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Occupational injury rates among Norwegian farmers: A sociotechnical perspective

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ABSTRACT

Introduction: This study addressed relative injury risk among Norwegian farmers, who are mostly self-employed and run small farm enterprises. The aim was to explore the relative importance of individual, enterprise, and work environment risks for occupational injury and to discuss the latent conditions for injuries using sociotechnical system theory. *Method:* Injury report and risk factors were collected through a survey among Norwegian farm owners in November 2012. The response rate was 40% (n = 2,967). Annual work hours were used to calculate injury rates within groups. Poisson regression using the log of hours worked as the offset variable allowed for the modeling of adjusted rate ratios for variables predictive of injury risk. Finally, safety climate measures were introduced to assess potential moderating effects on risk. *Results:* Results showed that the most important risk factors for injuries were the design of the workplace, type of production, and off-farm work hours. The main results remained unchanged when adding safety climate measures, but the measures moderated the injury risk for categories of predominant production and increased the risk for farmers working with family members and/or employees. An overall finding is how the risk factors were interrelated. *Conclusions*: The study identified large structural diversities within and between groups of farmers. The study drew attention to operating conditions rather than individual characteristics. The farmer's role (managerial responsibility) versus regulation and safety climate is important for discussions of injury risk. *Practical Applications:* We need to study subgroups to understand how regulation and structural changes affect work conditions and management within different work systems, conditioned by production. It is important to encourage actors in the political-economic system to become involved in issues that were found to affect the safety of farmers.

1. Introduction

National statistics indicate a substantial risk of fatal agricultural injuries (Norwegian Labour Inspection Authority, 2015). Nonfatal injury statistics are insufficient, in terms of both prevalence and circumstances, which is also an international concern (Donham & Thelin, 2016; Leigh, Du, & McCurdy, 2014; Solomon, Poole, Palmer, & Coggon, 2007). Moreover, studies of injury risk in farming lack information about exposure time (Jadhav, Achutan, Haynatzki, Rajaram, & Rautiainen, 2015), which makes it difficult to compare results and address preventive efforts, as these data are difficult to obtain. Various types of risk factors have been suggested for agricultural injuries, such as individual characteristics, activities, and production. Meanwhile, other studies emphasize risk factors that are less attached to activity or production, such as stressors and structural characteristics of the farm enterprise. These may serve as underlying features, also called latent conditions, through which agricultural injuries could be better understood. Using sociotechnical systems theory for discussing latent conditions in farming is an unexplored field.

The aim of this study is to assess the relevance of structural factors for occupational injuries among Norwegian farmers when controlling for work hours. The specific research questions are as follows:

1. What factors – in terms of individual and enterprise characteristics and work environment – predict injury risk among Norwegian self-employed farmers?
2. Do farmers' perceptions of safety climate affect the injury risk?

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The study has a multidisciplinary point of departure, which we find suitable for a discussion of occupational injuries in a wider perspective. Sociotechnical system theory is used to discuss the results in light of latent conditions in the farmers' work system (Smith & Carayon-Sainfort, 1989). The following sections will present current research on agricultural injuries, our theoretical point of departure, the Norwegian study context, and the conceptual approach.

1.1. Occupational injury risk within farming

It is well documented that farming is dangerous in terms of fatalities and injuries (Jadhav et al., 2015; Jadhav, Achutan, Haynatzki, Rajaram, & Rautiainen, 2016). At the individual level, risk factors for injuries are gender, age, physical health, and types of employment (Day et al., 2009; Horsburg, Feyer, & Langley, 2001; Jadhav, Achutan, Haynatzki, Rajaram, & Rautiainen, 2017; Rautiainen, Ledolter, Donham, Ohsfeldt, & Zwerling, 2009; Sprince et al., 2003; Virtanen, Notkola, Luukkonen, Eskola, & Kurppa, 2003). Studies also point to specific activities like handling animals, tractors, and other machinery as frequent direct causes of nonfatal injuries (Erkal, Gerberich, Ryan, Renier, & Alexander, 2008; Jadhav et al., 2017; Karttunen & Rautiainen, 2013; Solomon, 2002; Taattola et al., 2012; Virtanen et al., 2003). Moreover, numerous farm characteristics have been shown to be risk factors for injuries. One study found a difference between production types, with dairy farmers and pig farmers having the highest increased injury risk (Hartman et al., 2004). Factors like income level, field size, and occupational health service membership are risk factors for injuries (Rautinainen et al., 2009). Several studies have indicated that organizational aspects are important for risk, where injury risk is associated with being a full-time farmer and/or a farm owner (Jadhav et al., 2015), number of employees (Jadhav et al., 2017; Van den Broucke & Colémont, 2011), two operators and operators with fellows (Karttunen & Rautiainen, 2013), and cooperation with other farmers (Taattola et al., 2012). One study found single working farmers to be less at risk (Svendsen, Aas, & Hilt, 2014). Results are therefore inconclusive regarding the organizational aspects of farming. Heavy workloads, in terms of hours, have also been found to be a risk factor in several studies (Glasscock, Rasmussen, Carstensen, & Hansen, 2006; Hartman et al., 2004; Svendsen et al., 2014). Glasscock et al. (2006) found that stressors and stress symptoms like role conflict, economic concerns, administrative burden, and unpredictability are additional risk factors for injuries. Therefore, the status quo is indicative of how both organizational and managerial issues should be addressed to a higher extent than today when injury risks are studied in farming. Moreover, the effect of injury risk relative to exposure time (Jadhav et al., 2015) and off-farm work on injury represents a knowledge gap in this field (Jadhav et al., 2016).

1.2. Theoretical framework

Occupational injuries get little public attention (Lindøe, Engen, & Olsen, 2011) and are often viewed as individual accidents (Reason, 1997), where the worker is both the agent and the victim (Hovden, Albrechtsen, & Herrera, 2010). Thus, attempts are often made to explain occupational injuries through individual characteristics and direct causes. Direct causes or active failures are more visible than potential structural causes (latent conditions) of these events. Based on the worldwide changes in working life structures (e.g., technology and labor markets), Hovden et al. (2010) suggested that models derived from research in complex, high-risk, and socio-technical systems are also relevant for preventing occupational accidents, whose causes are influenced by external/contextual factors, like political climate and financial pressure (Rasmussen, 1997). Therefore, there is a need for discussing agricultural risk factors at a systemic level, moving away from the individual focus.

Sociotechnical system theory emphasizes the organization's interdependence of both the technical and social systems to obtain the most efficient results. This calls for addressing organizational design, such as the design of jobs and ways of organizing the work (Davis, Challenger, Jayewardene, & Clegg, 2014). Several sociotechnical models are in use, serving different purposes (e.g., Carayon, 2009; Leveson, 2004; Rasmussen, 1997; Smith & Carayon-Sainfort, 1989). However, all of them acknowledge that organizations and work systems depend on the environment by which they are regulated and otherwise influenced. Latent (underlying) conditions for accidents may therefore be economic constraints or production requirements that affect how the work is organized, as well as changes and irregularities within the system. A lack of awareness of the system mechanisms may itself be a latent condition, especially relevant in smaller work systems with few or no formal employees.

When studying farmers and agriculture, an appropriate model for understanding safety is the model described by Carayon et al. (2015), integrating the "balance theory of job design for stress reduction" (Smith & Carayon-Sainfort, 1989). This model places the worker in the center of the work system, and the work system is seen as *the local context in which work activities are performed,* embedded within a larger sociotechnical context, involving organizational structural elements and the external environment including regulatory regimes (Carayon et al., 2015). The "sharp end" refers to the area where the worker/operator faces the physical and technical challenges of the production (Reason, 1997), and while "sharp end" operators in other industry productions may be bounded by procedures set by others, the center position in the model (Carayon et al., 2015) gives a high degree of influence over the current work situation. Seeing the worker in the center, we believe, makes this model practically focused and compatible with unpredictability. First, worldwide agriculture is dominated by family farming[1] (Donham & Thelin, 2016), agricultural enterprises are small (<50 employees) and micro (<10 employees)[2], and the owner is the main worker (i.e., the leader-owner), which is similar to small and micro enterprises in general (Hasle, Limborg, Kallehave, Klitgaard, & Andersen, 2012). Second, due to technological development and high employment costs, Northern Europe and Scandinavia lead the world in the level of automated milking systems (AMS), requiring fewer employees (de Koning & Rodenburg, 2004; Hansen, 2015), making the farmer him/herself highly exposed to the technological changes. In Carayon's model (2015), technology is equally weighted with other elements of the system (organization, task, environment, individual), and the worker is to a greater degree an agent with the power to act, compared to other models (e.g., Rasmussen, 1997) and might reflect farmers covering roles as workers, owners, and leaders. Moreover, farming is in general characterized by small-scale, manual, linear, and somewhat transparent work, which can therefore be defined as the "sharp end" (Reason, 1997) (Fig. 1).

Within a system perspective, addressing the farmer as a manager becomes critical; hence, the literature on small enterprises and the management of OHS is relevant. Small enterprises have restricted resources for handling occupational health and safety (hereafter, OHS) (Champoux & Brun, 2003; Hasle & Limborg, 2006), often resulting in a lack of formal documentation and man-

[1] http://www.fao.org/3/a-i4036e.pdf. The state of food and agriculture 2014 (in brief) by the Food and Agriculture Organization of the United Nations. Downloaded June 14, 2017.

[2] http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/index_en.htm.

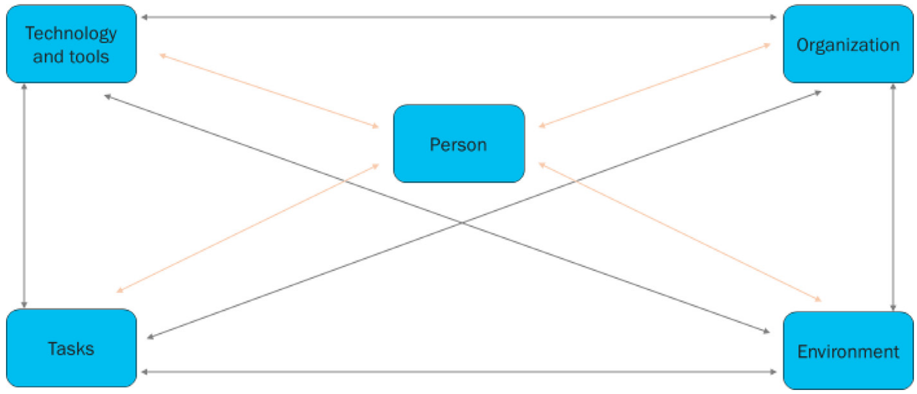

Fig. 1. The work system (Smith & Carayon-Sainfort, 1989).

agerial responsibility for these matters (Hasle & Limborg, 2006; MacEachen et al., 2010; Sorensen, Hasle & Bach, 2007). The OHS responsibility may even be redistributed to the worker (Hasle et al., 2012), and leader-owners often face dilemmas between interests of the enterprise (economy, survival) and workers' interests (future work, health, and safety) (Hasle et al., 2012; Vickers, James, Smallbone, & Baldock, 2005). Moreover, in farm enterprises, risk is more accepted, but also harder to detect (Storstad, Holte, & Aas, 2013), and animal husbandry makes the work environment unpredictable (Follo et al., 2016). Furthermore, cross-sectorial studies indicate that industries with a low degree of formal organization and where safety pressure from external stakeholders is low have fewer incentives for systematic safety improvements (Gaupset, 2000; Lindøe et al., 2011; Vickers et al., 2005).

Current research and quotes from Norwegian farmers (unpublished data) support the impression that farmers are not perceived as managers (by others or themselves) and that the farm is seldom referred to as an enterprise as such. Moreover, as industries and organizations change, the awareness of the unsolved challenges regarding workplace safety increases, motivating continuous efforts to understand the underlying mechanisms of occupational injuries. Knowing that choices made in the work system are heavily influenced by external factors pinpoints the irony of personalizing agricultural injuries and calls for efforts to address emergent risks on a systemic level (Carayon et al., 2015). Accordingly, external factors should be given more attention regarding their impact on structural factors and decisions made by the farmer as a manager, pointing to laws and regulations, authorities, stakeholders, etc.

2. Study context

Norwegian agriculture mainly consists of self-employed farmers (Statistics Norway, 2016a), although they often receive help from family (Logstein, 2012), which is rarely displayed in formal statistics. In recent decades, structural changes have reduced the number of holdings, farmers, and man-labor years (Statistics Norway, 2016b). Yet, holdings are larger and more efficient, and there has not been an overall reduction in the production of agricultural products (Statistics Norway, 2016b). However, cold and wet climates, large areas with steep terrain, and small and scattered fields challenge the development of modern agricultural production. The increased use of AMS (de Koning & Rodenburg, 2004; Hansen, 2015) may have had an impact on how the industry is organized, in terms of each farmer's workload, number of employees, and degree of cooperation with other farmers (Statistics Norway, 2016b).

In a system perspective, Norwegian agriculture differs from other countries, particularly in terms of political arrangements (Rommetvedt & Veggeland, 2017). It constitutes a political-economic system, including the government, the parliament, political parties, public administration, corporate organizations, producers, and the individual as a consumer and a voter (Rommetvedt, 2002). In matters of promoting agricultural interests in policy-making farm-owners are represented through two associations (Norwegian Farmers' Union and the Association for Smallholders), and the farm economy is heavily dependent on the annual negotiations between them and the government (Farsund, 2002). When it comes to OHS regulations, self-employed farmers are not subject to the regulations outlined in the Working Environment Act (2005) unless they are considered employers. When they are an employer, the requirements relate to safety training for and security of the employees, but not the employer him/herself[3]. Detailed OHS regulations relate more to the use of machinery and quality of products than requirements for safe work. Little formalization is put on farmers' solutions for practical work or for managing workplace safety.

In addition, most agricultural producers are certified according to the Norwegian Agricultural Quality System and Food Branding Foundation (Norwegian abbreviation: KSL). The KSL includes OHS and performs farm audits at given intervals, depending on type of production (Holte & Follo, 2018). The farm economy is partly dependent on satisfactory quality results, because the farm can be "punished" through lower prices for the products they deliver, which makes the KSL an important external factor influencing the farmer's work system.

3. Conceptual approach

The conceptual model (Fig. 2) is based on a combination of demographic and enterprise characteristics as well as variables related to work environment. Each of these three groups of variables is treated as independent risk factors for being injured during work. Because work hours are controlled for, individual variables are equally interesting as variables related to the farm as an enterprise/organization. Physical and quantitative demands are known to increase the risk of injuries (Cantley, Tessier-Sherman, Slade, Galusha, & Cullen, 2016; Hollander & Bell, 2010; Kjestveit, Tharaldsen, & Holte, 2011; Treiber, 2009) and are included as work environment variables, in addition to workplace design. Off-farm work hours are included as an independent variable, representing an aspect of the overall job demand. We called the first search for predictors (horizontal arrows) Model 1.

[3] The Working Environment Act (2005): §2-1, §2-2.

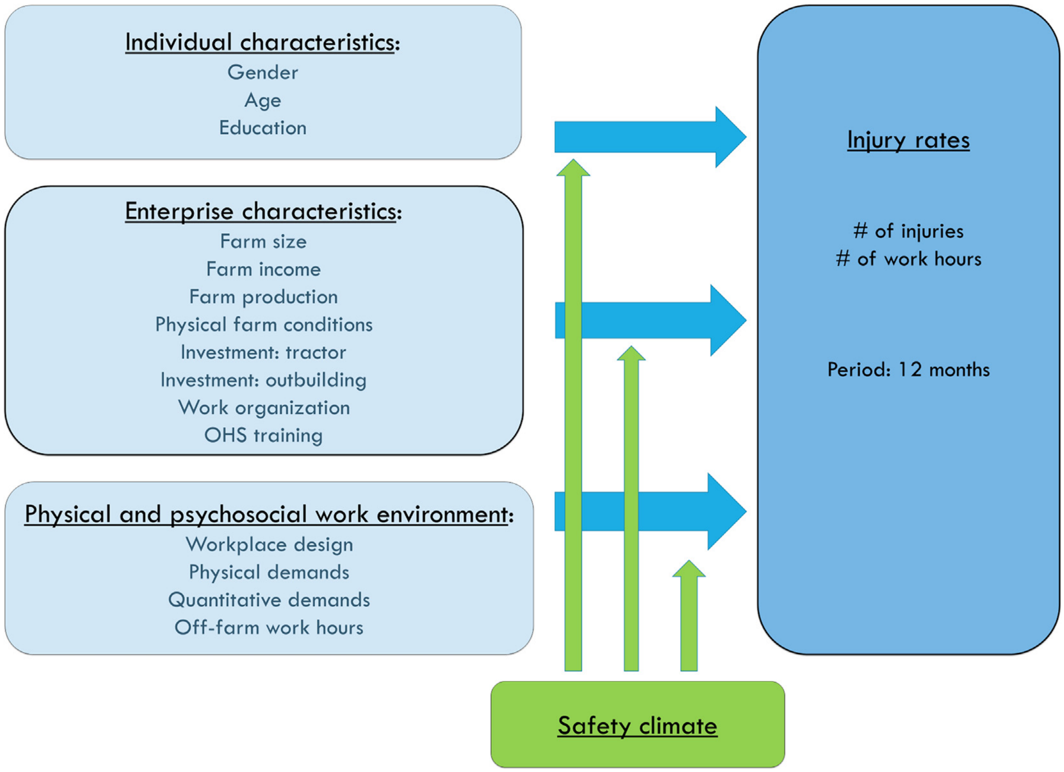

Fig. 2. Conceptual model — searching for predictors.

Safety culture is increasingly recognized as important for injury prevention within agriculture (McNamara et al., 2018; Törner et al., 2002) and should also be considered when using sociotechnical system theory (Carayon et al., 2015). Because culture is difficult to measure, safety climate assessments are performed for this purpose, as it gives a snapshot of the prevailing situation (Mearns, Whitaker, & Flin, 2003). A favorable safety climate is found to correlate positively with safety behavior and the reduction of injuries among employees in large companies (e.g., Ajslev et al., 2017; Antonsen, 2009; Dahl & Kongsvik, 2018; Mearns et al., 2003; Neal & Griffin, 2006; Treiber, 2009). Agriculture and other small-scale industries that miss formal organizational structures, management, and co-workers are perceived as having less fit to safety climate measures. Therefore, we have partly borrowed and partly developed suitable variables to include in our measures of safety climate, as described in section 4.1.5. A discussion of how safety climate assessments affect the main results is of special interest in our study because having what could be called a "good" safety culture is about handling risk, which is essential in workplaces characterized by unpredictability (Grote, 2012). High-risk organizations typically aim to reduce uncertainty because their survival is dependent on low accident rates (Grote, 2012). Where elimination is difficult, the focus must lie on coping with uncertainty (Grote, 2012).

To investigate the potential in joint cultural elements, the found predictors in Model 1 were tested again by including indexes for safety climate. The repeated version of the model while including safety climate (vertical arrows) was called Model 2.

4. Materials and methods

The study was designed as a national survey among farm owners who were 18 years or older. The questionnaire covered individual and enterprise characteristics, such as age, education, marital status, farm income, work hours, employees, machinery, health and worries, physical and psychosocial work environment, injuries, and safety climate.

4.1. Population and data collection procedures

Study participants were recruited through the registry of producers in the Norwegian Agricultural Authority, where persons who perform agricultural production and who apply for farm production subsidies are registered. The registry allows only one person per farm enterprise (i.e., the farm owner). In 2012, there were 43,917 agricultural enterprises registered, and 7,500 random units were drawn as a study sample.

A paper questionnaire was post mailed to the participants in November 2012, with an online option for answering. Reminders were sent out four weeks later. Ultimately, 59 questionnaires were returned due to unknown address and the like, giving a net sample of 7,441 farmers. Sentio Research Norge AS performed the actual data collection.

To ensure adequate treatment of the independent variables, some variables were refined, and indexes for work environment and safety climate were prepared. Details are given in the following subsections.

4.1.1. Self-reported work environment

Fourteen items on the questionnaire measured physical and quantitative work demands; these were subject to exploratory factor analysis with Oblimin rotation. Dissimilar response categories (8 items + 6 items) limited the options for indexes, but three indexes obtained satisfactory coherence (Cronbach's alpha): (1) workplace design, which includes three questions related to cramped space, bad lighting, and bothersome equipment (yes/no; Cronbach's alpha = 0.653); (2) physical demands, which include three questions related to demands for heavy lifting and repetitive movements, as well as work in bent, twisted, or any other strained positions (yes/no; Cronbach's alpha = 0.626); and (3) quantitative demands, which include three questions related to demands of a high work pace, very hard work, and too much work effort (yes/often; yes/sometimes; no/seldom; no/hardly ever; Cronbach's alpha = 0.772). The questions stem from Karasek and Theorell's (1990) work, and this index has also been used in other studies (Bjerkan, 2010; Logstein, 2016).

4.1.2. Predominant production

Details related to farm production were given directly through the registry of producers and revealed an overlap of production types (see Fig. 3). Mutually exclusive categories of predominant farm production were created using the following principles: (a) dairy cattle superseded all else; (b) other cattle superseded anything but dairy cattle; (c) due to being almost omnipresent, fodder was not excluded from other productions unless the respondent only produced fodder; (d) fodder and grain were set as distinct categories; and (e) the "other" category included other combinations and productions with a prevalence <5% (horses, fruit and vegetables, pigs, poultry, and fur farming).

4.1.3. Work organization

The farmers were asked to report annual work hours at the farm performed by people other than themselves. Based on this information, three categories of work organization were constructed: (a) the lone farmer, who had no one to help with farm work; (b) the family farmer, who worked together with his/her spouse and/or other family members; and (c) the farmer who hired one or more employees and/or relief workers, irrespective of family.

4.1.4. Other workplace characteristics

The variable *Physical farm conditions* was based on a question where the respondents could tick off one or several difficulties regarding farm condtions outdoor. Except for one response (No difficult farm conditions), six categories referred to difficulties regarding small, scattered, and/or uneven fields, long distances to fields, road/railroad crossings with fodder and/or livestock, challenging roads/bridges to fields, and steep terrain. A sumscore was used to reorganize into three final categories ($\leq$1 difficulty = not very complicated; 2–3 difficulties = complicated; 4–6 difficulties = very complicated).

The degree of mechanization on the farm was self-assessed by the farmer through a specific question with three response categories (high degree; middle degree; low degree).

Respondents were asked for age of tractors. We chose to use the newest tractor as an indication of investment (>5 years = old; $\leq$5 years = new). The equivalent was done for outbuildings, where a split at 12 years was set to correspond to the year that AMS was first introduced in Norway. In the outbuilding question, one was to name the year of construction or re-construction, and the newest year was used in the analysis.

4.1.5. Assessments of safety climate

The questionnaire contained 40 statements regarding safety climate. The statements were partly based on Almås (1982) (n = 5), Törner et al. (2002) (n = 5), NOSACQ-50 (Kines et al., 2011) (n = 3), and the Petroleum Safety Authority Norway's (2014) Risk Level Project (n = 5). The remaining statements (n = 22) were developed by the project group to cover topics that emerged from qualitative interviews conducted in the overall Accidents in Norwegian Agriculture (AINA) project (unpublished data).

An exploratory factor analysis was conducted using principal axis factoring and Oblimin rotation, and items with correlations <0.3 were excluded. In general, the correlations were low (<0.4), and different solutions for missing values were used to look for correlation patterns. Five indexes were suggested in the model, but only three were found to be adequate. In total, 20 items were included in the indexes. *Safety System* (Climate 1) measured the respondents' attitudes towards a systematic safety approach, including safety audits. *Accept/Normalization* (Climate 2) measured the attitude towards the farmers' own possibilities to affect injuries and safety level. *Safety Practice* (Climate 3) measured the actual safety behavior, as perceived by the respondents (Table 1).

4.2. Data analyses

The quantitative analyses are described in five steps. All statistical analyses were made using SPSS version 25.0. Goodness of fit was tested using Pearson's chi square/df.

First, a 12-month injury prevalence for farmers was calculated. The number of injuries was based on two questions regarding occurrence and number of accidental injuries in relation to farm work during the past 12 months. In addition, injuries that were described in detail in a second questionnaire[4] were included if they were reported to occur in 2012, corresponding to the preceding 12 months. Reporting being "injured" with no information about frequency was coded as a single injury. Outliers were Winsorized (Yang, Xie, & Goh, 2011) and replaced with the nearest "non-suspect" value, which in this case was six. See Table 2 for the distribution of injuries.

Second, the material was explored using descriptive statistics. Correlations between the independent variables were investigated, and cross-tabulations with chi-square tests were made for variables of special interest.

In the third step, crude injury rates for all independent variable categories were calculated and expressed as injuries per 100,000 hours worked. Thereafter, crude rate ratios were calculated, using the category with the lowest crude rate within each variable as a reference category. Self-reported work hours at the farm during the preceding 12 months (string variable) were used to indicate work hours. When reporting their own work hours, the respondents were given the example of 1,700 hours as the annual workload for an industrial worker; 5% and 95% percentiles were used to eliminate extreme values, which resulted in an interval of 150–3,400 (n = 2,605, missing = 362, mean = 1,435, SD = 899).

Step four consisted of calculating adjusted rate ratios. A Poisson regression was used because of a count outcome and low injury prevalence (Agresti, 2013; Coxe, West, & Aiken, 2009). Crude rate ratios (CRR) were used as selection criteria for the regression analysis. Variables with 0.8 < CRR < 1.2, as well as variables with <15% impact on other variables, were left out. The outcome (injuries) is relative to work hours, thus *Log (work hours)* was the link function in our model. To clarify, variables whose categories obtained p-values <0.05 were kept in the model even if the overall variable did not meet this criterion. Confidence limit ratios (CLRs) were reported for the final variables (see Table 3).

In the final and fifth step, step four was repeated for the revealed risk factors and for indexes for safety climate. These were added to detect moderating effects on injury risk.

5. Results

5.1. Presenting the sample

Of 7,441 farmers approached, 2,967 responded, giving a response rate of 40%. The respondents were found to be represen-

[4] The second questionnaire contained questions specifically aimed at the circumstances of accidents and injuries that had occurred at the farm during the preceding 5 years and was a supplement to the injury questions in the first questionnaire.

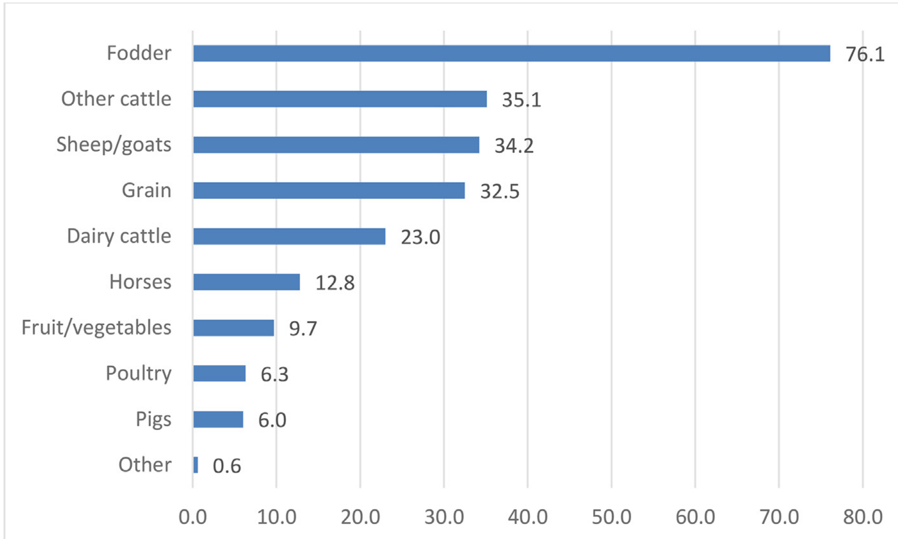

Fig. 3. Production at the farm (%; several categories possible, so the total >100).

Table 1
Safety climate indexes.

#	Index name	Cronbach's Alpha	# of items
1	Safety System	0.738	7
2	Accept/Normalization	0.700	6
3	Safety Practice	0.716	7

tative in terms of age, geographical belonging, and type of production (Storstad et al., 2013). Production characteristics are given in Fig. 3, showing that there was a heterogeneity and overlap regarding productions and that 76% of the farms produced fodder. For practical reasons, fodder was therefore not excluded from animal-related activity when constructing mutually exclusive predominant production categories (Fig. 4).

Work hours at the farm were unevenly distributed, as were off-farm work hours. Both entities are shown in Fig. 5. Cross-tabulations were made for work organization*work hours, predominant production*work hours, and predominant production*off-farm work hours, and the chi-square tests were all significant at the $p = 0.000$ level.

Thirty percent of respondents reported being full-time farmers (i.e., no other paid work). In terms of work organization, workers with hired help had the highest prevalence of full-time farmers (39%), while family farmers had the lowest (22%). In terms of predominant production, full-time farmers were most common among dairy farmers (51 %), followed by sheep/goat and other/mix (28 %). Grain producers had the lowest prevalence of full-time farmers (16%) and the highest prevalence of full-time off-farm work (47%).

Furthermore, 59% of family farmers worked more than 850 hours/year off farm, followed by lone farmers (52%) and farmers with hired help (34%). A higher percentage of farmers with workers said that they were full-time farmers (39%), followed by lone farmers (30%) and family farmers (22%). The chi-square test was statistically significant with $p < 0.005$.

All correlations between independent variables are <|0.3|.

5.2. Injury prevalence and rates

Only 6.7% of respondents had been injured in an occupational farm accident during the preceding 12 months, irrespective of the number and work hours (see Table 2 for injury distribution). Crude rates (CR) and CRR for independent variables are presented in Table 3. High CRRs (>2.0) were found for age (<35, 35–44, 45–54), certain types of predominant production (other cattle, fodder, and other/mixed production), education (university), work organization (family farm, relief/other workers, and family), physical farm conditions (very complicated), and workplace design (highly challenging).

5.3. Regression results

Poisson regression analyses used injury rates results for modeling (see Table 3 for details). Goodness-of-fit tables showed that Pearson's chi square/df = 2.011, which indicated overdispersion. Deviance was therefore scaled with Pearson's chi square in the adjusted model.

5.3.1. Model 1: Testing independent variables

Results from the adjusted model (Adj RR) are shown in Table 3. Only workplace design had an overall significant model effect ($p = 0.012$). Respondents with highly challenging design faced an injury risk 2.23 times greater than the risk of respondents who reported good design ($p = 0.009$, CLR = 2.85). Predominant production had a borderline non-significant model effect ($p = 0.056$); however, three of the response categories had significantly higher injury risk than the reference category (Adj RR/p-value): other cattle (2.56/0.028), fodder (3.36/0.015), and other/mixed production (2.91/0.007). High CLRs (>4.8) were observed for all three categories.

Table 2
Injury prevalence, total sample ($n = 2967$).

# Injuries	0	1	2	3	4	5	6	Missing	Total
Frequency	2707	166	15	6	3	3	4	63	2967
Percent	91.2	5.6	0.5	0.2	0.1	0.1	0.1	2.1	100

Table 3
Crude rates and regression results: model 1 (independent variables) and model 2 (adding safety climate).

Variables and categories (n*)	# Injuries**	# Hours worked	Crude rate (CI 95 %)	Crude Rate Ratio (RR) (CI 95 %)	Model 1			Model 2		
					Adj RR (CI 95 %)	CLR***	p-value	Adj RR (CI 95 %)	CLR***	p-value
Age										
<35 (158)	30	222,405	13.5 (8.7–18.3)	4.14 (2.2–7.8)						
35–44 (499)	53	639,810	8.3 (6.1–10.5)	2.34 (1.3–4.2)						
45–54 (873)	93	1,147,970	8.1 (6.5–9.7)	2.35 (1.3–4.1)						
55–64 (897)	72	1,186,208	6.1 (4.7–7.5)	1.71 (0.96–3.0)						
≥65 (438)	16	438,926	3.6 (1.9–5.4)	1						
Missing (102)	*1*									
Gender										
Female (358)	32	393,604	8.1 (5.3–10.9)	1.22 (0.8–1.8)	1.31 (0.7–2.3)	1.60	0.358	1.25 (0.7–2.1)	1.38	0.402
Male (2575)	229	3,298,184	6.9 (6.0–7.8)	1	1			1		
Missing (34)	*4*									
Education										
University (700)	64	731,729	8.7 (6.6–10.9)	2.06 (1.3–3.3)						
Upper secondary (academic) (382)	36	500,539	7.2 (4.8–9.5)	1.59 (0.9–2.7)						
Upper secondary (voc./agric.) (1385)	138	1,894,267	7.3 (6.1–8.5)	1.66 (1.1–2.6)						
Primary/secondary school (432)	24	535,582	4.5 (2.7–6.3)	1						
Missing (68)	*3*									
Income****										
No/negative income (312)	16	268,352	6.0 (3.0–8.9)	1.01 (0.6–1.8)	0.68 (0.3–1.8)	1.56	0.440	0.73 (0.3–1.8)	1.47	0.484
1–49999 NOK (513)	30	355,928	8.4 (5.4–11.4)	1.38 (0.9–2.2)	1.31 (0.6–2.9)	2.33	0.508	1.19 (0.6–2.5)	1.91	0.650
50–99999 NOK (492)	44	444,671	9.9 (7.0–12.8)	1.76 (1.2–2.6)	1.86 (0.96–3.6)	2.65	0.068	1.79 (0.97–3.3)	2.33	0.064
100000–199999 NOK (629)	66	895,577	7.4 (5.6–9.1)	1.33 (0.9–1.9)	1.38 (0.8–2.4)	1.58	0.250	1.51 (0.9–2.5)	1.55	0.101
≥ 400,000 NOK (297)	37	527,591	7.0 (4.8–9.3)	1.12 (0.7–1.7)	1.00 (0.5–1.9)	1.38	0.993	1.00 (0.6–1.8)	1.23	0.989
200000–399999 NOK (658)	69	1,186,473	5.8 (4.4–7.2)	1	1			1		
Missing (66)	*3*									
Mechanization										
High degree (732)	70	913,135	7.7 (5.9–9.5)	1.07 (0.7–1.6)						
Medium degree (1707)	159	2,263,383	7.0 (5.9–8.1)	0.98 (0.7–1.4)						
Low degree (418)	34	471,017	7.2 (4.8–9.6)	1						
Missing (110)	*2*									
Predominant work										
Other cattle (not dairy) (360)	47	489,721	9.6 (6.9–12.3)	2.70 (1.6–4.6)	2.56 (1.1–5.9)	4.82	0.028	2.32 (1.1–4.9)	3.82	0.027
Fodder (only) (222)	18	189,261	9.5 (5.1–13.9)	2.60 (1.4–5.0)	3.36 (1.3–9.0)	7.69	0.015	2.90 (1.2–7.1)	5.86	0.019
Other/mixed production (704)	80	865,347	9.2 (7.2–11.3)	2.51 (1.5–4.2)	2.91 (1.3–6.3)	5.00	0.007	2.65 (1.3–5.4)	4.04	0.006
Dairy cattle (683)	88	1,355,303	6.5 (5.1–7.8)	1.64 (1.0–2.7)	2.19 (0.97–5.0)	4.01	0.060	1.99 (0.96–4.2)	3.20	0.066
Grain (only) (459)	11	265,876	4.1 (1.7–6.6)	1.07 (0.5–2.3)	1.17 (0.4–3.8)	3.47	0.799	1.23 (0.4–3.6)	3.15	0.698
Sheep/goats (510)	19	542,679	3.5 (1.9–5.1)	1	1			1		
Missing (29)	2									
Farm size										
< 50 da (356)	21	268,469	7.8 (4.5–11.2)	1.42 (0.9–2.3)	1.61 (0.8–3.4)	2.59	0.204	1.79 (0.9–3.5)	2.54	0.084
50–99 da (529)	30	454,913	6.6 (4.2–9.0)	1.04 (0.7–1.6)	1.05 (0.5–2.0)	1.51	0.885	1.15 (0.6–2.1)	1.49	0.664
250–499 da (641)	79	1,069,314	7.4 (5.8–9.0)	1.26 (0.9–1.7)	1.24 (0.8–2.0)	1.27	0.398	1.20 (0.8–1.9)	1.13	0.429
≥ 500 da (263)	48	413,072	11.6 (8.3–14.9)	1.99 (1.4–2.9)	1.81 (0.96–3.4)	2.43	0.065	1.62 (0.9–2.9)	1.98	0.105
100–249 da (1139)	84	1,508,359	5.6 (4.4–6.8)	1	1			1		
Missing (39)	*3*									
Joint operation										
Yes (115)	14	172,817	8.1 (3.9–12.3)	1.23 (0.7–2.1)						
No/missing (2852)	251	3,566,620	7.0 (6.2–7.9)	1						

Table 3 (*continued*)

Variables and categories (n*)	# Injuries**	# Hours worked	Crude rate (CI 95 %)	Crude Rate Ratio (RR) (CI 95 %)	Model 1			Model 2		
					Adj RR (CI 95 %)	CLR***	p-value	Adj RR (CI 95 %)	CLR***	p-value
Investment: Tractor										
Old (>5 years) (1870)	170	2,150,626	7.9 (6.7–9.1)	1.24 (0.95–1.6)						
New (≤5 years) (930)	88	1,403,565	6.3 (5.0–7.6)	1						
Missing (167)	*7*									
Investment: Outbuilding										
New (≤12 years) (855)	100	1,237,265	8.1 (6.5–9.7)	1.14 (0.9–1.5)						
Old (>12 years) (1999)	164	2,418,757	6.8 (5.7–7.8)	1						
Missing (113)	*1*									
Work organization										
Relief/other workers and family (1210)	146	1,983,819	7.4 (6.2–8.6)	2.29 (1.3–4.1)	1.93 (0.8–4.8)	4.01	0.157	2.52 (0.99–6.4)	5.43	0.053
Family farm (1177)	97	1,262,679	7.7 (6.2–9.2)	2.44 (1.3–4.5)	1.77 (0.7–4.4)	3.67	0.221	2.41 (0.9–6.1)	5.20	0.066
No help (533)	13	404,939	3.2 (1.5–5.0)	1	1			1		
Missing (47)	*9*									
Physical farm conditions										
Very complicated (671)	94	1,019,282	9.2 (7.4–11.1)	2.05 (1.5–2.9)						
Complicated (1147)	117	1,498,790	7.8 (6.4–9.2)	1.65 (1.2–2.3)						
Not very complicated (1091)	52	1,166,145	4.5 (3.2–5.7)	1						
Missing (58)	*2*									
OHS training										
Yes (1302)	149	1,867,447	8.0 (6.7–9.3)	1.26 (0.98–1.6)						
No/missing (1665)	116	1,871,990	6.2 (5.1–7.3)	1						
Workplace Design										
Highly challenging (3 items) (885)	139	1,235,102	11.3 (9.4–13.1)	2.77 (1.8–4.2)	2.23 (1.2–4.1)	2.85	0.009	2.01 (1.1–3.6)	2.43	0.017
Challenging (2 items) (628)	55	799,032	6.9 (5.1–8.7)	1.78 (1.1–2.8)	1.66 (0.9–3.2)	2.35	0.131	1.59 (0.9–3.0)	2.09	0.139
Moderate (1 item) (648)	35	804,460	4.4 (2.9–5.8)	1.1 (0.7–1.8)	1.04 (0.5–2.2)	1.66	0.917	1.05 (0.5–2.1)	1.55	0.897
Good (no items) (629)	31	740,949	4.2 (2.7–5.7)	1	1			1		
Missing (177)	*5*									
Physical demands										
Very high (4 items) (581)	39	508,336	7.7 (5.3–10.1)	1.32 (0.8–2.1)						
High (3 items) (871)	118	1,372,409	8.6 (7.0–10.1)	1.55 (1.1–2.2)						
Moderate (2 items) (744)	65	971,633	6.7 (5.1–8.3)	1.14 (0.8–1.7)						
Little (1 item) (579)	40	710,128	5.6 (3.9–7.4)	1						
Missing (192)	*3*									
Quantitative demands										
High demands (1549)	187	2,323,110	8.0 (6.9–9.2)	1.41 (1.1–1.9)						
Low demands (1254)	72	1,270,500	5.7 (4.4–7.0)	1						
Missing (164)	*6*									
Work hours off-farm										
< 200 hours (290)	40	500,483	8.0 (5.5–10.5)	1.29 (0.9–1.9)	1.19 (0.7–2.1)	1.47	0.566	1.21 (0.7–2.1)	1.33	0.470
200–849 hours (330)	32	511,056	6.3 (4.1–8.4)	1.00 (0.7–1.5)	0.79 (0.4–1.5)	1.14	0.492	0.82 (0.4–1.5)	1.05	0.511
850–1699 hours (563)	38	562,499	6.8 (4.6–8.9)	1.13 (0.8–1.7)	1.12 (0.6–2.1)	1.44	0.710	1.16 (0.7–2.0)	1.31	0.602
≥ 1700 hours (741)	56	525,635	10.7 (7.9–13.4)	1.72 (1.2–2.4)	1.83 (1.02–3.3)	2.28	0.045	1.74 (1.01–3.0)	2.00	0.046
No work elsewhere (834)	88	1,386,217	6.3 (5.0–7.7)	1	1					
Missing (209)	*11*									
Climate 1: Safety system										
Above mean (positive) (1448)	146	1,821,236	8.0 (6.7–9.3)	1.36 (1.1–1.8)				1.44 (0.99–2.1)	1.07	0.050
Below mean (1412)	112	1,787,197	6.3 (5.1–7.4)	1				1		

(*continued on next page*)

Table 3 (*continued*)

Variables and categories (n*)	# Injuries**	# Hours worked	Crude rate (CI 95 %)	Crude Rate Ratio (RR) (CI 95 %)	Model 1 Adj RR (CI 95 %)	Model 1 CLR***	Model 1 p-value	Model 2 Adj RR (CI 95 %)	Model 2 CLR***	Model 2 p-value
Missing (107)	7									
Climate 2: Accept/normalization										
Below mean (1412)	190	1,919,713	9.9 (8.5–11.3)	2.41 (1.8–3.2)				2.33 (1.6–3.5)	1.92	0.000
Above mean (positive) (1510)	75	1,789,540	4.2 (3.2–5.1)	1				1		
Missing (45)	*0*									
Climate 3: Safety practice										
Above mean (1420)	141	1,803,151	7.8 (6.5–9.1)	1.13 (0.9–1.4)						
Below mean (positive) (1400)	121	1,765,776	6.9 (5.6–8.1)	1						
Missing (147)	*3*									

Note. *Total number of respondents, n = 2967, **Total number of injuries = 265, ***CLR = Confidence Limit Ratio (upper-lower), ****NOK = Norwegian kroner.

Work hours (off-farm) had a non-significant model effect. However, respondents who annually worked >1700 hours off farm had a significantly higher injury risk compared to the reference group (no work elsewhere) (Adj RR = 1.83; p = 0.045; CLR = 2.28).

Relatively high Adj RR, although non-significant, was found for categories of the confounders farm size (<49 da, ≥500 da), income (50–99,999 NOK), and work organization (family farm, relief/other workers).

5.3.2. Model 2: Testing moderating effects of safety climate

Adding safety climate indexes did not change the main results from Model 1. However, it resulted in nearly a 10% decrease in injury risk for highly challenging workplace design. The injury risk was also reduced for categories of predominant production, with the largest change for farmers with fodder (13.7%). Among all the variables (predictors and confounders) in Model 1, the change in percent was largest for work organization. Within this variable, farmers with relief/other workers and family showed a 30.6% increase in Adj RR, whereas the increase was 36.2% among family farmers. In addition, adding safety climate changed the relevance of farm size (borderline non-significant). In Model 1, farmers with large farms (≥500 da) had the highest injury risk, followed by farmers with the smallest farms (<50 da). In Model 2, these two categories had changed places, and the effect was >10%.

Looking at the safety climate indexes themselves, acceptance/normalization (Climate 2) was a significant predictor of injury (p = 0.000), and respondents who expressed the most acceptance/normalization of accidents had twice the risk of injuries compared to the reference group. Safety system (Climate 1) was a borderline non-significant predictor for injury (p = 0.050), with the highest risk for respondents who had positive assessments of the safety system.

6. Discussion

In this study, we explored occupational injury risk among Norwegian farm owners through the calculation of CRRs and Poisson regression, with work hours as the offset. The main findings were that the poor physical design of farmers' workplaces served as the most significant independent predictor of injury. We also found a higher injury risk for certain categories of predominant production, for extensive work off farm, and for farmers working with family/employees. When including the safety climate, the risk for farmers with family and/or employees increased. For predictors related to workplace design and production, adding the safety climate reduced the injury risk. Isolated farmers expressing high degrees of acceptance/normalization of accidents had more than twice the risk of injury compared to the reference group.

In this section, we discuss how these results are new contributions to the understanding of injury risk among farmers and more thoroughly address how our findings enhance our systematic understanding of managing risk in agriculture.

6.1. New contributions regarding risk factors

In this study we calculated rates not often seen in studies within agriculture; therefore, the results are not directly comparable to others. As discussed in Section 1.1, previous research found that dairy production represented high injury risk due to the heavy workload and animal contact. In our study, dairy farmers were mostly full-time farmers, having the highest number of work hours at the farm, resulting in a medium level of injury rate. Full-time farming gives more continuity than having additional work off farm; it also involves somewhat routinized work tasks, which has been suggested to lower the injury risk (Van der Broucke &

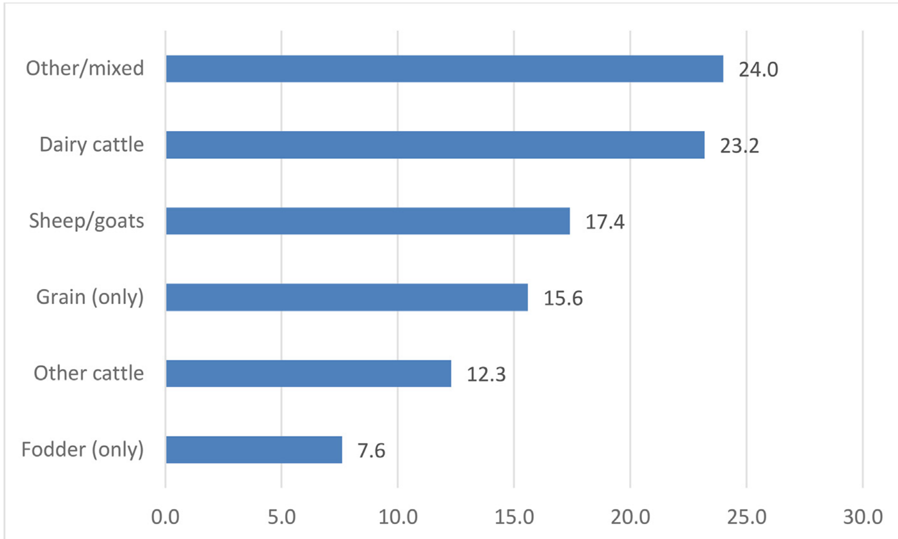

Fig. 4. Predominant farm production (%): Refined variable with mutual exclusive categories. (Note: Fodder is only excluded from "Grain (only)" because ¾ of all the farms produce fodder).

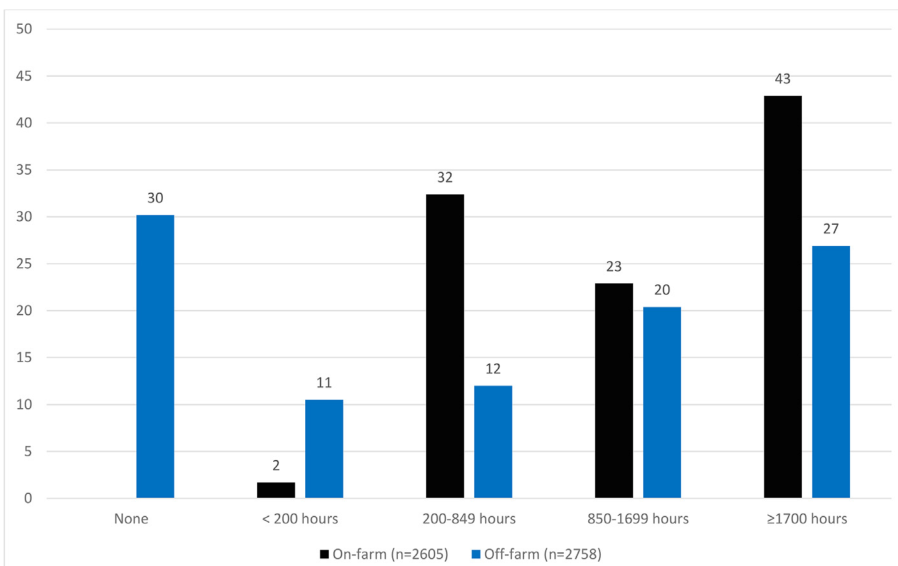

Fig. 5. Farm owners' annual work hours: on-farm (refined for regression) and off-farm (original) (%).

Colémont, 2011). Although the danger of handling large animals is still present, it seems that this is "evened out" by exposure time. Furthermore, dairy production is strictly constrained through quality standards, which will be further dealt with in Section 6.2. The producers of fodder (only), other/mixed, and other cattle (not dairy) all had higher injury risk than dairy farmers. These farmers also worked less on the farm and had more off-farm work hours than dairy farmers. No other studies could be found that combined on- and off-farm work hours. Compared to those with the farm as the only workplace, we found an almost two-fold risk of occupational injury for farmers working more than 1,700 h off farm. As a large amount of on-farm work hours is associated with a high injury risk (Hartman et al., 2004; Jadhav et al., 2015; Svendsen et al., 2014; Van den Broucke & Colémont, 2011), independent of where you work, the amount of work (i.e., total workload) is significant.

Another new contribution of this study is the finding that injury risk is reduced for all predictors of injury when controlling for safety climate. We found the largest risk-reducing effect for farmers with fodder production, followed by farmers with challenging workplace design. It is hard to find corresponding research designs to confirm or contradict these results. A Swedish survey among farmers included safety climate, showing that work pressure was positively correlated with perceived risk, risk acceptance, and injury experience but negatively correlated with engagement in safety work (Törner et al., 2002). Farmers who had several employees reported more safety activity, which was explained by the farmers' legal obligations as employers. More safety activity was also reported by those with injury experience (Törner et al., 2002). We know from other sectors that safety climate is important for safety behavior and outcomes, but these studies rarely include the perspective and challenges of small enterprises.

Our main predictor, the physical design of the workplace, to our knowledge, has not been found as a risk factor in other studies within agriculture. The overall findings, including the lack of individual characteristics as predictors for injuries, raise the need for highlighting organizational and managerial issues as well as a sociotechnical system perspective as an approach when discussing findings.

6.2. Managing risk on different levels

The model described by Carayon et al. (2015) defines the work system as the local context in which work activities are performed, although it is heavily influenced by external factors like legislation, markets, political direction, and so forth (i.e., the national context). The national context for Norwegian farmers is well described in the political-economic system model by Rommetvedt (2002), which enables us to discuss risk management in a wide perspective. Our study fits the description of "mesoergonomics," introduced by Karsh, Waterson, and Holden (2014), as it refers to the study of variables in two or more levels, having ergonomic constructs as the dependent variable. External levels (e.g., government, policy makers, and regulatory bodies) have lately received more attention in studies of causalities, herein also calling for interdisciplinarity (Karsh et al., 2014).

A part of organizational decisions is deciding on what and how to produce, thereby affecting the overall latent condition for injuries through the implications it directs in the work system (Carayon et al., 2015; Reason, 1997). An example of such mechanisms is given in Holte, Follo, Kjestveit, and Stræte (2019), where implementing AMS affects workplace design, activity level, and the distribution of work tasks. Although change in technology is the farmers' decision, it is indirectly influenced by political incentives and subsidies related to modern production methods (Ministry of Agriculture and Food, 2016). This is also evident for workplace design, which is an independent injury risk factor in our analyses, although it is affected by production through general standards and for livestock husbandry in particular[5]. This demonstrates how production (tasks, technology, organization) is a latent condition for injuries because investments in technology and/or buildings affect the physical environment. However, regarding modernization and investments, the old age of outbuildings is surprisingly not a risk factor for injury. An interpretation of this is that poor workplace design may be found in new environments as well, which calls for considering OHS issues altogether (individual, environment, tasks, technology, organization) when investing and modernizing. Design is therefore an embedded risk factor when national policy enforces larger, more efficient farms (Ministry of Agriculture and Food, 2016).

The impact from regulation varies due to system characteristics (literally: type of production). In other sectors, regulation as such has shown positive effects on safety practices and injuries (Andersen et al., 2019; Lindøe & Olsen, 2004; Vickers et al., 2005). Safety climate may reflect these practices and the underlying culture (Mearns et al., 2003), and Carayon et al. (2015) recommended including safety climate when discussing organizational aspects of sociotechnical system theory and workplace safety. Our results indicate that safety climate is even more important for injury risk in less regulated productions. Fodder production has relatively low documentation requirements compared to, for example, animal husbandry, which may explain why the risk for this category of farmers is more affected when safety climate is controlled for. These farmers are also more likely to work alone. If the farm production entails fewer system requirements, documentation and auditing may be perceived as an unnecessary burden (Holte & Follo, 2018). The same reasoning can be used for the use of family and/or hired help at the farm. Observing the impact of safety climate on injury risk demonstrates the importance of organizational factors (climate) when working together compared to working alone.

Based on our analyses, we argue that farmers may play two roles: (1) owner and manager of the enterprise, making them responsible for daily work, planning, resource allocation, and strategic decisions, or (2) a "worker," tackling consequences due to externally given policies and regulations, indirectly influencing through collective channels (farmers' organizations, etc.). In the first role, the farmer is supposed to perform active risk management, while in the second role, the farmer is coping with risk. The positive correlation found between injuries and normalization (Climate 2) indicates that coping with risk (Grote, 2012) is closer to what farmers do than risk management (role 1). The results that showed safety climate plays a larger role for farmers with hired help and family than for lone farmers also underscores this anticipation. The same goes for the finding of the old age of outbuildings not being a risk factor for injury, indicating a lack of OHS focus regarding new investments, as previously described. Coping with risk is associated with flexibility in decisions and actions among those in the "sharp end," where plans and task standardizations are few (Grote, 2012). They use tacit knowledge and operational freedom in handling unpredictability (Grote, 2012). This may be linked to the culture of accepting injuries as a normal part of their work. Moreover, from the qualitative interviews in this project we know that animal husbandry in particular makes the work environment unpredictable (Follo et al., 2016). Hence, our findings also correspond to existing knowledge regarding small enterprises, where day-to-day challenges are the focus due to restricted resources (Champoux & Brun, 2003; Vickers et al., 2005). Similar reasoning can be used for the finding of farmers with managerial responsibility having higher injury risk. They might not allocate work tasks associated with risk to employees, but instead perform these tasks themselves; hence, this is a way of coping with risk without actively managing risk. Moreover, eliminating risk requires knowledge, work task standardization, and a clear distribution of responsibility (Grote, 2012), which is hard to find in small enterprises (Hasle & Limborg, 2006; MacEachen et al., 2010; Sorensen et al., 2007). For farmers, being a manager may increase the injury risk through the factors found by Glasscock et al. (2006): work overload/time pressure, role conflict, economic concerns, administrative burden, and unpredictability. It may further reduce farmers' continuity on their own farm efforts, as illustrated by the higher risk for those having a full position (or more) off farm.

Our results indicate that injury risk emerges due to specific aspects embedded at the systemic level (Carayon et al., 2015). Therefore, we claim that farms need to be managed according to their context and that efforts to increase OHS need to reflect the heterogeneity of the industry. Moreover, the shift from small to larger farms is a relatively new trend in Norwegian agriculture. This raises the question of whether the ongoing industry changes may actually give an even higher risk of injury because of the new complexity and the lack of awareness regarding latent conditions in the work systems. Taken together, we therefore need to raise awareness of the managerial aspects of running a farm enterprise while taking external aspects into consideration. The political-economic system is an important contributing factor regarding strategic choices in Norwegian agriculture (Farsund, 2002; Rommetvedt, 2002; Rommetvedt & Veggeland, 2017). Both governmental bodies and the industry should be attentive to the effects of these choices because larger farm sizes have been found

[5] Loose housing is required for cattle from 2024 to 2034 depending on when the existing outbuilding was built (https://lovdata.no/dokument/LTI/forskrift/2013–08-07–955).

to increase injury risk (Rautiainen et al., 2009). Despite our results being indicative, policies, regulations, funding programs, training programs, and planning and design, as part of the strategic choices, will be of significant importance in the years to come to ensure promotion of OHS in agriculture. Moreover, research that deepens our understanding of the complexity and interdependencies is highly needed.

6.3. Limitations and methodological considerations

The questionnaire was sent to 7,500 farmers, or 17% of the total population of farmers applying for subsidies in the national registry of farm producers in 2012 (Directorate of Agriculture, 2020). The quality of the final data set was strengthened by extracting farm production details directly from this registry. The survey sample was confirmed to be representative in terms of geographical distribution and type of production (Storstad et al., 2013).

There is always a risk of recall bias using questionnaire surveys. However, unpublished data from qualitative in-depth interviews in the project enabled us to use mixed methods in the interpretation of the results. Furthermore, the unique sample size increased the validity by enabling strict criteria for missing values in, for example, sum-score variables and indexes based on factor analysis.

In our study, 6.7% of the respondents reported having had an occupational injury during the preceding 12 months, which corresponds to results in other studies (Jadhav et al., 2017; Rautiainen et al., 2009; Van den Broucke & Colémont, 2011). Still, the prevalence is lower than we expected. Our qualitative interviews indicate that farmers have trouble remembering smaller injuries and that small ones are not counted. As the questionnaire did not include a definition of severity, we regarded the injury incidence as fairly trustworthy as a demonstration of the underreporting of injuries from which agriculture suffer. The confidence intervals of some of the results are rather wide, especially for categories of predominant production. We anticipate this to be a statement of the heterogeneity of the sample and a consequence of the struggle of isolating productions from each other. The results are nonetheless important because of the link to work hours (exposure), and they can serve as a starting point for further research.

The study is based on data collected in 2012 and may be considered somewhat old. This paper argues that the trend of modernizing Norwegian agriculture is an ongoing process, starting before 2012 and we find that our data fulfills the purpose of describing an industry in transformation. The inclusion of annual work hours and safety climate makes the data highly valuable for a sociotechnical discussion of latent conditions, irrespectively of its age.

7. Conclusions and practical applications

This study improves existing knowledge regarding injury risk factors in agriculture as the combination of a systematic approach and work hours illuminated injury causes that are more complex and interrelated than those most frequently presented in published research. The results point to the importance of studying physical design of workplaces as a separate topic as well as studying subgroups of farmers based on diversities in work tasks, technology, work organization, and so forth. Less heterogeneity in subgroups will make work system characteristics easier to detect and understand, which will increase the practical use of study results in injury prevention.

Our initial anticipation was that latent conditions affect occupational injuries in the way they are treated by the farmer, which our study results confirmed. The predictors of injury and CRRs point to organizational complexity and call for sociotechnical understanding. According to our study, risk factors are highly interrelated in the work system and difficult to separate from each other. This sector needs to raise awareness regarding work system dynamics, especially when it comes to the external influence and for design issues in particular. In addition, farmers need support when it comes to detecting and understanding risk mechanisms in their own work systems.

Funding and ethics

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This study was approved by the Regional Committees for Medical and Health Research Ethics — Central Norway (number 2011/2239, later 2011/2239-26). Anonymity of the respondents was ensured through the use of an external actor when drawing the respondent sample. We found no ethical constraints for publishing these results.

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