Accidents in family forestry's firewood production

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Abstract

Firewood is commonly used around the world, but little is known about the work involved in its production and associated accidents. The objectives were to identify relationships between accidents and: time exposure, workers' age and sex, equipment used and work activities in family forestry's firewood production. Data from a postal survey in Northern Sweden were compared to a database of injuries in the same region. Most accidents occurred to 50-69 year old men, who also worked most hours. No significant differences in sex and age were found between expected and recorded accident frequencies when calculated from total work hours; however, when calculated using numbers of active persons significant differences were found for both age and sex. Frequency of accidents per unit worked time was higher for machines involving activities than for other activities. Accidents that occurred when using wedge splitter machines were responsible for most of this overrepresentation. Fingers were the most commonly injured body parts. Mean accident rate for the equipment used was 87 accidents per million work hours, and the rate was highest for wedge splitters (122 accidents per million work hours). Exposure to elevated risks due to violation of safety procedures is discussed, as well as possible preventative measures.

Keywords: Accident ratio, Exposure, Work time, Wedge splitter, Axe, Saw.

1. Introduction

Firewood (defined here as solid wood, mainly from the tree trunk) is mankind's oldest energy source and is still extensively used around the world (Anon 2005; Röser et al. 2003; Warsco 1994). In Sweden, for example, firewood accounts for 21.6% of the energy used to heat detached houses (Statistics Sweden 2003) and 1.5% of the country's total energy consumption (National Board of Forestry 2005). In Australia, about 23% of the households use firewood (Driscoll et al. 2000).

Although some firewood is commercially produced in countries like Sweden and Australia, firewood production is principally a small-scale activity. Firewood production is normally prompted by possession of a residence that has a firewood-based heating system. The firewood needed is often produced by the consumer (Christiansen et al. 1993; Driscoll et al. 2000). This implies that work is self-paced and mainly conducted on a leisure-time basis. Further, there is no employer-employee relationship nor is there typically any government regulation of the work. Motives for its production include both economic and recreational factors according to Isachsen (1984). Driscoll et al. (2000) found that 84% of the timber used for firewood in Australia is obtained from private property. Thus, it is not surprising that firewood production has been assumed to be closely related with family forestry, i.e. with private individuals' ownership and management of forest land, since forest owners have free access to the raw material – the trees.

The work conducted on one's own forest property is called self-employed work, regardless of whether it is done for a living or for other reasons. In Sweden, self-employed forestry has a long tradition, rooted in the self-sufficient agrarian society of previous centuries (Törnqvist 1995). In recent decades, there have been substantial changes to many aspects of family forestry; inter alia the proportions of female and non-farming owners of forest land have increased, as have the proportions of owners who do not live on their properties (Lidestav and Nordfjell 2005). However, men over 50 years old are still predominant in Swedish self-employed family forestry (Lindroos et al. 2005). Firewood production has seldom been included in studies on self-employed family forestry work. However, recent research in Sweden has shown that the activity causes half the accidents in family forestry (Wilhelmson et al. 2005), and the numbers of relevant machine sales indicate that levels of firewood production are high in the country (Lindroos et al. 2005).

This study considers aspects of firewood production limited to the processes of transforming logs into appropriate pieces, including the storage and transportation of firewood to the burning facility (see Table 1). The work involved in harvesting trees and extracting the logs out of the forest is excluded.

Firewood production work is characterised by highly repetitive operations with simple, but potentially dangerous, equipment. Different kinds of equipment cut and split logs in different ways, and thus involve different sorts of risks. Cutting involves risks of cuts from rotating chains or blades, while splitting is associated with risks of crushing injuries from pressing or rotating components as well as cuts from split edges.

Accident prevention measures can include both technical solutions and safeguards. Firewood machines sold in Sweden since 1995 need to comply with European standards (EN 609-1; EN 609-2; EN ISO 11681-1; prEN 1870-6) that are designed to eliminate or reduce risks arising from machine use. Inter alia, the standards prescribe that the machines should be used by a single operator and that they should have safety features such as the wedge splitters' two-hand controls. Provided that operators comply with these stipulations, the machines are designed to ensure

operator safety. However, firewood production is believed to often be conducted by more than one person and accidents appear to be numerous and severe, especially to hands (Hellstrand 1989; Kristiansen and Seligson 1981; Larsson 1990; Wilhelmson et al. 2005).

Different activities in the firewood production process are associated with different levels of accident risk. Furthermore, age- and sex-related differences are likely to occur, in accordance with its recorded effects on accident rates in other situations (e.g. Laflamme et al. 1996; Massie et al. 1995). However, little is known about family forestry's firewood production in demographic terms and relative accident rates. Further, knowledge is scarce about the proportions of accidents associated with the various techniques used and, consequently, about the distribution of risk factors. The work is assumed to be performed during short, widely spaced periods of time, which has debatable consequences for accident risks. Low exposure times might statistically imply low accident probabilities, but has also been argued to increase rates of accidents per unit time worked due to a lack of practice in handling the seldom-encountered risks (Elvik 2006; Fischer et al. 2005; Weegels and Kanis 2000).

In order to increase knowledge of firewood production in family forestry in general and of related accidents in particular, two studies in Northern Sweden were conducted and the data were jointly analysed. Specific objectives were to identify relationships between accident rates and: time exposure, workers' age and sex, the types of equipment used and work activity. Further objectives were to calculate relative accident rates for specific work activities and equipment involved in family forestry's firewood production.

2. Material and Methods

2.1 Study region

The study targeted the Umeå region, consisting of a medium-sized Swedish city (Umeå) surrounded by five municipalities (Bjurholm, Nordmaling, Robertsfors, Vindeln and Vännäs). In each of these rural municipalities there is a commercial and administrative centre, but they are mainly characterised by small, scattered villages and forested land. The total number of inhabitants in the region was 142 000, 71 000 of whom resided in the city of Umeå, and the land area was 9372 km² (Anon 2006). The region was considered to represent typical Swedish conditions. Two surveys were conducted in the area, one focussing on firewood production and one focussing on occurred accidents.

2.2 Participants

2.2.1 Survey of firewood production

Chimney sweeping was compulsory by law throughout the period covered by the study and registers were held by companies with geographically distributed responsibilities for the sweeping. The registers in the region were searched for households with firewood heating systems, and the 11 498 households found were used as a sample frame. Simple random sampling was used to select 1500 households, to which a mailed questionnaire was sent in April 2006. The sample did not significantly differ from the sample frame with respect to either municipality or stove type proportions ($\chi^2 = 20{,}67$, d.f. = 23, $p = 0.60$). Fourteen households (1%) in the sample no longer existed and thus the 904 replies corresponded to a reply frequency of 61%. Compared to the sample, reply proportions were independent of municipality and stove type ($\chi^2 = 14.10$, d.f. = 15, $p = 0.52$),

indicating that there were no significant differences between responding and non-responding households in these respects. Six hundred and eight households produced firewood, of which 319 also owned forest land (>1 ha). Data were analysed for the 301 forest-owning households that reported the age, sex and hours worked by persons involved in firewood production.

2.2.2 Survey of firewood-processing accidents

Data on personal injuries from 1996 to 2001 were collected, irrespective of severity, from the injury database maintained by the Umeå Accident Analysis Group at the University Hospital in Umeå. The injury database contained a total of 60 196 injury registrations for the period 1 January 1996 – 31 December 2001 and was coded with a 'Classification of External Causes of Injuries' (NOMESCO 1997). This coding enabled a structured search using three main criteria to determine which accidental events had causes related to self-employed family forestry work. These criteria were the place of injury, injury mechanism and product code and are described in Wilhelmson et al. (2005). A total of 1466 injuries during the period were discerned as being possibly related to the target activity. Medical journals were reviewed to identify cases that could clearly be excluded. In 2002 a questionnaire was sent to the remaining 485 persons to confirm that the accidents were related to the target activity and to provide a more complete understanding of the causes of the accident. Responses were received from 385 people (80%), 225 of whom confirmed that the accident had happened during self-employed family forestry work. Respondents were not significantly different (χ^2-test, $p < 0.05$) from non-respondents with respect to sex, age or the seriousness of the accident. Some of the survey results have been previously reported (Wilhelmson et al. 2005). In this article, however, a more thorough analysis of firewood production accidents is presented, based on the 116 accidents that happened during firewood production.

2.3 Questionnaires

2.3.1 Survey of firewood production

The questionnaire started with a direct question as to whether anyone in the household was involved in firewood production. The following section concerned questions about the specific category and age of equipment used in firewood production. Pictures and definitions of the standard configurations of machines were provided to help with identification. Most equipment is well known and processors perform processing (Table 1), but screw splitters and wedge splitters deserve an explanation. Both machines force into the wood a metal object, in the form of a rotating spiral cone for screw splitters and a wedge for wedge splitters. The second section of the questionnaire concerned the division of labour between household members for six different activities involved in firewood production (Table 1). The last section included miscellaneous questions regarding, inter alia, the volume of firewood produced each year, the ownership of forest land (>1 ha) by members of the household and the health care institution that would be sought in case of an accident.

Table 1. Definition of firewood processing activities

Activity	Definition
Cutting	Dividing wood perpendicular to the tree's growth direction.
Splitting	Dividing wood parallel to the tree's growth direction.
Processing	Work with a machine that performs both cutting and splitting, sequentially or simultaneously.
Stacking	Arranging firewood for drying
Transport	Moving firewood from the cutting and splitting site to the drying site and from the drying site to the burning facility.
Miscellaneous	Other firewood production related activities than the ones defined above.

2.3.2 Survey of firewood accidents.

The questionnaire on firewood accidents started with stating the accident concerned (type and date) and a direct question as to whether the accident had happened during self-employed family forestry work according to a stated definition. The first section concerned details regarding the work conducted at the time of the accidents in terms of activity, equipment, number of workers involved in the work, work time preceding the accident and perceived difficulty of the task. The second section addressed perceived causes of the accident and outcomes in the form of persistent physical symptoms or changed behaviour. The third section concerned the respondent's normal gainful occupation, the annual amount of time spent on forestry work and preventative measures they would recommend.

2.4 Statistical methods

Responses from the two surveys were treated as categorical data, except for ages and the work hours in the firewood production survey, which were treated as continuous data. Categorical data were analyzed with χ^2- tests, with Yates correction for continuity when necessary. For continuous data, means, standard deviations (SD) and medians were calculated and comparisons between groups were made with T-tests. The critical significance level was set to 5%.

Accident rates per million work hours were calculated for activities and equipment, assuming that the two surveys addressed the same population despite time differences. To enable this to be done, annual mean number of accidents during the different activities and using the various pieces of equipment were calculated from the firewood accident survey. Accident rates per million work hours were then calculated using an estimate of the total annual firewood production from family forestry based on the mean work time per forest-owning household that produced firewood reported in the firewood production survey. Corrections were made for households that no longer existed (0.9% of the total sample) and households that would seek medical assistance outside the region (4.7% of forest-owning, firewood-producing households).

3. Results

3.1 Firewood production survey

3.1.1 Sex and age

The reporting 301 households contained 544 firewood-producing persons, who annually spent, in total, 29 698 h on the work. The mean annual work time was 95.8 h (SD 89.6 h, median 75.5 h) per household and 54.6 h (SD 59.9 h, median 40 h) per person. Most persons (44.1%) were found in the age classes "50-59" and "60-69" years and these age classes also accounted for most work time (53.2%) (Fig. 1, left and centre panel). Men constituted 385 (70.8%) of the active persons and performed the work done in 84.7% of the working hours. Mean work time per active person increased with age class for both sexes (Table 2). Men spent on average more than twice as much time on firewood processing work compared to women. The mean age for all active persons was 49.0 years (SD 18.3, median 52), with no significant differences between sexes (T=1.49, d.f.=542, p=0.137). Median age for men was 52 years and for women 49 years.

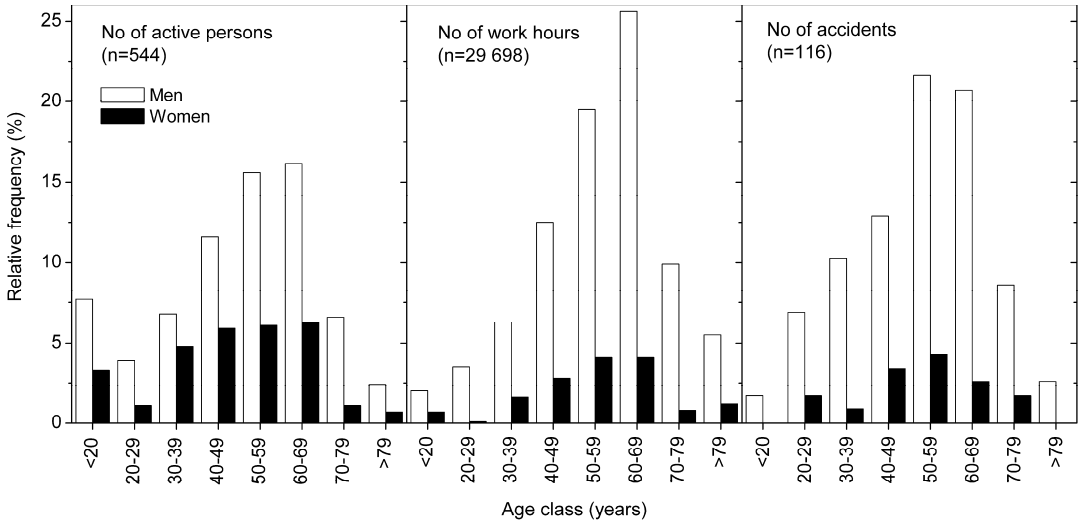

Figure 1. Relative frequency distributions of active firewood-processing persons (left panel) and work time (center panel) as a function of sex and age class from the firewood production survey. Right panel is relative frequency of accidents by sex and age class from the firewood accident survey.

Table 2. Mean firewood production time (h) by sex and age class

	Age class (years)								
Sex	<20	20-29	30-39	40-49	50-59	60-69	70-79	>80	Total
Men (n=372)	14.2	49.6	50.3	59.0	68.1	86.2	81.5	124.8	65.3
Women (n=155)	11.1	6.0	18.7	25.6	37.0	35.4	40.3	86.0	28.6
Combined (n=544)	13.3	39.9	37.2	47.7	59.4	72.1	75.6	115.6	54.6

3.1.2 Work activities

Half (49.8%) of the total work time reported was spent on cutting, splitting and processing by men (Fig. 2, left panel). Within sexes, men spent 58.8% of their work time on cutting, splitting and processing and 41.2% on other work activities, while women spent 60.4% on stacking and transport. Half (49.4%) of the persons spent less than 40 h per year on firewood production and only 2.0% spent annually more than 240 h.

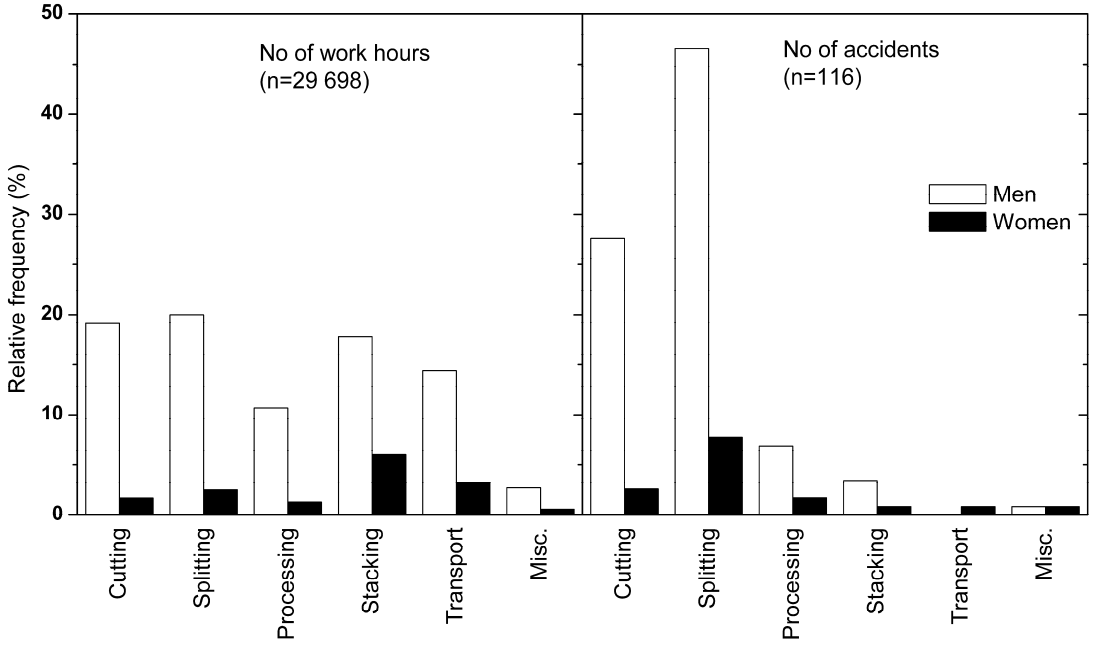

Figure 2. Relative frequency distributions of firewood production time (left panel) from the firewood production survey and accidents (right panel) from the firewood accident survey as a function of activity and sex.

3.1.3 Equipment

Most of the work time spent on cutting, splitting and processing (16 421 h), involved use of wedge splitters (Table 3 and Fig. 3, left panel). Work with the four categories of equipment "Chainsaw", "Circular saw", "Wedge splitter" and "Processor" collectively constituted 85.5% of the work time. Of the equipment used, circular saws had the highest mean age (21.6 years) and accounted, together with screw splitters, for the highest proportions of machines older than 11 years (predating 1995), in terms of both numbers (>70%) and work hours (>61%) (Table 3).

Table 3. Equipment work time and age by firewood equipment category

Equipment category	Work time (h)	Age (years)			% older than 11 yrs	
		n	Mean (SD)	Median	% of n	% of h
Hand saw	85	4	13.8 (13.7)	12	50.0	47.4
Chainsaw	2592	108	7.8 (6.0)	5.5	22.2	21.4
Circular saw	3264	100	21.6 (13.9)	20	70.0	61.3
Hand axe	1455	36	15.1 (19.0)	10	33.3	38.3
Screw splitter	496	15	14.3 (6.3)	15	73.3	77.2
Wedge splitter	4631	146	9.5 (7.3)	10	29.3	27.2
Processor	3549	78	10.4 (12.1)	8.5	25.6	27.1
Misc. cutting devices	117	2	6.5 (2.1)	6.5	0.0	0.0
Misc. splitting devices	102	4	37.5 (15.0)	40	100	100
No reply	120					

3.2 Firewood accident survey

3.2.1 Sex and age

With respect to sex, most accidents occurred to men (85.3%) (Fig. 1, right panel), and with respect to age, people in the age class 50-59 years (25.9%). The mean age of injured persons was 52.8 years (SD 15.8, median 54.5) and there was no significant difference in the mean age of injured men and women (T=0.195, d.f.=114, p=0.846). Median age for men was 55 years and for women 53 years.

3.2.2 Annual work time and work activity

Half (51.5%) of the injured persons normally spent less than five workdays per year on firewood production, and 7.8% spent more than 30 workdays on it. A work day was assumed to correspond to 8 hours. The activity being performed at the time of the accident was splitting in more than half (54.3%) of the cases (Fig. 2, right panel). Cutting, splitting and processing work was in progress when 93.1% of all accidents occurred.

3.2.3 Equipment

In 94.0% of the accidents, work with firewood equipment was involved. Discrepancies with the cutting, splitting and processing accidents in section 3.2.2 are due to the fact that in three cases no firewood equipment was involved in the accident (two cutting and one splitting accidents) and that equipment in the miscellaneous category was being used in two cases (axe and processor). The data for accidents associated with specific types of equipment show that wedge splitters were being used in more cases (39.4%) than any other type, followed by circular saws (16.5%) (Fig. 3, right panel).

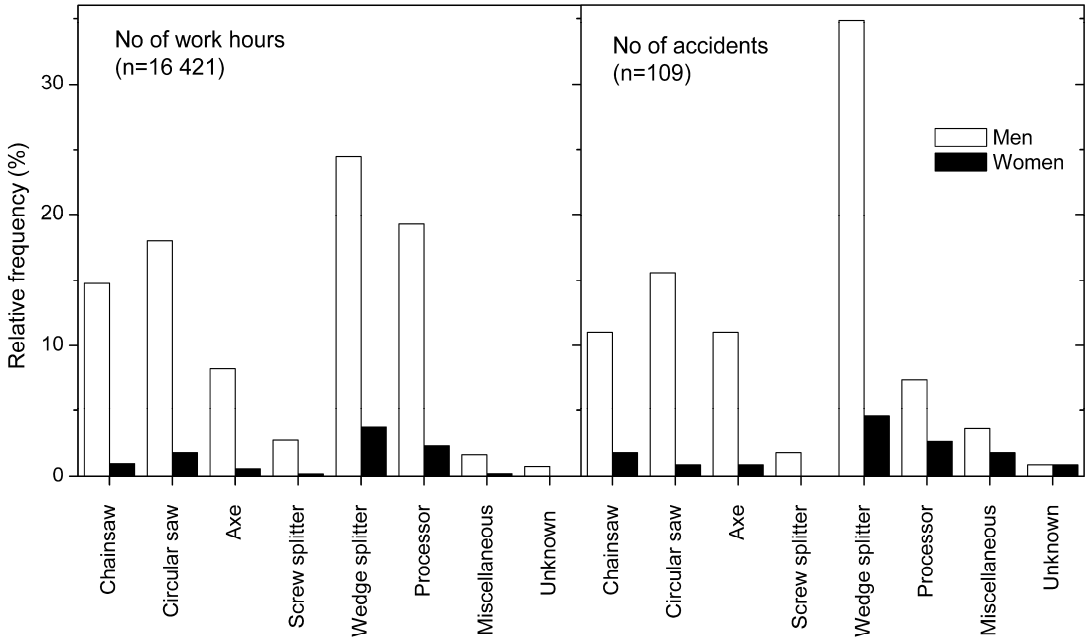

Figure 3. Relative frequencies of time spent using specific types of equipment (left panel) from the firewood production survey and of accidents associated with their use (right panel) from the firewood accident survey as a function by sex.

3.2.4 Accident types

The most common type of accident was crushing during wedge splitting (34.5%), which together with cutting by blade or chain constituted 53.5% of the accidents (Table 4). To avoid low cell counts in the analysis, "Axe cuts", Cutting from blade or chain" and "Crushing from wedge splitting" were merged in the category "Direct machine contact" while "Falling or flying wood piece", "Rolling log", "Fall" and "Other" were combined in the category "No direct machine contact". A 2 × 2 χ^2 analysis found no significant differences (χ^2 =0.424, d.f.=1, p=0.515) between proportions of men and women in the two new categories.

Table 4. Frequencies of firewood-processing accident types by sex

Accident type	Men		Women		Combined	
	n	%	n	%	n	%
Axe cut	10	10.1	1	5.9	11	9.5
Cutting by blade or chain	19	19.2	3	17.6	22	19.0
Crushing during wedge splitting	35	35.4	5	29.4	40	34.5
Falling or flying wood piece	13	13.1	4	23.5	17	14.7
Rolling log	7	7.1	2	11.8	9	7.8
Fall	8	8.1	1	5.9	9	7.8
Miscellaneous	7	7.1	1	5.9	8	6.9
Total	99	100	17	100	116	100

3.2.5 Injury distribution

Most (71.6%) injuries occurred to upper extremities (fingers, hand, wrist and under arm). Injuries to fingers alone accounted for 57.8% of the injuries. Lower extremities (feet, ankles, knee, thigh and toes) were injured in 14.7% of the cases, while thorax and spine regions (shoulder, hip and back) were injured in 3.4% of the cases. Injuries to the head and face accounted for 11.2% of the total, and most (61.5%) of these cases were eye injuries.

The most common injuries were cuts (40.5%) and fractures (20.7%). Fifteen persons (12.9%) suffered amputations, all of which were finger amputations, and 11 were due to crushing while operating a wedge splitter. Contusions were suffered by 10.3% of the cases and the remaining 15.5% were distributed amongst miscellaneous injury types. Of all the injured persons, 38.0% required taking sick leave because of their injury. Of the injured who required sick leave, 37.5% were on sick leave for more than 29 days. Persistent symptoms were reported by 51.3% of all the injured persons. As a consequence of their accidents, 46.6% reported that they changed their work procedures or worked more cautiously after the accident. Eight persons (6.9%) stopped producing firewood.

3.2.6 Multiple workers

Less than half (43.1%) of the accidents happened when the injured person was working with someone else (Table 5). Work with processors had the highest proportion (72.7%) of "multiple–workers" accidents among the equipment categories. During work with wedge splitters, half (51.2%) of the accidents happened when the injured person was not working alone (Table 5). The most common type of "multiple-worker" accident was crushing while working with a wedge splitter, which accounted for 40.8% of the accidents. Accidents were more evenly spread between accident types amongst single workers.

Table 5. Frequencies of single worker and multiple worker accidents, by firewood equipment categories

	Single worker accidents		Multiple workers accidents	
Equipment category	n	% per row	n	% per row
Chainsaw	9	64.3	5	35.7
Circular saw	11	61.1	7	38.9
Axe	11	84.6	2	15.4
Screw splitter	1	50.0	1	50.0
Wedge splitter [a]	20	46.5	22	51.2
Processor	3	27.3	8	72.7
Miscellaneous equipment	3	75.0	1	25.0
Unknown equipment	1	50.0	1	50.0
No equipment	7	77.8	2	22.2
Total [a]	66	56.9	49	42.2

[a] = one answer was missing for this accident type.

3.3 Combining the production and accident surveys

3.3.1 Accident rates

Splitting was associated with a far higher rate of accidents (123 per million work hours) than any other activity (Tables 6 & 7). Cutting, splitting and processing work was associated with a 10 times higher accident rate than all of the other activities combined. Among the equipment types, wedge splitters and axes were associated with the highest accident rates (similar to those of the splitting activity), and processors the lowest.

Table 6. Mean annual accident frequencies, annual work time and accident rate per million work hours by activity

	Cutting	Splitting	Processing	Stacking	Transport	Miscellaneous	Total
Accidents (n)	5.8	10.5	1.7	0.8	0.2	0.3	19.3
Work time (1000 h)	78.5	85.4	45.2	89.8	66.9	12.3	378.1
Rate (n / million h)	74.3	123.0	36.9	9.3	2.5	27.0	51.1

Table 7. Mean annual accident frequencies, annual work time and accident rate per million work hours by equipment category

	Chain saw	Circular saw	Axe	Screw splitter	Wedge splitter	Processor	Total [a]
Accidents (n)	2.3	3.0	2.2	0.3	7.2	1.8	18.2
Work time (1000 h)	33.0	41.6	18.5	6.3	59.0	45.2	209.1
Rate (n / million h)	70.7	72.2	117.0	52.8	121.6	40.6	86.9

[a] Including accidents and work time for the categories miscellaneous and unknown.

3.3.2 Distribution of expected accidents

Chi-square tests of differences were conducted separately for sex and age since expected frequencies for some permutations of sex and age classes, based on either numbers of active persons or total work time, were too low for meaningful combined analysis. The frequencies of recorded accidents deviated significantly from those expected based on numbers of active persons, both between sexes (χ^2 =11.2, d.f.=1, p=0.001) and between age classes (χ^2 =15.2, d.f.=7, p=0.034). The differences can be clearly seen in Fig. 1. The low numbers of recorded accidents in the age class "<20" years contributed especially strongly to this difference. When expected accident frequencies were based on total work time, there was no significant difference between recorded and expected accidents between sexes (χ^2 =0.001, d.f.=1, p=0.943). In the comparison of age classes, the classes "<20" and "20-29" years were combined to avoid low frequencies. Amongst the seven new age classes there were no significant differences between recorded and expected accident frequencies based on work time (χ^2 =9.4, d.f.=6, p=0.153).

The annual work time class ">30 work days" was collapsed with the class "5-30 work days" due to low numbers of expected frequencies for these classes. There was no significant difference between the recorded and expected accident distributions between the two new classes "<5 work days" and "≥5 work days" per year (χ^2 =0.17, d.f.=1, p<0.168). For work activities, recorded and expected accident frequencies differed significantly when the latter were based on activity work time (χ^2 =95.6, d.f.=5, p<0.000), as shown in Fig. 2. Over-representation of splitting accidents and under-

representation of stacking and transport accidents contributed substantially to this deviation (χ^2 =51.8, 18.6 and 18.7, respectively).

When analysing data related to the various types of processing equipment, the "Hand-saw", "Screw splitter", "Miscellaneous equipment" and "Unknown" classes were collapsed in order to avoid low expected accident frequencies. As expected from the pattern seen in Fig. 3, the test revealed significant differences between the distribution of recorded accidents amongst equipment categories and the expected distribution based on work time (χ^2 =16.3, d.f.=5, p=0.005). Over-representation of wedge splitter accidents and under-representation of processor accidents contributed substantially to this deviation (χ^2 =4.9 and 6.7, respectively).

4. Discussion

4.1 Results

4.1.1 Normal work

One of the objectives of this research was to examine the amount of work conducted and the work distribution in family forestry's firewood production. The results indicate that the typical worker is a man between 40-60 years of age. The relative number of persons and number of hours spent on firewood production steadily increase from an age of around 30 years, peak in the 60-69 years age class, possibly due to physical limitations brought on by aging, which may also account for the fact that the number of hours spent on production per person increases successively with age. Another possible reason for the increased mean work time may be that motives change with age. This hypothesis is supported by the results of a small-scale study by Carlsson (2003), indicating that old, firewood-producing persons attach great importance to the work in terms of recreation and work satisfaction. The relatively low number of persons younger than 30 years is likely related to the fact that most home owners are older.

While the participation of women in firewood-production is relatively low compared to that of men, it is relatively high compared to their participation in other forms of forestry work (Lindroos et al. 2005). Women spent most of their time in stacking and transport activities, but it is interesting to note that over a third of the women's time was spent in cutting, splitting, and processing activities. These are the most equipment-intensive parts of the production process, and given that such equipment is generally designed to conform to men's dimensions, e.g. of hand size and grip strength, it could be hypothesised that this may lead to increased risk of injury (Morse and Hinds 1993; Nag et al. 2003). There was, however, no such indication in the current study.

4.1.2. Safety problems

Lack of safety features or violations of safety regulations generally increase the probability that an accident will occur, and the existence of both of these factors was indicated in this study. The results found that some machines used predated the introduction of the European safety standards in 1995 (albeit no more than 25-30%). Consequently, those cutters, splitters and processors probably lacked certain safety features. In addition, at least four accidents were caused by more than one person using, or working by, a machine at the same time and thus violating the regulations stating that the machines should be used by single operatives, in accordance with the design of their safety features. In total, approximately half of all machine accidents occurred when the injured person did not work alone, but the second person's role in the majority of the cases is not known. As a preventative measure single-working was recommended only by three injured persons, while one

person, curiously, started using an assistant on the wedge splitter after a finger amputation accident. Since the corresponding frequency of multiple-worker operation in accident-free firewood processing is not known, little can be said about the influence of multiple-working on accident rates at this stage. Nevertheless, there are obviously a large number of persons who are exposed to elevated risks due to deliberate or unconscious violation of safety regulations.

4.1.3 Accidents

The frequency distributions of accidents among age-groups, sexes and equipment categories seemed at first glance to be skewed, with a high number of sixty-year-old men injured in work with wedge splitters. This was partly true, since wedge splitter accidents were over-represented in relation to the amount of time spent working with them. Interestingly, no significant differences were found for sex and age when comparing expected with recorded accident frequencies using exposure in terms of work hours; whereas the same calculations using number of active persons resulted in significant differences for both sex and age. Thus, it would seem that work hours are a better indicator of accident frequency. In other words, older men are overrepresented in the accident frequencies, but that is likely due to the fact that their exposure in terms of work hours is greater.

As previous studies have reported (Hellstrand 1989; Kristiansen and Seligson 1981; Larsson 1990), accidents to upper extremities were common. The use of screw splitters, which accounted for large proportions of total accidents in the 1980s according to various authors (e.g. Hellstrand 1989), were found to be rare in this study. Most accidents still occurred during splitting, but now due to use of wedge splitters. Compared to cutting, splitting productivity has more to gain by multiple workers working in unison which may be why this violation of safety regulations might explain many splitting accidents. Moreover, it might also be related to firewood splitters' relatively low accident saliency. Compared to cutters with rapidly running chains or blades, the splitters' slow moving piston probably gives little references to dreadful accidents and might thus be handled with less caution (c.f. Wogalter et al. 1999).

4.1.4. Accident rates

The accident rates associated with firewood-producing equipment were high compared with those associated with many other consumer products. Of 76 common products studied by Hayward (1996), the accident rates for only two (hedge-trimmers and scaffolding) exceeded the lowest rate found in this study. Axes and chainsaws were included in both studies, but the accident rates associated with them were found to be 6-9 times higher in the present study than in the cited study.

Since firewood production often has a target quantity and productivity differs between equipment categories, the accident rate per production unit could be a significant parameter. For example, accident rates per hour worked with firewood processors were found to be low, while productivity generally is higher than when other types of equipment is used. Hence, a small amount of relatively low risk time is required for the production of a given volume of firewood when processors are used rather than other types of equipment, implying that they have clear safety advantages. On the other hand, comparably little time per person was spent annually on firewood production and the consequences of the low amounts of time spent on the activities involved for accident risks are not clear, as mentioned in the Introduction.

4.2 Strengths and limitations of the study

The paucity of accurate nationwide information on firewood production accidents is illustrated by the discrepancies between the current study and official records. Burström et al's. (2005) study on national records of occupational accidents and work-related diseases (ISA) for the same period found less than half (n=29) the number of accidents associated with the use of firewood equipment than was found in the current regional study on forest-owning households. This discrepancy also clearly indicates that the accidents are seldom considered to be "occupational" by the injured people, and thus confirms the assumption that firewood production is mainly a "leisure time" activity. However, the current study also has limitations in terms of work hour and accident estimations. Retrospective questionnaire and interview studies on work time are subject to biases depending on various factors including memory, willingness to reply, socio-economic factors and misunderstandings (Bonke 2005; Niemi 1993). Short-term but recurrent tasks are particularly unlikely to stand out from other uses of time and to be difficult to recall correctly. The amount of time spent on unpaid work is generally underestimated, and in addition, people who spend small amounts of time on unpaid work tend to underestimate their efforts while those who spend large amounts of time on such work tend to overestimate the actual number of hours worked (Bonke 2005).

The accident survey was to some extent based on retrospective self-reporting, but the questionnaire was likely to provide a recall cue and moreover concerned an event that must have been highly memorable. Accident numbers were likely to have been under-estimated, considering the missing replies in the survey. Another 30 accidents could be added to the total found, to account for accidents that occurred to the 100 persons who did not respond, assuming that the rate of firewood-processing accidents for them was the same as for the responding persons. This addition would increase accident rates by 26%. Furthermore, the survey only covered fairly severe accidents, which prompted the injured person to seek hospital attention. In Swedish family forestry, Neely and Wilhelmson (2006) found that medical attention was sought by only 67% of the people injured in accidents. Moreover, the present study compared data on accidents from a 6-year period with annual exposure levels five years later, assuming that the accident rates and activity parameters had remained constant, which may not have been entirely valid.

Overall, due to the limitations outlined above, both the numbers of hours worked and accidents were probably under-estimated in this study. Despite these sources of error, they probably provide more accurate estimates than current official statistics.

4.3. Conclusions and implications for accident prevention

The results of this article are likely to be particularly relevant to other regions in which firewood is used and produced similarly as in the present study, such as large portions of Europe, North America and Australia. The use of firewood is not likely to decrease in the near future, due to rising costs of alternative heating resources (e.g. electricity and petroleum products). In Finland it was found that 15 000 households planned to start using firewood and 200 000 households planned to increase their consumption (Tuomi 2003). Recently, research in both Sweden and North America has begun to take a closer look at the type of accidents and the circumstances surrounding them in small-scale logging of the type associated with family forestry (Fischer et al. 2005; Neely and Wilhelmson 2006; Wilhelmson et al. 2005). However, to our knowledge, this is the first study to specifically look at the firewood production process.

The results show that the amount of time worked was the single most important factor affecting accident rates, and that use of one type of equipment (wedge splitters) was associated with especially high frequencies of accidents. However, higher rates of accidents were associated with use of all categories of equipment than most other consumer products (Hayward 1996). In addition, many old machines with possible deficiencies in safety features were in use and many accidents occurred when safety regulations were violated by people failing to work alone. Prevention strategies could therefore focus on changing behaviour, safety features, or both. However, challenging obstacles would have to be overcome. Attempts to change working practices through education would require extension services to a vast body of people who are currently unorganised and under no authority's responsibility, while developing more effective safety features would require thorough analysis of self-employed leisure time workers' conditions, which are highly variable, and complicated in terms of implementing regulations by the lack of any employer-employee relationship. Prevention work would also benefit from further knowledge regarding firewood-producing persons' risk perceptions and the frequency and drivers of violations of safety regulations.

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