103-5186 EUR). Of the patients visiting a nurse the cost was 68 EUR/patient (range 68-271 EUR), and to a hand therapist 271 EUR (range 68-1695 EUR).

In total, the median direct health care costs (hospital stay, clinical visits, surgery and rehabilitation) were calculated to 3936 EUR/patient (range 472-33184 EUR). The median health care costs for an isolated nerve injury was approximately half of the cost for a concomitant tendon injury; 2741 EUR (range 472-8165 EUR) compared to 5403 EUR (range 946-33184 EUR).

Figure 3a illustrates the distribution of mean costs by type of resource use for isolated nerve injuries (n=77), nerve injuries with concomitant tendon injury (n=83) and the group other (n=16). Costs of surgery and inpatient stay were the dominant source of costs, while 5% or less was costs of nursing and rehabilitation visits.

Figure 3b shows the distribution of total costs by place of injury. Work-related injuries occurring indoor were the most costly, both in terms of health-care costs and costs of lost production. Costs of lost production were also greatest in relative terms amongst work-related injuries (indoor 63%; outdoor 66%), while injuries at home or during leisure time were associated with shorter duration of sickness absence and lower costs. The median costs of lost

production from work were EUR 6361 (IQR 723-10220) for indoor work and EUR 4845 (IQR 728-10386) for outdoor work (Table 1).

Regression analysis of total costs identified a significant association between total costs of digital nerve injuries and age of the patient (Table 2). Costs were increasing by age, but at a diminishing rate. Patients who underwent surgery 1-3 days after the injury had lower costs compared to persons who underwent surgery on the day of injury. Also, costs were significantly lower for persons who underwent surgery more than three weeks after the injury.

Discussion

To our knowledge no previous epidemiological study concerning traumatic injuries to digital nerves, with or without a concomitant tendon injury, including costs for treatment and amount of loss of production, i.e. sick leave, has been reported. We retrospectively analyzed these factors in patients from our department 1995-2005. We found that the incidence of a digital nerve injury in a moderate sized city (Malmö, Sweden) is 6.2 / 100000 inhabitants and year. The incidence of hand injuries in general varies between different countries, ranging between 6 and 36/1000 inhabitants/year, but tendon and nerve injuries are rare comprising only 0.3-3% of the cases [13]. If the incidence is essentially the same in Western countries there would be around 18 600 and 28 300 new cases of digital nerve injuries every year in US and in the European community, respectively. These cases, even if it is considered as a minor injury, would cause considerable costs for the society. The incidence found in this study, and the comparatively high frequency of young males, is in accordance with previous studies on hand trauma [13]. The majority of patients are men with either an isolated digital nerve injury or an injury combined with a flexor tendon injury. The reason why there appears to be a gender difference is not completely obvious, but males seem to have occupations with more manual

activities. Furthermore, during the last decades reconstruction of homes in Sweden, done by the owners during leisure time, seem to be more common and supposedly mainly done by men.

The patients were almost equally injured at home, during leisure time and work. This is interesting since data from 50 years ago suggests that roughly half of the hand injuries occurred at work, and less than 1 % during leisure time [14]; thus indicating a significant decrease in work related injuries [15]. These changes are most probably related to improved protective procedures at companies and factories supported by labour unions and the Swedish government. When patients have worked on their own, for example in reconstruction of their own house, certain protective procedures are probably not performed since it is only regulated by law in a workplace.

Of the 77 patients who worked, 49% were injured at work causing loss of production, i.e. sick leave; varying between 3-337 days. Twenty-three patients had sick-leave due to an injury that occurred in workplace. Such injuries may be even more severe than the generally injured patients as these more often increase the risk for admission to the hospital as reported earlier [15]. Although a digital nerve injury is considered to be a "minor" hand injury, it still causes costs for the society and loss of considerable productivity since most of the patients are of productive age. Unemployed had a median sick leave of 60 days, which was not different from the employed patients (56 days), although the latter had more often a single digital nerve injury (38% and 47%, respectively). One hypothesis before our study was that there could be secondary benefits of disease as the numbers of paid days of unemployment are restricted, but does not include unemployed days on sick leave. However, this was not the case. Numerous

other factors could be considered and may be relevant in discussion of the Swedish social insurance care system. How digital nerve injury causes reduced capacity of search for employment in so many cases is also unclear.

In patients with a median and an ulnar nerve injury, 87 % of the cost are due to lost production [13,16]. Analyses are currently done regarding the loss of productivity, i.e. the costs that are induced by the sick leave. It is possible, based on the median earnings of individual objects occupation, to calculate such costs and add those to the direct health care costs thereby better reflecting the costs for society. Costs were calculated in the present study. The results indicated that if a concomitant flexor tendon injury was present the costs were twice as high as after a single digital nerve injury. Interestingly, costs were higher after work-related injuries occurring indoor and with costs of lost production approaching 63-66 % of the total costs. This indicates that a digital nerve injury, with or without a flexor tendon injury, have relatively lower costs for lost production, which is understandable due to its less impact on hand function compared to a median or ulnar nerve injury.

The digital nerve injuries induced impaired ADL function and subjective complaints of cold sensitivity, fumbleness and mild to moderate pain in at least thirteen percent of the patients, despite surgical treatment. According to Meiners et al. [17], it is concluded that digital nerve lesions have little consequence on the ability to return to work and the time off work compared to more proximal injuries. In their study 2 of 37 patients did not return to work at all, and 92 % returned to work within one year. In our study, information regarding further employment was available in 50 case notes, and out of these 4 patients did not go back to work, i.e. 92 % actually went back. However, we miss information about the remaining 38

patients. A source of error concerning this material could be that only in the most severe cases further employment was mentioned in the case note. Primary repair within 24 hours was done since it gives better outcome, measured by 2-point discrimination, light touch, stereognosis and sweating activity [2], and is, due to technical reasons, easier to perform. However, the range of time for "primary" repair is not specified in earlier studies. From the neurobiological point of view some factors point to a better axonal regeneration if the nerve is repaired within 14 days [18-22]. A report by Sullivan et al [23], states that immediate repair do not allow better recovery than repair within six days [23]. Nor did Weinzweig et al [5] find any significant difference in recovery of sensibility according to time interval from injury to repair [5]. Interestingly, the regression analyses indicated that the patients that were operated on the same day had higher costs, which may signify that these injuries were considered to be potentially more severe. Generally, digital injuries are repaired within a few days since the risk for infection of the wound increases if repaired 3-6 days after injury. If this would show applicable to the above given data, this implies that the cost for surgery could be cut to approximately 52 % as the cost for emergency surgery per minute is twice that of elective surgery and the mean time consumption 4.5 minutes longer. This calls for further investigation, and if the hypothesis that there is no difference in outcome between emergency and elective surgery (or possibly better results after a little delay), a change in modus operandi is imperative. In addition, recent data from experimental studies point to that a delay of three days does not impair axonal outgrowth after a repaired rat sciatic nerve injury (Dahlin and Forsberg, unpublished data). However, we do not know if the immediately operated cases that were acutely operated on were more serious, i.e. with repair of a tendon, which could explain the longer duration of surgery.

The study was retrospective with all limitations related to such type of study. Some sources of errors are unavoidable. The most important are presumably cases of digital nerve injuries that have not been diagnosed at all or for some reason have not received the right ICD10-code. Being a retrospective study of case notes, missing data are not always possible to obtain. We chose to analyze digital nerve injuries in a limited geographical area with an urban population of a middle-sized city in southern Sweden where most certainly almost all digital nerve injuries are treated at the same hand surgical unit. It was not relevant to use data from the register of the National Board of Health since this national register only includes the patients that are hospitalized. From our study we would probably miss 36% of the patients if the national register would have been used.

In conclusion, the incidence of digital nerve injuries in a middle-sized city is 6.2/100000 inhabitants and year, mostly affecting men. Even this type of injury, which is considered as a "minor injury", leads to losses in productivity when the patients are not able to perform there normal work tasks due to the hand injury and thereby costs for society. While the persons in the sick-leave allowances may compensate the patient for income losses the real cost to society is the value of the foregone production. Important for the individual patient is also the permanent nerve dysfunction for the individual patient with subsequent ADL problems and subjective complaints of fumbleness, cold sensitivity and pain. Therefore focus should be directed against prevention of the injuries and to improve nerve regeneration from different aspects.

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Figure legends

Figure 1. Flow chart of the patients in the study.

Figure 2. (a) Number of patients related to age at the time of the injury divided by gender. (b) Number of digital injuries (%) affecting the various fingers.

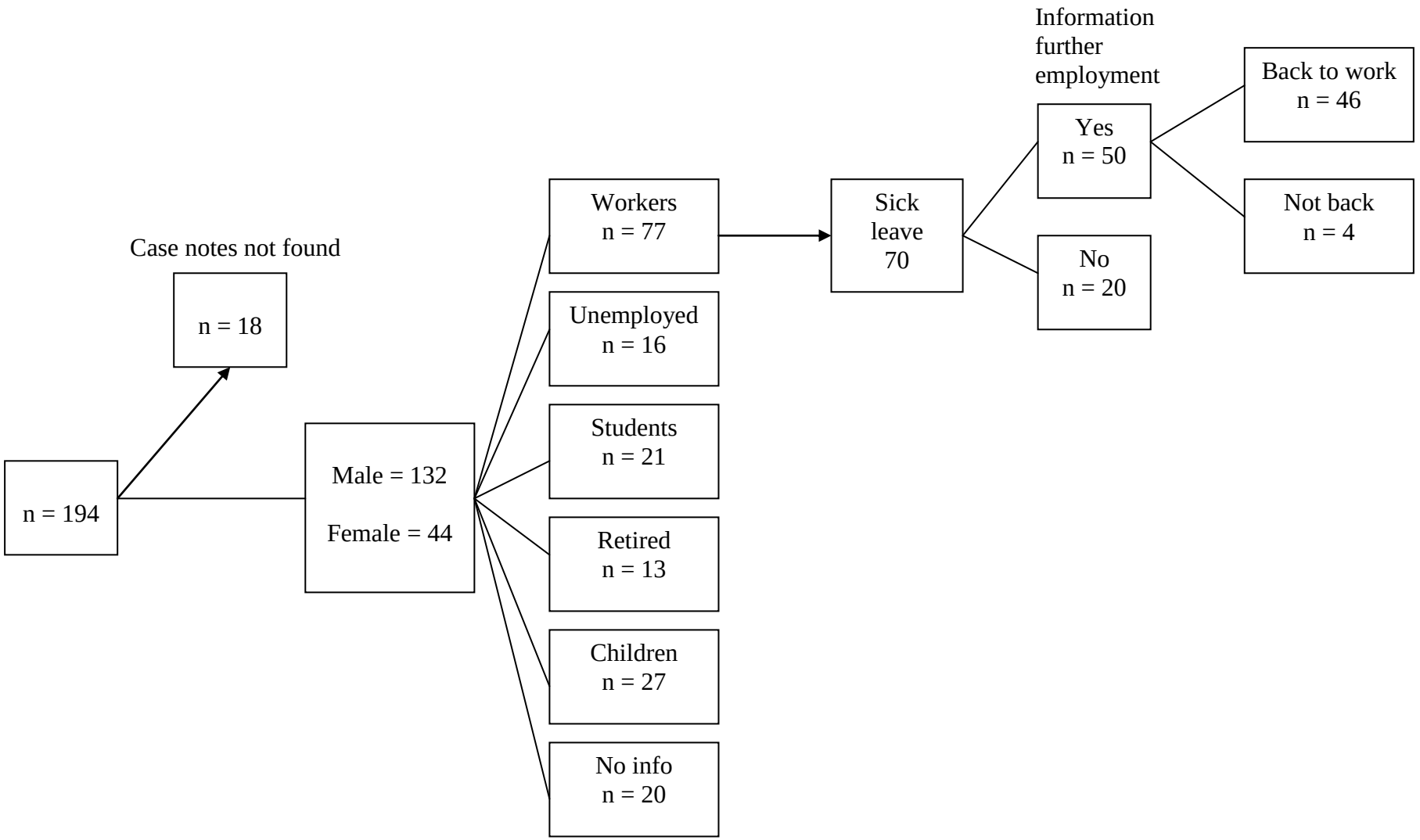
Figure 3. (a) Mean cost of health-care resources by type of injury (in EUR). (b) Mean costs of health-care resources and of lost production by place of injury.

Table 1. Costs of lost production by place of injury (expressed as EUR)

	N	Mean	Median	25 percentile	75 percentile
Outdoor work	16	5716	4845	728	10386
Indoor work	32	9007	6361	723	10220
Home	59	2383	0	0	0
Leisure	51	3255	0	0	0
Unknown	18	4650	0	0	5459

Table 2. Semi-logartihmic regression analysis of total costs after digital nerve injuries.

	Coefficient	p-value
Age	0.600	<0.001
Age square	–0.001	<0.001
Woman	–0.256	0.060
Type of injury		
Nerve (reference)		
Nerve + tendon	0.729	<0.001
Other	–0.169	0.354
Time between injury and surgery		
Same day (reference)		
1-3 days to surgery	–0.246	0.049
4-21 days to surgery	–0.238	0.384
Surgery more than three weeks after injury	–0.779	0.019
Constant	7.631	<0.001
N	173	
R-square	36.05	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Male = 132
Female = 44
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n = 77
Unemployed
n = 16
Students
n = 21
Retired
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Children
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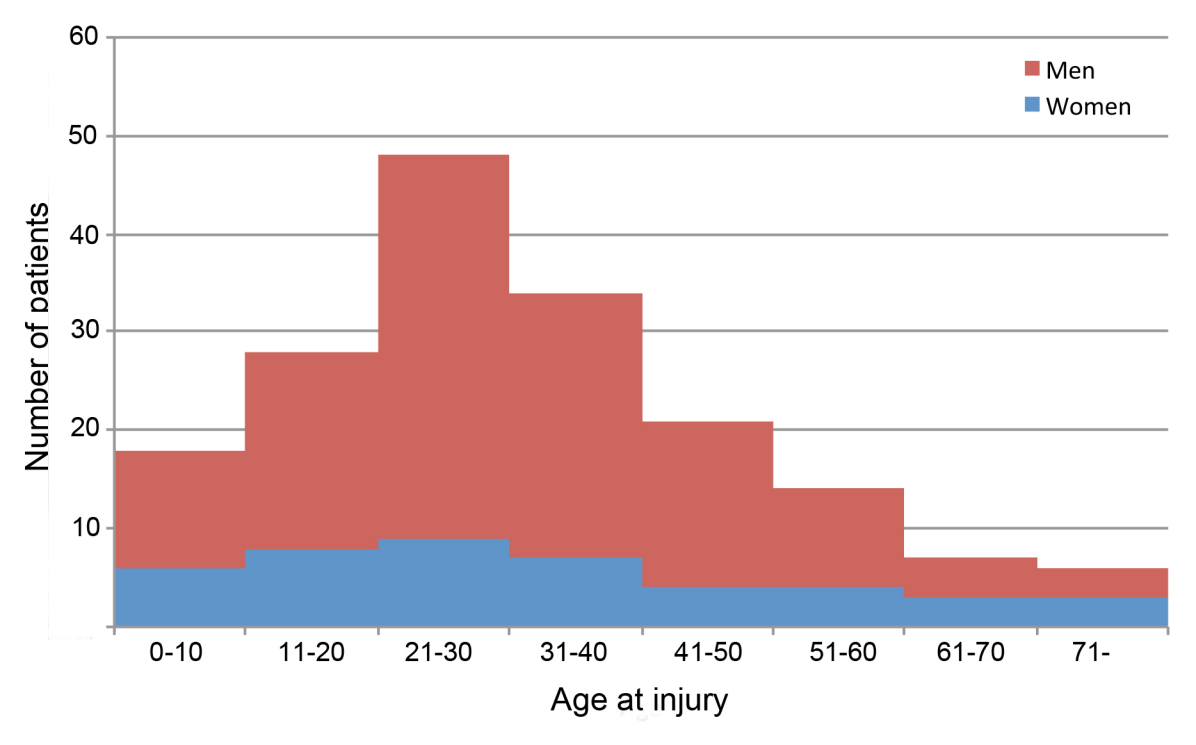
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Women
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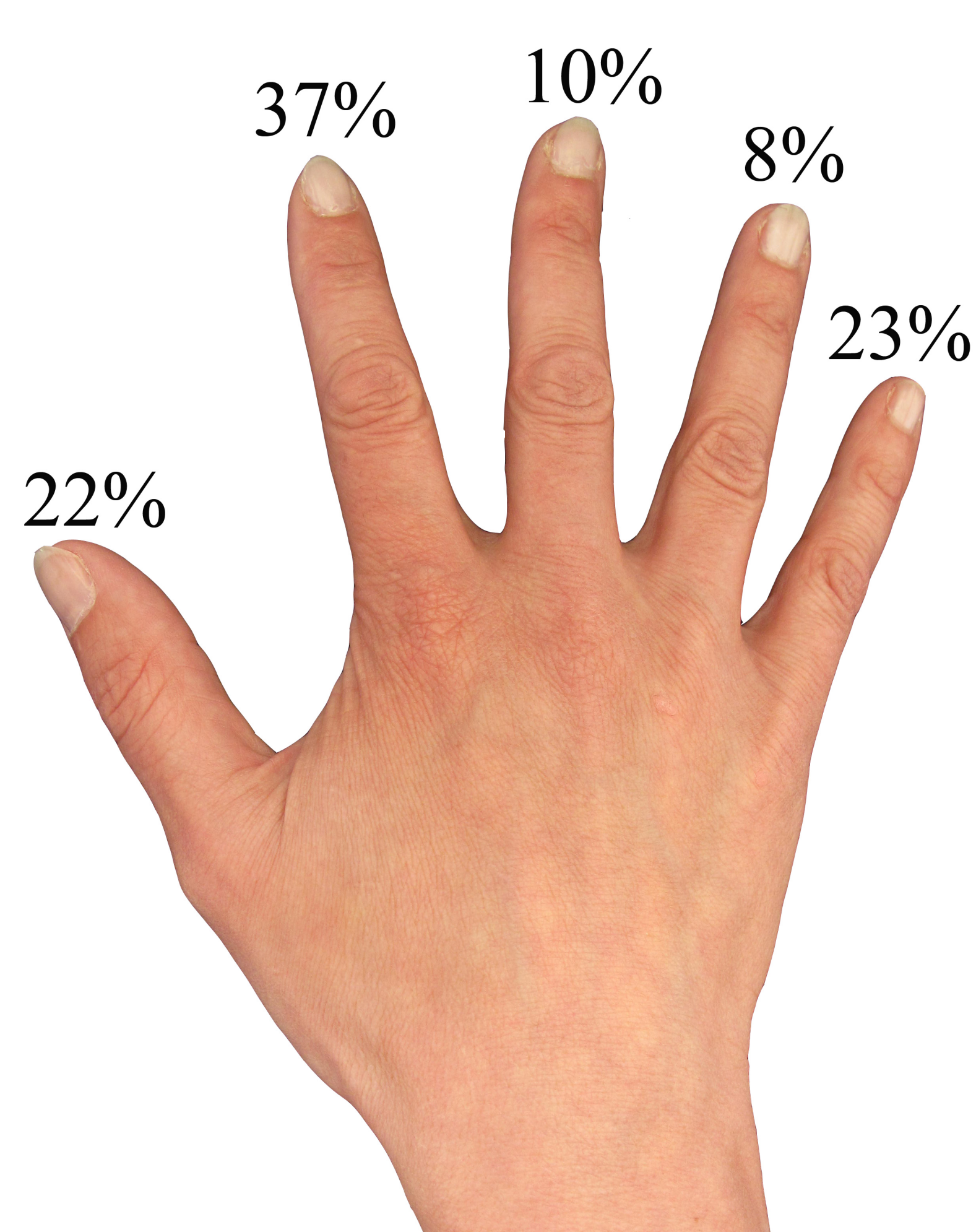
71-
Age at injury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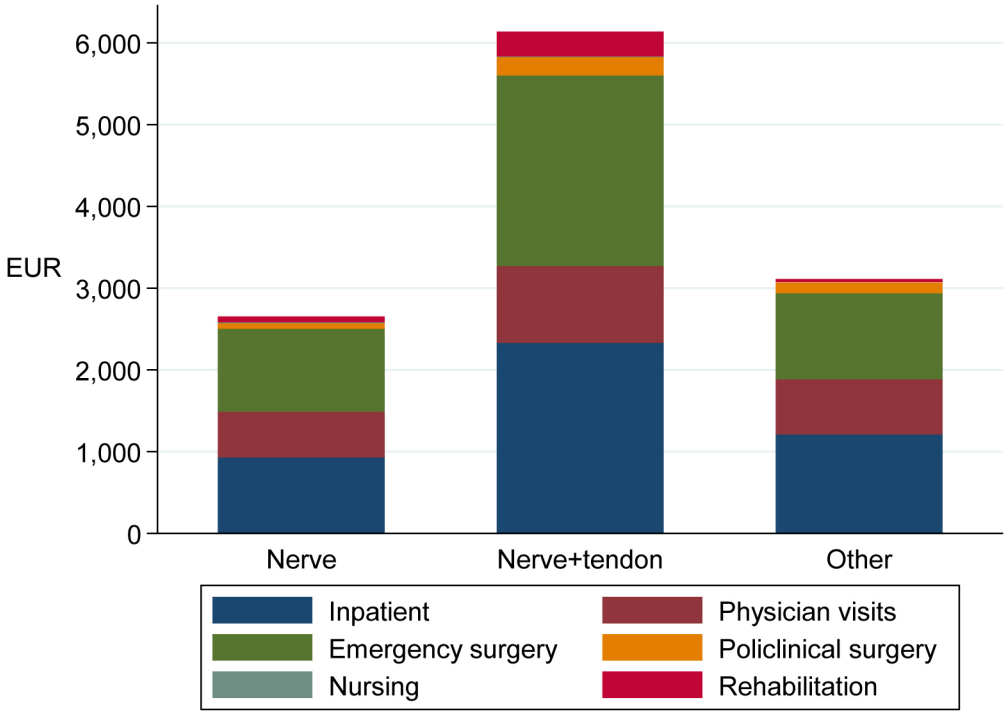
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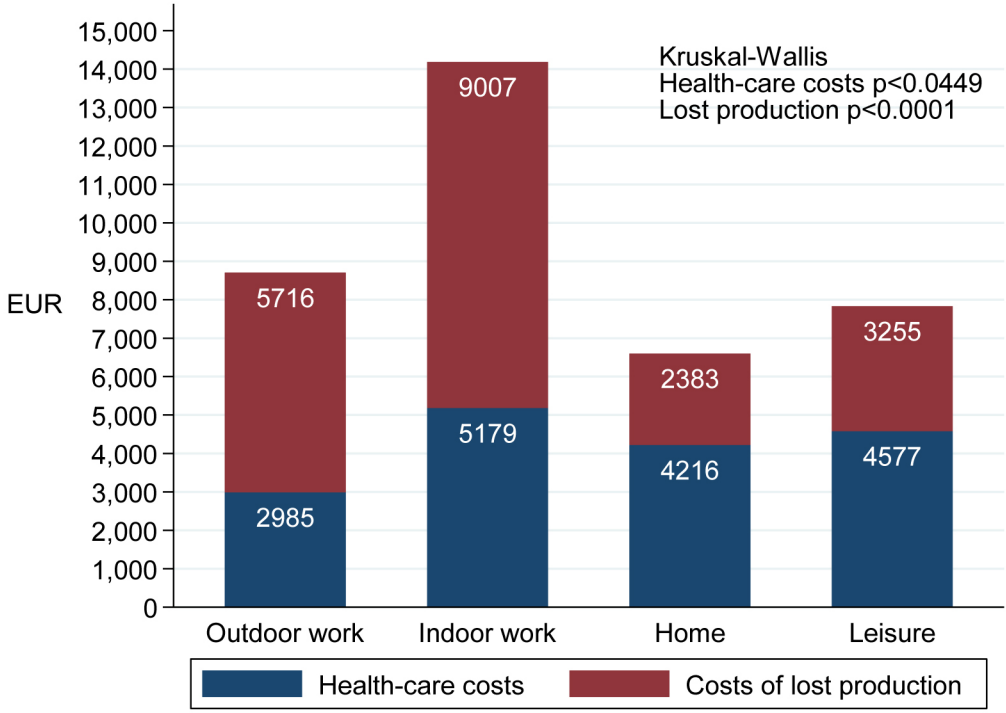
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Kruskal-Wallis
Health-care costs p<0.0449
Lost production p<0.0001
5716
2985
9007
5179
2383
4216
3255
4577
Outdoor work
Indoor work
Home
Leisure
Health-care costs
Costs of lost production