International Journal of Occupational Safety and Ergonomics (*JOSE*) 2011, Vol. 17, No. 2, 175–186

Hand Injury From Powered Wood Splitters: Machine Safety, Patterns of Use and Injury Events

Aron Lindqvist
Olle Nilsson

Department of Surgical Sciences, Uppsala University, Uppsala, Sweden

Introduction. *The purpose of this study was to describe factors of possible importance for the occurrence of hand injury from powered wood splitters.* ***Patients.*** *Patients were identified by a computerized patient registry. Information was obtained from hospital records, a written questionnaire and a structured telephone interview.* ***Results.*** *Very few splitters were constructed according to European standards. Twenty-one percent of patients injured with wedge splitters thought that having more than one person at the machine was one cause of the accident. Seventy-nine percent of patients injured with screw splitters stated that glove use was one cause of the accident.* ***Conclusions****. The level of safety in wood splitters that cause hand injury is often poor. Having more than one person at the machine during work may contribute to wedge splitter injury. Glove use commonly contributes to screw splitter injury. Prevention should be directed towards unsafe machines and dangerous patterns of use.*

log splitter non-intentional injury consumer product related injury occupational injury agricultural injury injury prevention

1. INTRODUCTION

1.1. Epidemiology

The epidemiology of hand injury from powered wood splitters is not well known but there are reports about such injury originating from the USA, Scandinavia, the UK and Turkey. In the USA the number of injuries associated with wood splitters in 2008 was estimated at 6882 [1]. Injury from powered wood splitters affects all age groups, including children [2, 3, 4, 5, 6].

1.2. Wood Splitter Types

There are two main types of powered wood splitters. In wedge splitters (WES) a piston with a plate at the end pushes the log towards a stationary wedge, or a moving wedge pushes the log against a stationary plate. In screw splitters (SS) the power source is connected with a steel axis to a threaded mandrel. The log is pushed towards the tip of the rotating mandrel, which is screwed into the log until it splits (Figure 1). Dual-purpose cutters and splitters have both a device to cut the log, usually a powered circular saw, and WES or SS to split it. When the sawn log drops directly into a trough ready for wedge splitting the machine is normally called a firewood harvester [7] (Figure 2).

1.3. Requirements in European Standards

Standards No. EN 609-1:1999 and EN 609-2:1999 regulate the design of wood splitters sold in Sweden [8, 9]. They stipulate that every splitter

We wish to express our sincere gratitude to Ulf Andersson, Gun Fridfelt and Uwe Synwoldt at the Swedish Work Environment Authority and Professor Ragnar Andersson at Karlstad University for their invaluable support, and to Bala Agri AB for the photograph used in Figure 2.

Correspondence and requests for offprints should be sent to Aron Lindqvist, Department of Surgical Sciences, Uppsala University, Ingång 70 I tr, Akademiska sjukhuset, SE-751 85 Uppsala, Sweden. E-mail: <aron_lindqvist@yahoo.se>.

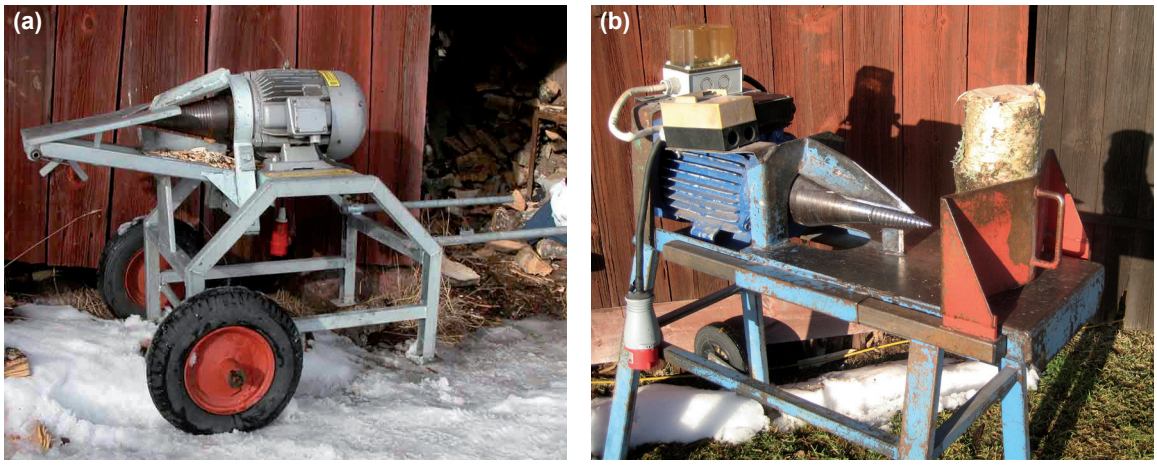

Figure 1. Screw splitters with protective devices: (a) factory-made screw splitter with warning notices, spring-loaded plate in position to protect user from tip of screw; (b) factory-made screw splitter with feeding device allowing user to push the wood onto the screw without holding the wood. *Notes*. Photography: Aron Lindqvist.

Figure 2. Factory-made firewood harvester with protective cover over cleaving zone. *Notes*. Photography: Courtesy of Bala Agri AB.

must have a warning notice, an instruction handbook specifying safe working practices, and a support for the log allowing it to be split without being held in position with hands or feet. In SS log support may be a feeding device with a handle and in WES there may be a V-shaped trough that keeps the log from rolling sideways more efficiently than a flat surface would (Figure 1b). European standards also require splitters to be stable enough so as not to fall over easily, and all electrically powered splitters should have a starting and stopping device within reach from the operating position.

Standard No. EN 609-1:1999 for WES requires guarding of the splitting zone either with an interlocking guard with guard locking—a

Figure 3. Home-made, lever controlled wedge splitter without warning notice or protective cover. *Notes.* Photography: Aron Lindqvist

protective shield over the splitting zone which is impossible to open while the piston is advancing—or with two-hand controls of the hold-to-run type, compelling the operator to have both hands on the controls, and thus in a safe position, to make the machine run [8]. It also specifies how machines with a moving wedge must be designed to protect the operator from entrapment between a log jammed on the wedge and other machine parts during return movement of the wedge.

Standard No. EN 609-2:1999 for SS requires guards to protect the operator from touching the screw, devices to prevent log rotation, so-called windmilling, and removal of partially split logs from the screw [7, 9].

1.4. Home-Made Wood Splitters

Some reports mention home-made wood splitters [2, 3, 10] (Figure 3). The authorities do not control them. According to Hellstrand, protective devices on home-made machines seemed inferior to those on factory-made machines [10].

1.5. Control Devices

Control design and function are important for machine safety. On WES, pedal control as well as dual controls are unsafe, and controls which do not work in the same direction as the moving part may cause confusion and danger [7]. Two-hand controls of the hold-to-run type should require reinitiation of the output signal, i.e., both controls should have to be released before a new cleaving cycle can be started. If not, the operator may manipulate controls to enable operation of the machine with only one hand, which allows faster work at the expense of safety.

1.6. Unsplit Wood

If the wood is not completely split it can get stuck on the wedge or screw. This may occur when a WES push-plate does not advance the full distance to the wedge. The WES operator can get injured during attempts to remove the jammed wood or while trying again to split it by inserting a new block of wood between the jammed wood and the push-plate [3, 11].

1.7. Patterns of Use

Many factors may contribute and interact to cause an injury [12]. Besides machine design, patterns of use could be of importance regarding the occurrence of wood splitter injuries. WES users often work in pairs, one placing wood in the trough and another handling the control. Due to a misjudgement in timing the control may be activated before the person who places the wood is aware of it and an injury may occur. If gloves are used during work with SS they can get caught in the rotating mandrel [10]. Owen and Hunter discouraged glove use during work with SS [7]. Gloves can also get caught during work with WES and an injury can occur [2].

1.7. Purpose of the Study

The purpose of this study was to provide a detailed description of some aspects of machine safety, patterns of use and injury events of possible importance for the occurrence of hand injury from powered wood splitters to facilitate prevention and further research.

2. PATIENTS

2.1. Study Design

Uppsala University Hospital (Uppsala, Sweden) is a referral hospital serving a population of ~1.5 million. The study was designed as a case series with retrospective collection of information. Patients were identified by a search in a computerized patient registration system based on the International Classification of Diseases 9 and 10. As a first step, codes indicating external causes (ICD-9 codes E918, E919, E920 and E928, and ICD-10 codes W23, W29, W30, W31 and W49) were combined with injury codes for all possible injuries to the upper extremity, including nonspecific conditions such as T07 and types of injury implying a cause of injury such as 994.8. Patients with codes indicating pseudarthrosis (733W and M84.1) were included without a code for an external cause. The first search yielded 1924 patients whose records were screened. All who had been injured with a saw, axe, wood splitter or unspecified machine, or during work with firewood, were contacted by mail or telephone and asked about the cause of their injury. In 124 cases, injury caused with a powered wood splitter was verified and these patients were included in the study. In addition, five patients were recalled by colleagues. These had been classified with codes T87.3, T92 and Y86, respectively, which had not previously been included in the search. A complementary search was, therefore, done using these and similar codes (subgroups of T75, T79, T87, T92, T94, T98 and Y86), which added the last two patients for a total of 131 patients [5]. Outpatients were not entered in the patient registration system used until February 9, 1999, and only two outpatients injured with wood splitters before this date were found and included in this study. One to nine years after the injury further information was gathered from the patients or their relatives with a written questionnaire and structured telephone interview.

2.2. Patient Inclusion

All patients with an upper extremity injury caused by a powered wood splitter who were seen from January 1, 1995, until December 31, 2001, at the Department of Hand Surgery, Uppsala University Hospital, were included in the study. Four patients were injured with the saw of a dual-purpose cutter and splitter. One of them was included in the study since in his case the splitter part of the machine was clearly involved in the mechanism of injury. The remaining three were excluded along with all other patients injured with saws. One patient injured with a wood splitter powered only by the hand of the user was excluded, as were all patients injured with axes.

2.3. Patient Material

Thus 131 patients injured with powered wood splitters were identified and included in the study. Seventy-three percent of them were males and 19% were outpatients. They were aged 3–85 years with a mean of 47 and 11% were below the age of 15. Eighty-two percent of the patients had

been injured with WES and 18% with SS [5]. About half of the injuries were severe and half were of moderate or minor severity [13]. Four patients were dead, two had dementia and four chose not to participate. The participation rate was 92%.

2.4. Defined Versus Open-Ended Questions

The questionnaire and structured telephone interview contained both questions with clearly defined answer alternatives and open-ended questions (OQ). An example of OQ is "Describe how the accident occurred". The questions with defined answer alternatives may give reliable information about proportions, such as the number of WES that were and were not powered by electricity, but OQ provide only a baseline for the occurrence of a particular factor in the material.

When similar injury events or circumstances of possible importance for injury prevention were reported by at least four patients in response to OQ, these are mentioned in results.

3. RESULTS

3.1. Factory- or Home-Made

Although most injuries were caused by factory-made machines, injury from home-made machines was fairly common (Table 1). Table 2 shows a comparison between factory- and home-made machines regarding some safety-related factors. All three WES manufactured with two-hand controls were factory-made. Only two patients were injured with home-made dual-purpose cutters and splitters, one WES and one SS. In 56 cases the brand or model of the machine that had caused the injury could be identified.

3.2. Circumstances Regarding Machine Use

Only 7% of the injuries occurred during gainful employment while 85% occurred during the patient's leisure time. In most cases the machine was owned by the patient's household or it had been borrowed (Table 3). The patient's employer owned the machine in only three cases. Time spent working with the machine on the day of the

TABLE 1. Comparison Between Wedge Splitters (WES) and Screw Splitters (SS)

Compared Factors	WES (%) (*n* = 107)	SS (%) (*n* = 24)
Factory-made/home-made	67/27	54/37
Warning notice/no warning notice	34/61	21/62
User's manual/no user's manual	32/59	8/71
Log support adequate/intermediate/inadequate	47/22/25	4/0/79
Emergency stop device/no emergency stop device	16/71	0/79
Removal device/no removal device	3/91	17/67
Protective cover/no protective cover	9/85	33/58

TABLE 2. Comparison Between Factory- and Home-Made Wood Splitters

Compared Factors	Splitter Type	Factory-Made	Home-Made
Warning notice/no warning notice	WES and SS	37/40	2/35
User's manual/no user's manual	WES and SS	34/44	1/36
Removal device/no removal device	WES and SS	4/79	3/33
Protective cover/no protective cover	WES and SS	17/67	1/35
Hold-to-run	WES	21	59
Return-on-release	WES	45	30
Whole cleaving cycle	WES	27	0

Notes. WES—wedge splitter, SS—screw splitter; hold-to-run, return-on-release and whole cleaving cycle refer to control function regarding forward piston motion.

TABLE 3. Ownership of Wood Splitters

	Wood Splitters (%)		
Owner	**WES (*n* = 107)**	**SS (*n* = 24)**	**All (*n* = 131)**
Patient's household	42	54	44
Rented	7	0	5
Borrowed	35	25	33
Other	11	4	10
total	95	83	92

Notes. WES—wedge splitter, SS—screw splitter; rented—splitter owned by establishment or person from whom it had been rented, borrowed—splitter owned by someone outside household who lent splitter, other—patient away from home helping a relative, friend or neighbour, or machine owned by patient's employer.

accident before it happened was 0–2 h in 47%, 2–4 h in 29%, 4–6 h in 12%, 6–8 h in 3% and over 8 h in 1.5% of cases. Lighting at the time of the accident was adequate in 90% of all cases, not really adequate in 2% and no patient stated that it was inadequate. Ninety-two percent stated that they were not under the influence of alcohol when the injury occurred, one patient reported a slight influence and none a strong influence. Apart from the injured children, it was clear from answers to OQ that children were present at the accident site in six more cases. In three of these they were directly involved in accident events and in three they were not.

3.3. User Information and Experience

Only 30% of all splitters had a warning notice. Of the 39 patients injured with these machines 30 had read the whole warning and two had read part of it. Most patients reported that the machine lacked a user's manual. Of the 36 patients who reported the existence of a user's manual 17 had read it all, four had read part of it and 13 had not read it. Seventy-one percent of patients had received verbal instructions on how to use the machine and 21% had not. Reported hours of experience using the machine at the time of injury were 0–3 in 16%, 3–10 in 9%, 10–30 in 18% and over 30 in 49% of cases.

3.4. On–Off Switch

Eighty percent of all wood splitters were powered by electricity and 76% were switched on with an electric switch, often a safety disconnection breaker. Fifteen splitters, all WES, were tractor powered. To ready such a machine for use it was necessary to connect it to the tractor and start the tractor engine. Twenty patients injured with SS participated in the study. All 20 reported that the cone rotated continuously once the machine had been switched on. Nine of them found the usual on–off switch easy to reach from the working position and eight did not.

3.5. Emergency Stop Device

Of the 76 patients injured with WES without an emergency stop device, 34 found the usual on–off switch easy to reach and 31 did not. In WES equipped with such a device, in nine cases it was a button, in three a lever, in three a wire and in two the type was unknown. Of the six WES lacking a lever, pedal or handle to control the piston three had an emergency stop device, two had an on–off switch that was easy to reach, and one had neither. No patient with SS injury reported that the machine had an emergency stop device.

3.6. Types of Control Devices in WES

The control device in WES was a lever in 73%, a pedal or other foot regulated device in 7% and two-hand controls in only 3%. In 2% the splitter movement started when the lever for cutting was pulled and in 3% when the sawed off wood fell on a trigger—these more indirect types of control devices were found only on firewood harvesters. In 2% the control device was a handle and in 2% there was a choice between a pedal and a trigger. Responding to OQ, four patients reported inadvertently starting the piston when falling,

(a) (b)

Figure 4. Example of manipulation of control device: (a) factory-made, pedal controlled wedge splitter with warning notice; (b) pedal fitted with an extension making it easier to depress pedal, the patient stepped on the extension by mistake and was injured. *Notes.* Photography: Aron Lindqvist

when accidentally touching the pedal with one hand or when loose clothing was caught on the lever. Only 2% of those injured with WES had manipulated the control device while 92% had not (Figure 4).

Of the three WES with two-hand controls one was out of order and was run with only one of two levers. Another was started by a child not seen by the user. The last machine had intact two-hand controls requiring reinitiation of the output signal and the patient worked alone when injured. How he was injured is still unclear.

3.7. Direction of WES Control Lever Movement

When the user moved the lever of a lever-controlled WES the piston moved in the same direction in 53%, in the opposite direction in 20% and in a direction perpendicular to the movement of the lever in 17%. Responding to OQ, six patients injured with lever-controlled WES reported stopping the piston when they felt their hand being injured, and then putting it in forward motion again for a split second, causing further injury to their hand. When they realized that the piston was advancing again they immediately reversed its movement. In two of these cases the piston moved in the same direction as the lever, in one case it moved in the opposite direction and in one case it moved perpendicular to the movement of the lever. In two cases the direction of piston movement in response to lever movement is unknown.

Of the six patients who had restarted the machine in the wrong direction the two patients injured with machines where the piston moved in the opposite direction or perpendicular to the movement of the lever, claimed that this "illogical" mode of functioning was the reason they had restarted the piston in the wrong direction. Two who had restarted the machine in the wrong direction claimed they had done so because they were standing on the wrong side of the machine, which caused confusion about directions.

3.8. Control Function in WES: Forward Motion

For forward piston motion 29% of WES had a hold-to-run type of control device. In 36% the

piston stopped and returned to its starting-point if the user let go of the control device. In 17% the piston continued through a whole cleaving cycle once its movement had been initiated. In 3% (three cases) the piston should have stopped and returned to its starting-point when the user let go of the control device, but a spring of importance for lever function was broken. In two of these cases the breakage resulted in inappropriate continued forward piston movement, which was part of the cause of the injuries.

3.9. Control Function in WES: Return Motion

For return piston motion 17% of WES users reported that the control device had to be held in position for return movement until it was completed and 12% reported that once initiated with the control device, return movement continued by itself until completed. Thirty-seven percent stated that the piston returned when the user let go of the control device and 17% that once piston movement had been initiated it continued through a whole cleaving cycle including return. Only two patients reported injury caused by return piston movement. In the first case wood stuck on the pressure plate of WES with hold-to-run control injured the operator by pushing his hand onto the lever, thus making it impossible for him to stop the piston with this lever. In the second case a piece of wood pushed the hand onto the rotating circular saw of a dual-purpose cutter and splitter [13]. Once initiated, the piston movement of that machine went through a whole cleaving cycle.

3.10. Log support

Most wood splitters gave less than adequate log support, particularly SS (Table 1). The only patient with SS injury who found log support adequate was also the only one injured with SS with a feeding device. Nineteen other SS users reported that it was necessary to hold the wood during the cleaving step. Responding to OQ, 31 patients injured with WES related that when the injury occurred they were correcting or maintaining the position of the wood with their hand, although that was unnecessary in many of these cases.

3.11. Mechanism of WES Injury

WES injuries occurred between wood and wedge in 54%, between wood and push-plate in 22%, between wood and another machine part in 7%, between two pieces of wood in 2% or in other ways in 3%. In 81% of WES the pressure plate did not advance the full distance to the wedge, or the wedge not all the way to the plate. The wedge and the plate met during the cleaving step in only 5%.

3.12. Unsplit Wood

Most splitters had no device for removal of wood from the wedge or screw. Of seven machines with removal devices four were SS equipped with a reversing gear to make the screw rotate backwards. However, sometimes this did not succeed in removing the wood because the safety disconnection breaker could stop the engine when the reversed movement struck resistance. On two WES the wedge could be detached from the rest of the machine, which could facilitate removal of wood from the wedge. On one WES, Dalaklyven (Dalaklyven, Sweden), the wedge was the moving part and anything stuck on it was scraped off against the edges of the opening it retracted into when returning to its starting point. Responding to OQ, six patients reported being injured while trying to remove wood stuck on the wedge, one of them because wood unexpectedly fell on the trigger and started piston movement. Six other patients reported being injured in a situation immediately after the machine had failed to split the wood.

3.13. Machine and Patient Stability

In 90% of all cases the machine was stable. Only one machine was unstable. Lack of machine stability did not contribute to injury. Responding to OQ, six patients reported that falling was one cause of their injuries.

3.14. Protective Cover for the Splitting Zone

Only 14% of all splitters had, or had been constructed with, some kind of cover protecting the splitting zone and few covers offered any substantial protection against injury. Of 10 WES with covers nine were firewood harvesters. In SS the type of cover was a spring-loaded plate in three cases, a metal cover shielding the screw when it was not used in two, a tube that automatically telescoped up through the table in front of the screw in one and a fixed metal shield above the screw in one. Seventy-five percent of all SS had something to prevent windmilling but in many cases this was only the table which could be decimetres from the tip of the screw and gave poor protection. Responding to OQ, eight patients reported how unsafe operating practises contributed to injury from machines equipped with protective covers; in four cases the cover had been removed, in two it had been folded away and in two the patient had deliberately put a hand under the cover.

3.15. Glove Use

Twenty (83%) of those injured with SS wore gloves at the moment of injury and 19 (95%) of these stated that this was one cause of the accident. Corresponding figures for those injured with WES were 82 and 16%. Eighty-four percent of WES users wearing gloves did not believe that gloves were a cause of the accident. Responding to OQ, those injured with SS invariably related that the screw caught the glove and then injured the hand.

3.16. Not Alone at Machine During Work

Five (21%) of those injured with SS were not alone at the machine when the accident occurred but only one of them (20%) believed this was one cause of the accident. The corresponding figures for those injured with WES were 52 and 50%. Of all patients 29 reported that not being alone at the machine contributed to the accident. Responding to OQ, 14 of these, all injured with WES, claimed that a communication failure between the person responsible for the control device and the patient was one cause of the injury, and five others reported having been distracted.

4. DISCUSSION

4.1. Limitations

In this study some factors suspected to be of importance for the occurrence of hand injury from powered wood splitters were investigated with a written questionnaire, a structured telephone interview and a review of patient records. However, patients answered the questions several years after the injury. Although it is our impression that many patients vividly remembered injury events, the possibility that memories changed over time must be considered. Patients may also have been reluctant to report some circumstances, e.g., being under the influence of alcohol or having manipulated the splitter. Furthermore, patients may have been unaware of certain facts at the moment of injury. For example, patients injured with an unfamiliar splitter may not have been acquainted with details regarding machine construction or function. Such information could probably have been obtained with greater accuracy and detail if each accident site had been visited soon after the injury. Since this study is based only on patient reports and records the results must be interpreted with caution.

This study includes local patients along with patients referred for specialized care. Referred patients may have more severe injuries and also differ from local patients in other ways [14]. Many less severe injuries in our catchment area were probably not referred. Also, since outpatients were not registered in the patient registration system between January 1, 1995, and February 8, 1999, some outpatients from this period may have been missed. Therefore, this study does not show the full spectrum of hand injuries from powered wood splitters in our catchment area during the period of study. This spectrum was probably of less severity and the number of injuries larger than in our material.

4.2. Leisure Time Injuries

Most patients were injured during their leisure time and very few during gainful employment. This corresponds well with the observation of Hellstrand that 14 out of 15 patients with hand injuries from SS were injured during leisure time [10]. It also suggests that preventive measures directed towards those engaged in wood splitting on a professional basis may reach only a minority of wood splitter users who could benefit from preventive measures.

4.3. Children

Children were present during work with the wood splitter in at least 15% of cases. It is beyond the scope of this study to determine to what degree the injuries were caused by these children and whether or not the injuries would have been caused by an adult in the same situation. Nevertheless we believe that to assure the safety of children, as well as that of working adults, children should be kept at a safe distance from wood splitters. We believe it is important for this to be communicated in the warning notice of every wood splitter.

4.4. Emergency Stop Device

No SS and few WES in this study had an emergency stop device, and on many machines the on–off switch was not easy to reach. Regarding the majority of WES, which could be stopped with the control device normally used when operating the machine, it is hard to know if an emergency stop device would have improved safety. In contrast, SS had no control device that was normally used when operating the machine. Therefore, it seems more likely that an emergency stop device would have improved SS safety, at least in machines with an on–off switch that was not easy to reach. However, SS can cause injury very quickly. It is unclear if SS users can act rapidly enough to stop the machine before the damage is done. A patient in this study provided part of the answer. When the tip of the rotating screw caught his glove he desperately tried to stop the machine by grabbing the axis of the screw with his other hand, but without success. Some operators apparently react quickly enough to stop SS equipped with an emergency stop device.

4.5. Control Function

Hold-to-run would seem to be the safest type of control device for WES. Return-on-release controls leave the operator free to physically leave the control device during piston return, which theoretically could result in increased injury risk during this phase. A machine with a piston that goes through a whole cleaving cycle might thus seem even less safe because it can be left unattended by the operator during both forward and return motion. It was more common for home-made than for factory-made splitters to have hold-to-run controls and only factory-made machines had pistons that went through a whole cleaving cycle. Thus, it would seem that home-made machines had controls of a safer type than those of factory-made machines. However, in this study there were only two cases of injury inflicted by the returning piston and in one of these the machine had a hold-to-run type control. This does not indicate any great difference in safety between hold-to-run controls and other types of control functions. Furthermore, many of the machines with a piston that went a whole cycle were firewood harvesters that often had good protective covers, emergency stop devices and other safety measures. Therefore, it cannot be concluded from this study that differences regarding type of control function involved a significant difference in safety between home- and factory-made splitters.

4.6. Unsplit Wood

In most WES the wedge and the plate did not meet during the splitting of a log. This might be seen as a way of preventing injuries from occurring directly between the wedge and plate, but it did not prevent the injuries in this study, all of which were caused with machines with the wood as an intermediary transmitter of force. Jaxheimer, Morain and Brown even suggested that the wood splitter design might paradoxically be safer if the piston advances the full distance to

the wedge to avoid situations when the wood is only partially split and gets stuck on the wedge [3]. According to Owen and Hunter, such situations are associated with a high risk for hand injury [7]. In this study the number of patients injured when removing wood that had stuck on the wedge or in a situation immediately after such removal somewhat supports this view.

4.7. Glove Use

Seventy-nine percent of those injured with SS reported that glove use was one cause of the injury. This indicates that wearing gloves during work with SS is dangerous. However, only one injury in this study was caused with SS with a feeding device, and how often gloves cause injury in users of such machines is uncertain. Furthermore, SS users not wearing gloves would be at greater risk for minor injuries from the handling of wood. Therefore, a warning against glove use during work with SS that do not comply with the requirements of existing standards is considered appropriate and it is recommended that splitters that do not comply with standards should be exchanged for splitters that do.

4.8. Not Alone at the Machine During Work

Twenty-six percent of those injured with WES reported that not being alone at the machine was a part of the cause of injury. Communication failure between the operator handling the control device and the person placing the logs in the machine was the most common mechanism, followed by distraction. This gives some support to the observations of previous authors who have reported that not being alone during work with WES is of importance for the causation of injury [2, 3, 4, 7, 11, 15]. We believe it is beneficial for WES users to be aware of the potential dangers of not being alone at the machine during work, particularly the dangers of communication failure and distraction.

4.9. General Level of Machine Safety

Factory-made wood splitters more often had a warning notice and other safety measures than home-made splitters. On the other hand, controls of home-made WES were at least as safe as those of factory-made splitters. The overall impression is that although there might be a difference regarding safety between factory- and home-made splitters in this study, it is of minor importance compared to the huge gap between the reported overall level of machine safety and requirements in existing standards. Extremely few splitters in this study met these requirements. The vast majority of WES could be operated with one hand while the other was held in the cleaving zone. Only one SS could be used without holding the wood during splitting.

4.10. Conclusion

Integrating safety in the design of machines and environments is often a more successful approach in injury prevention than relying on information to change behaviour [12]. The continuing exchange of old and unsafe wood splitters for new ones that comply with existing standards is likely to prevent many injuries. However, even splitters that comply perfectly with standards can cause injury if not used as intended. WES with two-hand control requiring reinitiation of the output signal may be very unsafe if two people work together at the machine. A splitter with an interlocking device that shields the cleaving zone completely will become unsafe if manipulated to make splitting possible with the interlocking device folded away. When children are near the machine during work a risk for injury will remain. Although improved machine design can solve a very large part of the problem of hand injury from powered wood splitters, it is also essential to change patterns of machine use.

REFERENCES

1. Product summary report, all products. Injury estimates for calendar year 2008, National Electronic Injury Surveillance

System, page 13, Product Code 1457. Available from: National Injury Information Clearinghouse, U.S. Consumer Product Safety Commission, 4330 East West Highway, Bethesda, MD 20814-4408, USA.

2. Holm R. Handskader opstaet ved brug af hydrauliske braendeklovemaskiner [Hand injuries in the users of hydraulic wood-cutters]. Ugeskr Laeger. 1998;160:7255–8.
3. Jaxheimer EC, Morain WD, Brown FE. Woodsplitter injuries of the hand. Plast Reconstr Surg. 1981;68:83–8.
4. Kristiansen TK, Seligson D. Log splitter injuries to the hand. J Occup Med. 1981; 23:400–2.
5. Lindqvist A, Gerdin B. Hand injury from powered wood splitters. Scand J Plast Reconstr Surg Hand Surg. 2008;42:246–52.
6. Maral T, Tuncali D. An unusual hand injury caused by powered woodsplitter—split fingers. Hand Surg. 2000;5:169–74.
7. Owen GM, Hunter AGM. A review of log splitter safety. Saf Sci. 1993;17:57–72.
8. European Committee for Standardization (CEN). Agricultural and forestry machinery—safety of log splitters—part 1: wedge splitters (Standard No. EN 609-1:1999). Brussels, Belgium: CEN; 1999.
9. European Committee for Standardization (CEN). Agricultural and forestry machinery—safety of log splitters—part 2: screw splitters (Standard No. EN 609-2:1999). Brussels, Belgium: CEN; 1999.
10. Hellstrand PH. Injuries caused by firewood splitting machines. Scand J Plast Reconstr Surg Hand Surg. 1989;23:51–4.
11. May JW Jr, Hansen R. Log-splitter injuries. N Engl J Med. 1980;303:1127.
12. Berger LR, Mohan D. Injury control: a global view. Delhi, India: Oxford University Press; 1996.
13. Lindqvist A, Berglund M, von Kieseritzky J, Nilsson O. Assessment of the severity of hand injury from powered wood splitters. J Plast Surg Hand Surg. 2010;44(4–5)237–44 (DOI:10.3109/2000656X.2010.516590).
14. Waller JA, Skelly JM, Davis JH. Trauma center-related biases in injury research. J Trauma. 1995;38:325–9.
15. Trier H, Hovgaard C. Handskader ved brug af hydrauliske braendeklovere [Hand injuries caused by hydraulic wood-splitting machines]. Ugeskr Laeger. 1989;151:3080.