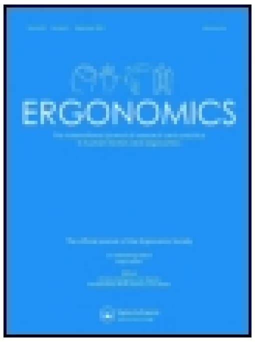

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Slip, trip and fall injuries in potato, sugar beet and open field vegetable production in Finland

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STF injuries are common in agriculture. The purposes of this study were to assess the magnitude of STF injuries, to identify contributing factors and to propose preventive actions to reduce injuries in potato, sugar beet and open field vegetable production in Finland. The material consisted of 1648 injury claim records and 22 interviews. The analysis showed 45% (n = 740) of the non-fatal injuries were STFs or jumps. Phrase analysis of injury descriptions provided further insight into the characteristics of STF injuries. The current findings suggest interventions should focus on making access paths (e.g. stairs, ladders, platforms) safer, minimising the need for mounting and dismounting equipment, decreasing manual material handling, improving contamination control and housekeeping in working areas and improving the safety of traffic areas and farmyards.

Keywords: slip, trip and fall injuries; agriculture; horticulture; phrase analysis

Introduction

Many studies have reported high rates of injuries in agriculture (McCurdy and Carroll 2000, Rautiainen and Reynolds 2002). Slip, trip and fall (STF) injuries represent a large proportion of agricultural injuries (e.g. Nordstrom *et al*. 1996, Solomon 2002, Rautiainen *et al*. 2004). In Finland, 57% of all compensated agricultural injuries in 2004 were STF-injuries (according to I.-M. Näkkäläjarvi, personal communication 11 December 2007). In Sweden, Pinzke and Lundqvist (2007) found 29% of accidents in agriculture were due to falls. McCurdy and Carroll (2000) also found falls to be among the most common injury sources in US agriculture.

Several specific STF injury hazards in agriculture have been identified in the literature. STF injuries frequently occur in tractor cab entry and egress (Hammer 1991, Suutarinen 1997, Leskinen *et al*. 2002). Contributing factors include dirty and wet steps, jumping and getting caught when dismounting (Hammer 1991). Leskinen *et al*. (2002) suggested the natural human movement patterns should be better taken into consideration when designing access paths. Fathallah *et al*. (2000) suggested that an optimal design of steps and handrails together with driver training could minimise STF-injuries during entry and exit.

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STF hazards during machinery maintenance and repair have been reported in agriculture (Johnson and Rautiainen 2004) and in forestry (Shaffer and Milburn 1999). Combines have elevated service areas and falls have occurred due to unsafe service ladders and platforms (Johnson and Rautiainen 2004). In their study of STF injuries, Bentley *et al.* (2005) found that design weaknesses in farm vehicles and equipment contributed to injuries. For example, lack of a viewing panel may result in unnecessary climbing to observe machine operation. The risk of injury can also be increased when design errors coincide with other factors such as slippery underfoot conditions, inappropriate or worn footwear and rushing.

Buildings and other structures can contribute to the risk of STF injuries. Kaustell *et al.* (2007) found 6% of all agricultural STF injuries and 14% of all STF injuries in dairy, beef and swine production in Finland were caused by floor structures. Suggested key areas of improvement included slip-resistant flooring, effective contamination control, better planning of macro structures (elevations, entrances, access ways) and logistics for material handling and storage spaces as well as consideration of safer working methods.

This paper focuses on STF injuries in potato, sugar beet and open field vegetable production in Finland. There were 5256 potato, sugar beet and vegetable farms (with over 2 ha in production) in 2004. Most of these were potato farms. In addition, growing potatoes for household use is very common on Finnish farms. The main vegetable crops have been carrots, onions and cabbages. Potato and vegetable growing are labour-intensive involving extensive manual material handling. Previous work with growers indicates that many farms have relatively old machinery and structures. Use of self-customised machines is common. Storages and material handling facilities may have been initially designed for other purposes and product handling lines and machines are often incompatible to some degree. These factors are among potential hazards in potato and vegetable production.

The purposes of this study were to assess the magnitude of STF injuries, to identify contributing factors and to propose preventive actions to reduce these injuries. The authors had a specific interest in identifying STF hazards (hazard defined in British Standards Institution 1996), which could be removed by better design of buildings and structures. The study is a part of a larger study, which focuses on safety and health issues in potato, vegetable and sugar beet production.

Material and methods

Injury claim records

The material consisted of 1648 injury claim records related to growing potatoes, sugar beets or vegetables (Figure 1). These claims were compensated by the Finnish Farmers Social Insurance Institution (Mela) during 1995–2004. This insurance system and the definition of compensable injury have been described by Rautiainen *et al.* (2005). In brief, Mela's accident insurance (workers' compensation) is mandatory for all self-employed farmers and their salaried family members. Hired employees are covered by other insurance schemes. About one-third of the insurance cost is covered by premiums paid by farmers and the rest is covered by the national health insurance and the state. Compensation includes medical care, lost time per diem (up to 1 year), disability pension (over 1 year disability cases), survivors' pension, rehabilitation and impairment allowance.

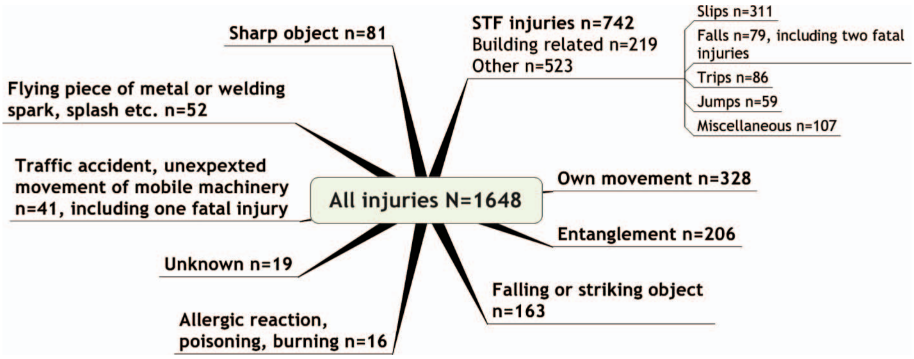

Figure 1. Compensated injuries in potato, sugar beet and open field vegetable production in Finland in 1995–2004. STF = slip, trip and fall.

Mela's existing injury coding augmented with further categorisation of injuries was used, based on keyword searches from incident descriptions. Three fatal injuries were excluded from the statistical analyses and the disability duration was truncated to 1 year for those cases with longer disabilities. The definition of STF injury in this study consisted of STFs on the same level, as well as falls and jumps from elevation in the selected agricultural production sector. The 1645 non-fatal claims were made by 1358 persons; 1155 persons (85%) made one claim and 203 persons (15%) made 490 claims ranging from two to eight claims per person.

Injury characteristics were identified from coded information including work activity, nature of incident and injury outcome, as well as short narrative injury descriptions. Work activity described the task during the injury/illness incident and had 150 categories. Cause was the primary factor leading to the injury/illness classified in 108 categories. Nature of incident described the mechanism of injury/illness event in 28 categories. ICD10 code was used for health outcome (World Health Organization 1993). Due to the large number of categories in these variables, they are not presented in this article but can be obtained by contacting the authors or from the dissertation by Rautiainen (2002). An earlier study found secondary analysis of injury descriptions provided useful information for identifying hazards (Kaustell *et al.* 2007). The same method was used in this study and injuries were categorised based on incident descriptions. Categories were created for injury type, incident location, type of underfoot contaminant or hazards and hazardous working method.

Statistical methods

Risk factors for serious injury were assessed using regression methods. The distribution of the number of disability days was highly skewed to the right and centred on two values, 0 and 7 d. Therefore, the number of disability days was categorised to the following three severity groups: 1) 14 d or under; 2) 15–30 d; 3) over 30 d. There were repeated claims from some persons and the observations of a person are dependent. This dependency was taken into account in the statistical analysis.

The statistical analyses were made in two phases. In the first phase, the data of severity groups 1 and 3 were analysed excluding group 2. The analysis was based on a logistic regression model for binary data. Let $Y_{ij} = 1$ if the number of disability days of person i due to injury j is in group 3 and $Y_{ij} = 0$ if injury is in group 1. The binary outcome variable Y is assumed to be a Bernoulli random variable with the probability π_{ij}, where π_{ij} is the probability of severity group 3 for person i and injury j. The logistic regression model, which is written in terms of π_{ij}, had the following form:

$$\log\left[\pi_{ij}/\left(1-\pi_{ij}\right)\right] = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \ldots + \beta_p x_{pij}$$

where β_0 is the intercept and β_ks are the coefficients of explanatory variables x_{kij}. In phase 2, the data of severity groups 2 and 3 were analysed. The model for phase 2 was similar to phase 1. Models were fitted using generalised estimating equations approach (Liang and

Table 1. Odds ratios and 95% CI for the final model in phase 1 and phase 2.

	Phase 1*			Phase 2†		
Explanatory variables	n	Odds ratio	95% CI	n	Odds ratio	95% CI
Intercept	.	2.97	1.56–5.67	.	1.49	1.05–2.13
STF Injuries						
Jumping	48	0.85	0.43–1.66	31	1.22	0.54–2.75
Slipping	237	0.67	0.44–1.02	172	0.90	0.56–1.45
Falling	141	0.77	0.49–1.23	99	1.17	0.68–2.00
Tripping	70	0.56	0.31–1.03	43	1.13	0.56–2.29
Miscellaneous	76	0.76	0.43–1.36	64	0.72	0.39–1.32
Other injuries						
Own movement	250	**0.17**	0.10–0.27	113	**0.30**	0.18–0.51
Sharp object	69	**0.08**	0.03–0.22	17	**0.28**	0.09–0.84
Allergic reaction, poisoning, burning	13	0.29	0.07–1.14	6	0.67	0.13–3.47
Falling or striking object	124	**0.42**	0.25–0.70	77	0.65	0.37–1.13
Traffic accident, Unexpected movement of mobile machinery	32	0.82	0.37–1.85	23	1.26	0.50–3.21
Flying piece of metal or welding spark, splashes, etc.‡	52	**0.04**	0.01–0.18	0		
Unclear	13	0.30	0.08–1.09	9	0.33	0.08–1.37
Getting entangled or being crushed = reference	155			127		
Age group (years)						
<25	21	**0.30**	0.10–0.93			
25–29	44	**0.10**	0.03–0.31			
30–35	94	**0.19**	0.09–0.41			
35–39	150	**0.24**	0.12–0.47			
40–44	186	**0.24**	0.12–0.46			
45–49	239	**0.35**	0.18–0.64			
50–54	246	**0.41**	0.22–0.76			
55–59	171	**0.46**	0.24–0.87			
60–64	79	0.57	0.28–1.17			
>64 = reference	50					

Values shown in bold indicate statistical significance at $p < 0.05$.
STF = slip, trip and fall.
*Phase 1: Severity group 1 (14 d and under) compared to severity group 3 (over 30 d).
†Phase 2: Severity group 2 (15–30 d) compared to severity group 3 (over 30 d).
‡Injury type was deleted from phase 2 analysis due to no observations in severity group 2.

Zeger 1986). Exchangeable working covariance matrix was used, i.e. correlation between observations from the same person was assumed to be a constant.

Table 1 presents estimated odds ratios and 95% confidence intervals that are obtained from the parameter estimates and standard errors based on the final models. All standard errors are robust estimates (Allison 1999). *p*-Values are based on χ^2 statistic. The software used was GENMOD procedure of SAS/STAT software, version 9.1.3 of the SAS system for windows (SAS Institute Inc., Cary, NC, USA).

Interviews

In addition to injury claim analysis, 22 potato and vegetable farmers were interviewed, and in-depth information was collected on perceived hazards and injuries in various work activities. Interviews produced 222 comments and examples of hazards and injuries; 27% (n = 61) of them were related to STF hazards. In addition, farmers mentioned common factors that they considered affecting their safety and health. The comments were analysed by applying the affinity diagram method (Beyer and Holtzblatt 1998). The aim was to create a picture of common hazards based on farmers' experience.

Results

Magnitude and severity of slip, trip and fall injuries

The analysis of claims showed 45% (n = 740) of non-fatal injuries were STFs or jumps. Slips were most frequent (42% of all STF injuries, n = 311). Falls from elevation were also common (24%, n = 177); 46% (n = 82) of falls were from machines or trailers, 15% (n = 27) from ladders and 14% (n = 25) were from storage boxes or other structures. Trips (12%, n = 86) and jumps from elevation (8%, n = 59) represented significant proportions of STF cases. The rest (14%, n = 107) were generally described as falls or stumbles or the exact mechanism could not be derived from the description. The most frequent injury outcomes were sprains and strains (50% of STF injuries, n = 367). Internal injuries or concussions (26% of STF injuries, n = 193) and bone fractures (21%, n = 153) were also common. The injured part of body was typically leg (41% of STF injuries, n = 304) or upper limb (24%, n = 174).

The total compensated disability time from all injuries (over 1 year disabilities truncated to 365 d) among self-employed farmers during the 10-year period was 51,191 d (140 person-years based on 365 workdays per year). STF injuries alone resulted in 27,562 disability days (54% of all injuries). About 32% of STF injuries were severe, leading to more than 1 month disability. Severe STF injuries resulted in 75% of STF disability days. Based on median disability duration, the most serious STF injury types were miscellaneous falls (median 19 d) and falls from elevation (median 17 d).

Results of statistical modelling

The strongest explanatory variables for disability duration were injury type ($\chi^2 = 134.72$, degrees of freedom (df) = 12, $p < 0.0001$) and age-group ($\chi^2 = 41.14$, df = 9, $p < 0.0001$) in phase 1 and injury type ($\chi^2 = 39.41$, df = 11, $p < 0.0001$) in phase 2, based on modelling and preliminary examination of the data. When these variables were in the models, none of the other potential explanatory variables (gender, work activity, cause of accident) improved the models significantly. Also those two-factor interactions that were possible to test (gender × injury type; gender × age-group; gender × work activity; gender × cause of accident) were not statistically significant.

For phase 1, the odds ratio of the first and last age-groups was 0.30 (95% CI 0.10–0.93). The odds of a severe injury for individuals in the youngest age group are about 30% of the odds for those in the oldest age group. Overall, the probability that an injury is severe increases with age. One exception was age group 1 (<25 years), the estimate of which was about the same as 45–49 years.

The severity of each specific STF injury type (Table 1) was similar to the reference injury type (entanglement or being crushed during potato, sugar beet and open field vegetable production). Several non-STF injury categories were significantly less serious than the reference category (and STF injuries). Gender had no association with injury severity when other explanatory variables were already in the model.

Injury rate

In 1995–2004 there were 1648 injuries in potato, sugar beet and open field vegetable production in Finland, which Mela compensated. The injury rate (injuries per 1000 hectares) decreased during this period, but potato and open field vegetable production was still relatively hazardous for the workers (Figure 2). In 2004, the injury rate per hectare was four times higher in potato and open field vegetable production compared to crop production in general (Tike 2006). Overall, the number of farmers decreased simultaneously with this positive trend. However, actual working hour data and the numbers of workers in this agricultural sector are not available and the rates per hours worked or persons in the sector cannot be calculated. Thus, injuries per 1000 hectares were the only available measure for injury rate.

The injury rate per 1000 hectares was lower in sugar beet production compared to potato and vegetable production. Typically, there are more manual work phases in potato and open field vegetable production compared to other crop production, which could explain the difference. Most of the injuries in outdoor work activities occurred during the harvesting period in September and October. Indoor injuries were more evenly distributed throughout the year (Figure 3).

Secondary analysis of contributing factors

STF injuries typically occurred during post-harvest activities (36% of STF injuries) or during harvesting or transporting products to storage (22%). The rest of the cases

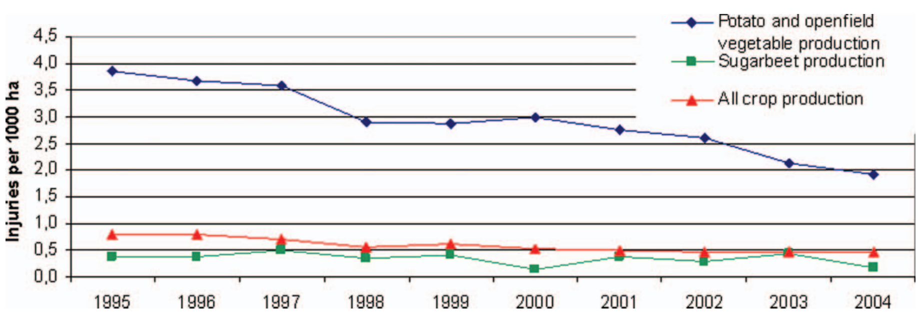

Figure 2. Injuries per 1000 ha in crop production work in 1995–2004 in Finland (Tike 2006).

occurred during tillage, seeding, planting, crop protection or fertilising (13%), and during miscellaneous maintenance, repair, transporting, etc. tasks (29%). Farmers usually conduct post-harvest and packing tasks in storage buildings. All descriptions of STF injuries were studied to identify whether the cases occurred indoors and whether the cases were obviously related to buildings or other structures. Contributing factors and categorised cases using these factors were also sought (Table 2). Courtney *et al.* (2001) found the descriptions of environmental conditions such as walking surfaces, contaminants, visual conditions, footwear, human factors and time sequences to be informative. Information was sought on location, working method linked to the injury and contaminant, obstacle or underfoot hazard when the incident occurred. In 83% of cases

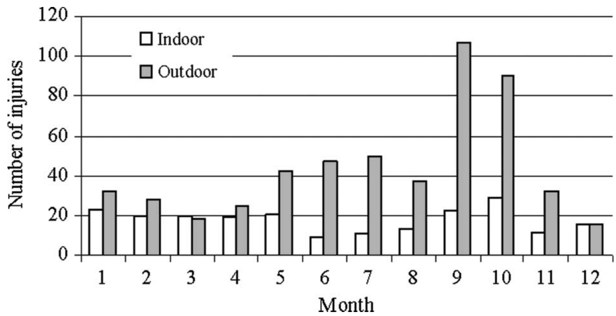

Figure 3. Injuries by incident month in indoor and outdoor work activities in potato, sugar beet and open field vegetable production.

Table 2. Contributing factors based on injury descriptions in building and non-building environments.

Building (n = 219)	n	Non-building (n = 523)	n
Location			
Floor	57	Harvesters, planting machines, other machines, trailers	164
Stairs, doorstep, landing	60	Field, storage pile	97
Ladder	22	Entry/exit path in tractor, harvester, truck, car, van	83
Climbing on storage boxes, other inappropriate structures	22	Yard, driveway	80
Climbing on machinery	6	Climbing on storage boxes, or other inappropriate structures	12
		Bicycle	9
		Ladder	8
Underfoot hazard			
Obstacle	29	Obstacle	56
Contaminant	23	Contaminant	87
Opening, collapsing surface	15	Opening, collapsing surface	40
Working method			
Carrying, lifting, pushing, pulling, e.g. hand truck, potato sack or box	85	Carrying, lifting, pushing, pulling, e.g. wheelbarrow, potato sack or box, pallet, or tarpaulin/cover	112
Climbing, jumping	27	Climbing, jumping	98

it was possible to identify location from the injury description. Working methods (carrying, lifting, pushing or pulling a load or climbing/jumping) were found in 44% of cases and underfoot hazards in 34% of cases. These categories were created by applying methods and results of Bentley *et al.* (2005) and previous studies (Kaustell *et al.* 2007).

Building-related slip, trip and fall injuries

Based on case descriptions, 219 injuries (30% of all STF injuries) occurred in buildings or in environments that involved structures. Out of these, 57 (26%) cases that happened on floors were identified and 104 (47%) were related to elevations; ascending or descending. The rest of the cases (26%, n = 58) were related to machinery or the location could not be derived from the injury description.

Material handling in storages often requires the use of stairs. The injured person typically carried moderate to heavy loads, e.g. potato seed boxes. In such cases, the person's vision is obstructed by the box. This can contribute to trips and false steps. Outdoor stairs, landings and doorsteps are slippery, especially during wintertime as illustrated in the following incident description:

> 'I was coming from the field and going to the cellar to get early variety seed potatoes. When entering the basement using the stairway outside my foot slipped from the edge of the stair and I fell to the side. The ligaments in my right ankle were sprained.'

Climbing and jumping inside buildings result from the necessity to work at different elevations. Falls from ladders (10%, n = 22) not set up properly were a particularly common injury type. Ladders were used during inspection of stacked products, regular maintenance of the building and adjustment of ventilation equipment. Farmers also used temporary climbing aids such as bins, boxes, etc. that are not designed for climbing (10%, n = 22). Falls occurred in unprotected (no railing) vertical shafts, e.g. filling storage rooms/bins (2%, n = 4).

> 'He was closing air vents near the ceiling of a potato cellar when the ladder slipped under him and he fell on the concrete floor.'

> 'When checking the humidity of the potato storage, the person was moving on top of a pile of storage boxes. The pile collapsed and he fell in between the boxes and strained his shoulder.'

Handling bulk products inevitably causes some contamination and results in slippery floors. The majority of floor-related slip injuries involved contamination (n = 14, 61% of slips). Moveable obstacles such as pallets and sacks along with fixed installations (other than stairs) were typical causes for trips (n = 18, 41% of trips).

> 'He was cleaning the potato storage with a wide broom when his foot slipped over squashed slippery potatoes on the floor. He fell on the floor and felt a sharp pain in his back.'

Walking surface openings, such as filling hatches and ventilation shafts of cellars as well as floor drains involve risk of stumbling and fall. Some injuries were caused by collapsing wooden underfoot structures or deteriorated protective railing that can easily occur in the extremely humid environment in potato storages.

> 'I was fetching potato seed from the cellar when a stair step collapsed and I fell on my arm.'

Manual work phases are very common in post-harvest activities in potato and open field vegetable production. Lifting, pushing and pulling loads lead to high number of STF injuries (39%, n = 86). The use of hand trucks or wheelbarrows can be singled out as specific injury-prone working methods (6%, n = 14). This is in accordance with the findings of Li *et al.* (2008).

> 'He was moving carrot boxes with a hydraulic hand truck. His foot slipped while pushing and he strained his back.'

Other slip, trip and fall injuries (non-building related)

In the secondary analysis of case descriptions, 523 injuries (70% of all STF injuries) had no clear relationship to buildings. These injuries occurred frequently in yards (15%, n = 80), fields and storage piles (19%, n = 97) or when working with machines and trailers (31%, n = 164), see also Table 2. Climbing and jumping on harvesters, planting machines, other machines or trailers during work tasks is common in field work. Slipping or falling from elevation when working on/with machinery was frequent. These injuries occurred when filling the planting machine, maintaining, repairing and controlling machines/processes, etc. Jumping down from a tractor, harvester or trailer was also a common incident type.

> 'I was washing a large potato harvester standing at the edge of the tank holding my other foot on the top conveyer. I pulled the pressure washer closer by the hose when my feet slipped from the surfaces and I fell down to the ground between the conveyer belts hitting my neck and head.'

Some frequent underfoot hazards were found from injury descriptions. Slippery and icy yard was by far the most common underfoot hazard reported (n = 70, 38%). Contaminants and obstacles including potatoes, sugar beets, peas, other plants, clay and moisture were typically associated with slipping injuries (n = 85, 36% of slips). Similar to indoor injuries, manual material handling such as pushing wheelbarrows, covering a sugar beet pile with tarpaulin or carrying potato sacks and boxes were frequent types of incidents (n = 112, 21%).

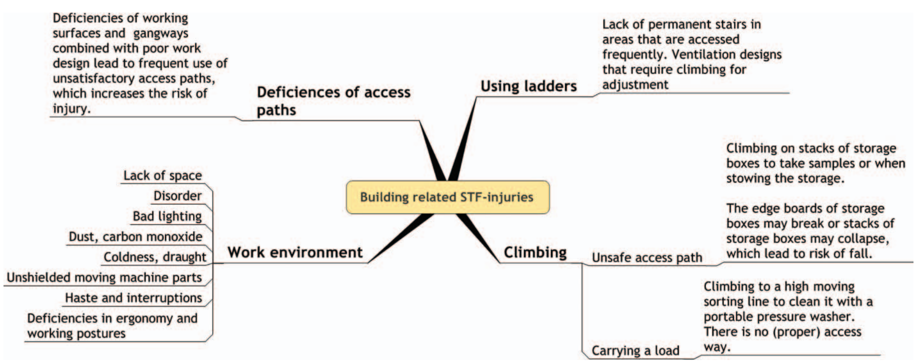

Figure 4. Safety hazards inside buildings expressed by farmers. STF = slip, trip and fall.

Slip, trip and fall hazards expressed by farmers

Building-related hazards

Indoor STF hazards expressed by farmers were mostly related to falls from height (Figure 4). Falls while climbing on storage boxes or machinery were recognised as hazardous by many farmers. Several also mentioned that carrying a load, typically a pressure washer, when climbing, was hazardous. Narrow and unprotected gangways were seen as potential injury-contributing factors. Only one farmer considered bad housekeeping to be a hazard. Manual work phases, such as lifting and using a hand truck were mentioned, but not specifically related to STF injuries. Dust, low temperature, draught and insufficient illumination were mentioned as general hazards that can contribute to STF injuries.

Outdoor hazards

Outdoor STF hazards were related mostly to climbing, jumping and falls from harvester or planting machines (Figure 5). Many farmers especially mentioned emptying the harvester bunker into storage boxes as a risky work phase. The worker must climb or jump into the trailer where the storage boxes are kept. In some cases the harvester has overturned during emptying. Also, climbing a moving harvester or climbing into the bunker of the harvester was recognised as hazardous. One farmer mentioned that the travelling speed of the harvester may suddenly change under difficult harvest conditions and this can lead to a fall from the machine, especially if the access gate is held open.

Only a few farmers recognised slips, e.g. on icy yard, on dirty machine platforms/stairs or on slippery soil as hazards. This is interesting as slips were the most frequent STF injuries in Mela's database during 1995–2004. It is obvious that farmers underestimate the risk and consequences of slips.

Many farmers mentioned that haste, fatigue and poor working habits can cause lack of attentiveness, which can lead to STF injuries. It was also seen that haste and perceived lack of time prevent adequate training of seasonal labour, which can lead to injuries.

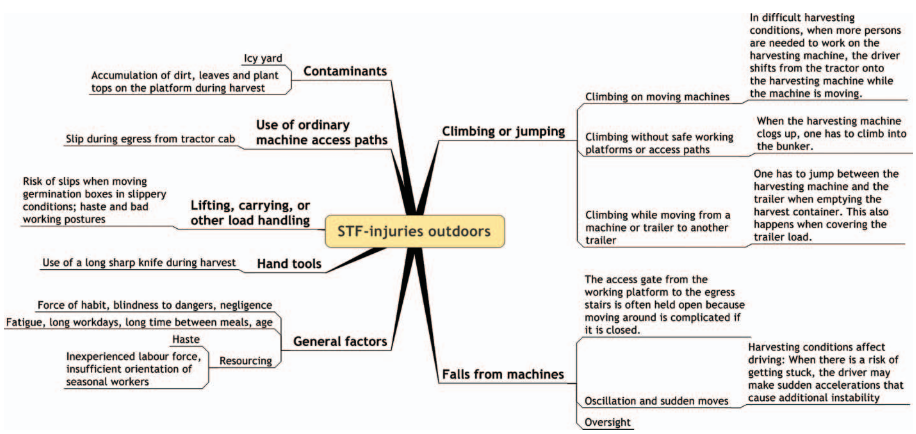

Figure 5. Non-building-related slip, trip and fall (STF) hazards expressed by farmers.

Discussion

STF injury was the most frequent injury type in potato, sugar beet and vegetable production in Finland during 1995–2004. STF injuries resulted in 54% of all lost work days due to injuries. This is due to the high number and severity of STF injuries. Slip was the most frequent STF injury type, which is consistent with an earlier study in animal confinement environments (Kaustell *et al.* 2007) and findings of Bentley *et al.* (2005). Severe (over 1 month disability) STF injuries caused 75% of all STF disability days. In multiple regression analyses, the severity of STF injuries was similar to entanglements and being crushed but more severe than most other injury types. This is consistent with studies where falls from tractor steps, stairs, scaffoldings and ladders have been found to be among the most frequent sources of serious injuries (McCurdy and Carroll 2000, Rautiainen *et al.* 2007). The same finding has been made in the construction sector by (Bentley *et al.* 2006).

In interviews, many farmers pointed out falling hazards that were also found from injury descriptions: deficiencies in access paths, use of ladders, as well as climbing on storage boxes, machinery and trailers. Farmers identified bad lighting and lack of space in relation to climbing on potato boxes or loads as risk factors in the working environment.

In Denmark, Kines (2002) found that the majority of fatal fall accidents in roof repair work occurred on farms. Most fatal accidents happened in the afternoon and without the use of personal fall protective equipment. In the afternoon, fatigue may affect the workers' risk perceptions and behaviour. Also, Nordstrom *et al.* (1996) and Paulson *et al.* (2006) stated that long working days/weeks increase the risk of falling injury. Work days can be extremely long in farming during harvest and other peak periods. In the present study, some interviewed farmers recognised that fatigue can lead to injuries. The September and October harvest season clearly coincides with the significant peak in injuries. Fatigue and time pressure are likely contributing factors to injuries during the harvest period. Reorganising the work may help to manage time pressure, reduce stress and rushing and improve safety (Kidd *et al.* 1996). Farmers also felt that long periods between meals and ageing may contribute to injuries. This injury claim analysis illustrated that the severity of injuries increased with age. Courtney *et al.* (2001) found that fall-related mortality increases with age. Kemmlert and Lundholm (2001) stated that older workers have lower accident rates in general, but they have higher rates of STF injuries than younger workers. If the average age of farmers increases in the future (following current trends), prevention of STF injuries may become a greater challenge (Courtney *et al.* 2001).

Building-related environments

In the present data, 30% of STF injuries occurred in buildings or in environments that involved built structures. This is in accordance with Pinzke and Lundqvist (2007), who reported that 28% of farm accidents in Swedish agriculture occurred indoors.

Gangway design (e.g. uniform stair dimensioning across various parts of the production facilities) and marking them could reduce trips. Clear marking of walkways and sufficient lighting could also point out areas that should be kept free of debris, pallets, sacks and other obstacles that are common contributors to injuries. Orderliness of working environments is key to preventing STF injuries (Kemmlert and Lundholm 2001, Lipscomb *et al.* 2006, Brogmus *et al.* 2007). As a reference, Bentley *et al.* (2006) found poor housekeeping also to be a risk factor in residential construction industry. The current results suggest that farmers underestimate slipping and tripping hazards, as well as the importance of housekeeping. The reasons behind this behaviour were not addressed in the present study. It is possible that cleanliness and orderliness at family-owned production premises are sensitive matters to discuss with visiting researchers. The farmers may have felt it was unnecessary to mention these issues, which the researchers can observe themselves. Possibly, there was a tendency by farmers to focus more on machine-related hazards because they recognised that the researchers came from a technology research institute. Moreover, it is possible that farmers become accustomed to and blind to the shortcomings of their working environment. Regardless of the underlying reasons, future studies should address the apparent gap between farmers' perceptions of STF injuries and housekeeping and frequency of related injuries. Effective interventions should also be developed. So far, systematic reviews of interventions for preventing injuries in the agricultural industry have shown little success (DeRoo and Rautiainen 2000, Rautiainen *et al.* 2008).

The number of falls from heights in buildings could potentially be reduced by using lifting devices (such as scissor lifts), by constructing adjustable elevated platforms in work and maintenance areas and by generally minimising elevation differences between work areas. Use of relatively low-tech solutions, such as mechanical or electric actuators to control ventilation or humidity measurement and control equipment, should be applied to eliminate the risk of falls during various kind of tasks that now involve hazardous climbing.

Carrying moderate to heavy loads was commonly related with STF injuries. This is in accordance with the findings of Davies *et al.* (2001) and Lipscomb *et al.* (2006), who examined hospitalised STF injury patients in general and construction-related STF injuries. In addition to obstructing the carrier's view to possible underfoot hazards, carrying a load affects the predominant balance and hampers recovery of balance after slips and trips. The working environment and injury types on construction sites are somewhat similar to those of farms growing potatoes, onions and carrots. Both include influence of weather, accumulation of debris on walking surfaces, manual work phases with load carrying and a physical environment that is at least partially constantly changing. The recommendations of Bentley *et al.* (2006) and Lipscomb *et al.* (2006) concerning the need for focus on environmental and organisational solutions definitely apply to the agricultural context.

Special attention should be paid to building-related factors. These include lighting, ventilation (exhaust gas, dust, temperature) control, etc., which affect human behaviour and performance. They were mentioned in the farmer interviews and they fit well to the findings of Bentley *et al.* (2006), Lipscomb *et al.* (2006) and Brogmus *et al.* (2007), concerning the significance of the human factor as one contributor to STF injuries.

Brogmus *et al.* (2007) suggested participatory design as one method to reduce the risk of STF injuries in hospital operation rooms. A similar approach could apply to agriculture. The layout of buildings and materials handling methods on a potato farm have typically evolved over time. The cost of machinery and availability of existing structures have often shaped processes, rather than use of professional/competent process designers. Bentley *et al.* (2005) found that plant design weaknesses are significant contributors to STF injuries. According to the present study, participatory design using the experience of all relevant workers could certainly be one effective approach to reduce the occurrence of STF injuries in built environments. The original design largely determines the safety of built environments. Built spaces inevitably shape ways of working and affect risk of injury.

The risk factors for STFs include many personal, work design and environmental factors. Therefore, a multifaceted approach is needed for prevention. The findings of Bentley *et al*. (2006), Haslam and Stubbs (2006) and Brogmus *et al*. (2007) support this conclusion. The factors identified from injury data and farmer interviews in the current study may provide detail for creating comprehensive intervention approaches to potato, sugar beet and open field vegetable production.

Outdoor environments

STF injuries occurred frequently when working or climbing on harvesters, planting machines or other machines and trailers. Hazards in mounting/dismounting and climbing have also been reported by Paulson *et al*. (2006). Pickett *et al*. (2001) and Lefort *et al*. (2003) found that falls from forest harvesting and agricultural machinery are common incident types. Proper entry and egress structures and minimising the need for these activities would potentially reduce slip and fall injuries. In Germany, most common fatal accidents in potato production involve workers falling off machinery in front of the wheels resulting in run-overs (Keller 2004).

Attention should also be paid to access ways for machine maintenance. Bentley *et al*. (2005), in their study of STF injuries on dairy farms, found design errors in machinery leading to improvised climbing around machines and potentially contributing to STF injuries. Machinery on Finnish potato, vegetable and sugar beet farms is rather old. This may increase the risk of falling accidents. Access paths and working spaces/platforms of new machines are safer and these machines also have new technologies controlling the process and decreasing the need for climbing. However, older machinery will likely stay in use for years. Interventions encouraging farmers to check the safety of their machinery and buildings could be useful in injury prevention.

Many injuries occurred when walking on slippery yards and driveways. Ice and snow were frequent contributors to STF injury. Maintenance of traffic and access areas is naturally important, particularly during winter. Spread of anti-slip materials during winter was highest on the list of preferred preventive measures among the outdoor working population studied by Gao *et al*. (2008). Nordstrom *et al*. (1996) reported that 52% of outdoor falls occurred on icy, wet or snowy surfaces. Gao *et al*. (2008) found that, especially, snow on ice is a dangerous underfoot surface. Slips in contaminated underfoot conditions could be reduced by using appropriate footwear with good soles (Grönqvist 1999, Bentley *et al*. 2005). This is especially true for activities such as moving materials and products with hand trucks and various climbing tasks, as well as walking on any surface, including icy farmyards. Sole material selection is, however, not straightforward; materials that are safe on wet and contaminated floors may not be suited for preventing slips when used outdoors in icy conditions (Gao *et al*. 2004).

Strengths and limitations

The strengths in this study include access to comprehensive mandatory workers' compensation data covering the entire self-employed farmer population in Finland. Consistent data over a long period of time were available for assessing the magnitude of the problem and risk factors for STF injury severity. Mela uses extensive coding systems, and secondary analysis of injury descriptions provided insight into the characteristics of STF injuries. Similar phase analysis has been used by Smith *et al*. (2006).

The weaknesses of this study include variation in growing potatoes, sugar beets and vegetables – the scale ranges from domestic use to large commercial operations and the growing methods and working conditions differ widely. Also, the insured persons in this study were self-employed farmers, excluding hired employees on large farms. Therefore, the current findings on incident characteristics may differ from those in large-scale potato, sugar beet and vegetable production in other countries.

Injury claim data are subject to under-reporting. Some claims are made but not compensated (below 10% in this system), but compensable unclaimed cases are more common. Based on several published surveys and the pyramid theory, Suutarinen (2003) estimated 10–30% under-reporting may occur in studies based on Mela's material. Much greater under-reporting was reported by Pinzke and Lundqvist (2007); only 8% of farm accidents reported in a mail survey emerged in official statistics of occupational injuries in Sweden. The true magnitude of unclaimed injuries and near misses is unknown.

Conclusions

The results of this study indicate that STF injuries represent a large proportion of the injury burden in potato, sugar beet and vegetable production. Interventions should focus on making buildings, structures, machinery and equipment safer. Special attention should be paid to user needs and usability design.

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