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Register-based predictors of violations of animal welfare legislation in dairy herds

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The assessment of animal welfare can include resource-based or animal-based measures. Official animal welfare inspections in Denmark primarily control compliance with animal welfare legislation based on resource measures (e.g. housing system) and usually do not regard animal response parameters (e.g. clinical and behavioural observations). Herds selected for welfare inspections are sampled by a risk-based strategy based on existing register data. The aim of the present study was to evaluate register data variables as predictors of dairy herds with violations of the animal welfare legislation (VoAWL) defined as occurrence of at least one of the two most frequently violated measures found at recent inspections in Denmark, namely (a) presence of injured animals not separated from the rest of the group and/or (b) animals in a condition warranting euthanasia still being present in the herd. A total of 25 variables were extracted from the Danish Cattle Database and assessed as predictors using a multivariable logistic analysis of a data set including 73 Danish dairy herds, which all had more than 100 cows and cubicle loose-housing systems. Univariable screening was used to identify variables associated with VoAWL at a P*-value < 0.2 for the inclusion in a multivariable logistic regression analysis. Backward selection procedures identified the following variables for the final model predictive of VoAWL: increasing standard deviation of milk yield for first lactation cows, high bulk tank somatic cell count (⩾250 000 cells/ml) and suspiciously low number of recorded veterinary treatments (⩽25 treatments/100 cow years). The identified predictors may be explained by underlying management factors leading to impaired animal welfare in the herd, such as poor hygiene, feeding and management of dry or calving cows and sick animals. However, further investigations are required for causal inferences to be established.*

Keywords: register data, predictors, animal welfare control, dairy cattle

Implications

In Denmark, the targeted animal welfare control utilizes register data variables from official databases for the identification of herds at risk of having animal welfare problems. In the present study, register data from privately owned databases are evaluated as predictors for breaches with animal welfare legislations as these might enhance the accuracy of the risk-based identification and improve the success of the current welfare inspection scheme.

Introduction

Traditionally, animal welfare assessment protocols have sought to ensure the basic animal needs as described in the 'Five Freedoms' by the Farm Animal Welfare Council (1992) being the freedom from hunger and thirst; freedom from discomfort and pain, injury and disease; freedom to express normal behaviour; and the freedom from fear and distress. In the legislative context, these needs have been addressed by establishing minimum standards regarding housing equipment and management (e.g. daily care and intervention), aspects typically assessed by resource-based measures (e.g. bed stall dimensions, number of feeding places, flooring, etc.). Recently published guidelines on the risk assessment of animal welfare by the European Food Safety Authority (EFSA Panel on Animal Health and Welfare, 2012) are based on the traditional approach of quantifying risk exposure scenarios and their welfare consequences on single adverse effects of animal welfare, for example, lameness. However, the risk assessment regarding animal welfare as a complex entity is still in its early phase.

The Danish Veterinary and Food Administration (DVFA) has conducted risk-based sampling of livestock herds for the official animal welfare inspections since 2008. This sampling

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is targeting 5% of the herds with more than 10 animals covering cattle, swine, broilers and mink. Welfare inspection in these herds implies checking of compliance with current animal welfare legislation, which is primarily based on resource-based measures for the given species (i.e. for dairy cattle Act on the Keeping of Diary Cattle and their Offspring, 2010) and the Danish Animal Welfare Act (2013). The risk parameters used in the targeted sampling vary for each year and each species, and for cattle, they have included herd size, antimicrobial consumption, mortality, production type (dairy or beef calves) and abattoir remarks. The novelty in the Danish risk-based welfare inspection system lies in using risk parameters derived from incidence data in national databases for a more targeted sampling. Previous studies have evaluated prediction models based on register data for assessment of animal welfare (Sandgren *et al*., 2009; Nyman *et al*., 2011; DeVries (2013)) by investigating both uni- and multivariable associations between register data variables and single animal-based measures (e.g. lameness, integument alterations, cleanliness, fearfulness towards humans, etc.). However, these previous studies have focused on animal welfare assessed by comprehensive, yet costly, animal-based measures in contradiction to the more easily obtainable resource-based measures.

Hence, the present study set out to evaluate secondary animal-based measures to predict the welfare outcome based on resource-based measures. The risk of herds having violations of animal welfare legislation (VoAWL) was estimated by investigating register data as predictors.

Material and methods

This study was designed as a cross-sectional prevalence study of compliance with animal welfare legislation combined with a retrospective follow-up with register data extracted for a 1-year period ahead of the actual herd visits. Herd visits were conducted during March 2010 to July 2011 by one out of four trained observers collecting different welfare measures for another study purpose.

Target and study population

The target population for the present study was Danish dairy herds with more than 100 cows and loose-housing systems with cubicles. In 2011, the average herd size for Danish dairy herds was 132 cows, and 64% of the Danish dairy herds had more than 100 cows and hence covering 82% of all dairy cows (Agricultural Statistics, 2011). The current study population was amalgamated from two samples drawn from the same respondent list of a survey ($n = 401$) on grazing strategies (Kristensen, 2010). The first study included 42 out of 131 grazing herds meeting the inclusion criteria back in January 2010 in order to investigate the effect of grazing on different welfare aspects. The second study drew a random sample of 90 herds, regardless of grazing/non-grazing status, from the same pool of respondents in April 2010 with 59 herds willing to participate. Because of overlap in 13 herds between the two studies, only 46 herds were visited by the second study, yielding a total of 88 herds (42 grazing and 46 non-grazing herds). The herds were distributed geographically dispersed all over Denmark. A total of 15 herds were excluded from the present study. Eight herds were excluded because of missing or incomplete registration forms, four herds because of having fewer than 100 cows on the day of visit, two herds because of deep bedding and one herd due to missing milk production recordings. Finally, 73 herds remained in the study for further analysis.

Official animal welfare control

Since 2008, an annual risk-based sample of 5% of all livestock herds with more than 10 animals kept for farming purposes have been visited by inspectors from the Danish AgriFish Agency (Ministry of Food, Agriculture and Fisheries of Denmark). On average, 669 cattle herds have been inspected per year. The welfare inspection evaluates farms based on the two overarching acts being the Danish Animal Welfare Act (2013) and the Act on the Keeping of Dairy Cattle and their Offspring (2010, subsequently referred to as 2010 Act) as well as acts and executive orders concerning farmed animals, euthanasia, protection of calves, tail docking and castration, disbudding/dehorning, the use of electrical aggregates, ear tagging and livestock owners' use of pharmaceuticals. The 2010 Act particularly defines the minimum housing and management standards for dairy cattle based on the most recent recommendations.

Outcome measure: VoAWL

All barns built after July 2010 are obliged to be designed according to the minimum standards given in the 2010 Act, whereas barns built before 2010 are obliged to upgrade the facilities according to given paragraphs related to five of the distinct transition terms (i.e. 1 July 2014, 2016, 2022, 2024 and 2029) until full implementation on 1 July 2034. Hence, the resource-based measures were selected in accordance to the Danish animal welfare legislation; however, as none of the barns included in the present study were built after 2010, all minimum standards within the 2010 Act did not apply to our study herds and resource-based measures were reduced to the following: (a) presence of injured animals not separated from the rest of the herd (§23, 2010 Act) and/or (b) animals in a condition requiring euthanasia still being present in the herd (§20, Danish Animal Welfare Act). These outcome measures were chosen because they were the most frequently violated aspects in recent welfare inspections accounting for 57% of the warnings and enforcement notices issued and 50% of the police reports and due to feasibility (Anonymous, 2011). In case of non-compliance requiring further guidance, inspectors issue warnings; enforcement notices with follow-up are issued in cases where the non-compliance is of more severe character and further guidance is not considered sufficient; finally, the farmer can be reported to the police in case animals are treated recklessly or when previous enforcements have not been met satisfactorily. A farm can receive both a warning, enforcement notice and be reported to the police for different non-compliance issues at the same inspection visit. In the present study, any herd having non-compliance with a minimum of one out of the two measures was regarded as a non-compliant herd with impaired welfare, irrespective of the action from the authorities (warning, enforcement notice or police report).

Explanatory variables extracted from register data

The Danish Cattle Database (DCD) is a comprehensive database compiling all mandatory and voluntary routine registrations from the official (Central Husbandry Register, VetStat) and privately owned databases (e.g. milk recording scheme, breeding organizations, abattoirs, laboratory results and veterinary treatments). A literature review resulted in an initial list of 36 register-based variables with assumed associations with dairy cattle welfare. However, because of a large number of missing observations 11 variables were omitted, leaving 25 variables for the present analyses. These variables covered health recordings, reproduction results, milk recordings, abattoir data and culling data (Table 1). Data were extracted from the DCD for each herd for a 1-year period ahead of the actual herd visit by the study project. Because of very low within-herd prevalence, the abattoir remarks on lean cows, new fractures, arthritis, joint luxation, locomotor disorders and bruises were excluded from further analyses.

Data analysis

All 25 register data measures were used as explanatory variables accompanied by information on grazing and milking system (automated or conventional) and by information from the Central Husbandry Register on region, production type (organic or conventional), investigator and the *Salmonella* Dublin status in a national surveillance programme (test negative or test positive). Seasonality of the herd visit was not assessed.

Explanatory variables were initially screened in a univariable logistic regression in the statistical software R (R Development Core Team, 2012) using the *glm* function. However, none of the qualitative variables were significantly associated with the outcome of interest. For the quantitative register data variables, unadjusted odds ratios (OR) and 95% confidence intervals (95% CI) were calculated for change in intervals (increase/decrease) depending on the explanatory variable (Table 1). The significant explanatory variables were then assessed for their distribution within the two outcome groups and based on their distribution in the groups of herds with and without VoAWL, the following variables were dichotomized: 'high bulk tank somatic cell count (SCC)' ($\geqslant$250 000) and 'normal range of SCC' (<250 000), 'suspiciously low number of veterinary treatment records' ($\leqslant$25 treatment records/100 cow years) and 'normal level of veterinary treatment records' (>25 treatment records/100 cow years), and 'suspiciously low proportions of abattoir remarks' (no remarks) and 'normal proportions of abattoir remarks' (>0 remarks).

Finally, a multivariable logistic regression model was used to identify predictors of herds with VoAWL, and to estimate the probability of VoAWL as a function of the predictor values. The final model was arrived at by a stepwise, backward variable elimination procedure including all variables with $P<0.2$ from the univariable analyses in the start model. Variables were considered significant in the final model at $P<0.05$. Interactions between all significant main effects were assessed, and considered significant at $P<0.05$. Confounding was assessed by evaluating changes in the parameter estimates between multivariable models with and without each variable. A change in parameter estimates of >20% was interpreted as confounding, and confounders were kept in the final model, independent on whether they were significant main effects or not. Finally, herd size and the three mortality variables were assessed for potential interactions and confounding in the final model, independent of these variables' *P*-values in the univariable analysis. The final model with the Akaike Information Criterion (AIC) closest to 0 was selected. Model fit was assessed by the likelihood ratio test of the significance of the model with predictors against the null model and by checking the dispersion parameter, the ratio of the deviance over residual degrees of freedom.

Results

Presence of sick animals not kept in separation or sick pen were found in 22 herds, whereas only one herd had the presence of animals requiring euthanasia, yielding a total of 23 out of the 73 herds with VoAWL.

Univariable analysis

The initial univariable screening of associations between explanatory variables and the classification as herds with VoAWL resulted in five variables with a *P*-value <0.2 (Table 1). Among these five variables, significant associations at a 5% level were found between being a problem herd with VoAWL and an increase in standard deviation of the average milk yield for both first and second lactation cows as well as an association with a decrease in the proportion of abattoir remarks.

Multivariable model

All of the milk yield variables were strongly correlated and only the variation (s.d.) in energy corrected milk (ECM) for first lactation cows was chosen for further analysis, because this led to a slightly better fitting model, when assessing the AIC between the final models. The standard deviation of mean milk yield for first and second lactation groups were both significantly associated with the VoAWL; an increase of 1000 kg ECM in standard deviation was associated with a 4.0 and 3.3 times higher odds of VoAWL in first and second parity cows, respectively. Bulk tank SCC was not significantly associated with VoAWL ($P = 0.19$) in the univariable analysis, but was included in the final prediction model, because dichotomized at cut-off 250 000, this variable was borderline

Table 1 *Descriptive characteristics of continuous register data variables investigated as explanatory variables for dairy cattle welfare in 73 Danish dairy herds with loose housing and cubicles, and the* P*-values from the ANOVA analysis of differences in means in the two groups with and without violations of animal welfare legislation*

Variable	Herds with no violations		Herd with violations				
	Minimum to maximum	Mean (median)	Minimum to maximum	Mean (median)	*P*-value	Interval (↑ or ↓)	Odds ratio [95% CI]
Herd size (cows)	100 to 405	171 (149)	98 to 427	192 (145)	0.27		
Mortality (%)							
Cow mortality	0 to 10	3.1 (2.7)	0.1 to 15	3.7 (3.4)	0.31		
Heifer mortality	0 to 1.6	0.04 (0.04)	0 to 1.7	0.04 (0.0)	0.92		
Calf mortality	0 to 7.3	2.4 (2.2)	0 to 9.9	2.7 (1.8)	0.53		
Milk yield (mean kg ECM)							
Total yield per cow year[a]	6356 to 11 860	9161 (9283)	5447 to 11 248	9064 (9366)	0.79		
Yield for first lactation cows	5814 to 12 999	8605 (8425)	5553 to 12 252	9248 (9286)	0.09†	↑1000 kg	1.3† [0.96; 1.9]
s.d. of milk yield for first lactation cows	1642 to 4434	2835 (2756)	1733 to 4554	3166 (3082)	0.05*	↑1000 kg	2.2* [1.0; 4.99]
Yield for second lactation cows	5995 to 12 888	9476 (9570)	6005 to 13 507	9646 (9485)	0.67		
s.d. of milk yield for second lactation cows	1401 to 4793	3154 (3157)	1462 to 4888	3556 (3562)	0.03*	↑1000 kg	2.2* [1.1; 4.8]
Yield for third and higher lactation cows	5500 to 13 350	9073 (9208)	5724 to 11 995	9348 (9039)	0.48		
s.d. of milk yield for third and higher lactation cows	1997 to 5055	3700 (3804)	2153 to 5254	4021 (4240)	0.09†		
Milk quality (1000 cells/ml)							
Bulk tank somatic cell count	101 to 387	230 (222)	147 to 348	251 (2267)	0.19†		
Reproduction parameters (month)							
Age at first calving	23 to 31	26 (26)	24 to 30	26 (26)	0.98		
s.d. of age at first calving	1.1 to 4.9	2.3 (2.2)	1–2 to 3.5	2.4 (2.4)	0.41		
Reported veterinary treatments							
Treatments/100 cow years (average)[a]	5.5 to 177	65 (55)	13 to 103	47 (41)	0.07†	↓10 treatments	1.1† [0.99; 1.4]
Locomotor disorders/100 cow years (average)[a]	0 to 21	5.6 (3.9)	0 to 19	5.1 (2.8)	0.67		
Locomotor disorders/total number of treatments (%)[b]	0 to 100	10 (7)	0 to 46	12 (10)	0.67		
Abattoir remarks (%)							
Lean cows at slaughter[c]	0 to 59	21 (19)	2.7 to 55	19 (15)	0.62		
Total number of abattoir remarks	0 to 24	4 (0)	0 to 10	0.8 (0)	0.01*	↓10%	4.4* [1.3; 36.4]
Lung disorder	0 to 8	0.6 (0)	0 to 1.6	0.007 (0)			
Liver abscess	0 to 13	0.08 (0)	0 to 2	0.02 (0)	–		
Peritonitis	0 to 6	0.06 (0)	0 to 2.3	0.01 (0)	–		
Liver cirrhosis	0 to 11	0.06 (0)	0 to 0.08	0.003 (0)	–		
Old fractures	0 to 1.8	0.009 (0)	0 to 1.5	0.006 (0)	–		
Chronic inflammation	0 to 3.1	0.03 (0)	0	0	–		

ECM = energy corrected milk.
Odds ratios (OR) and 95% confidence intervals are given for variables passing the initial screening ($P < 0.2$) at the given intervals.
[a]Cow year = sum of feeding days of all cows per herd per 365 days.
[b]Reported incidences of interdigital phlegmone, laminitis, sole ulcer, foot rot, interdigital dermatitis, swollen hock, arthritis and digital dermatitis.
[c]Cows with fat score 1 according to the EU Beef Carcase Classification.
Significance levels: $^{\dagger}P < 0.2$, $^{*}P < 0.05$.

significant in the final model ($P = 0.055$) with bulk tank SCC > 250 000 leading to three times higher odds of VoAWL than herds ⩽250 000 cells/ml.

The proportion of abattoir remarks was low in both outcome groups and hence omitted from the final model, because conditions that are rarely present are not suitable as predictors (only three of herds with VoAWL also had no abattoir remarks). Hence, the resulting model estimating the probability of VoAWL included standard deviation in ECM for first lactation cows, dichotomized bulk tank SCC and dichotomized number of recorded veterinary treatment per 100 cow years.

The likelihood ratio test gave $P = 0.001$ indicating that the final model including these predictors was significantly better than a model without predictors, and the dispersion parameter was 1.09, that is, close to the desired value 1 indicating no under- or overdispersion. Descriptive results and sensitivity and specificity estimates for the dichotomized predictors are given in Table 2. All three dichotomized variables showed low sensitivity (0.13 to 0.52) with a higher corresponding specificity (0.66 to 0.73). Model parameters and risk estimates for the univariable analysis are given in Table 3 and for the multivariable analysis in Table 4. The predicted probabilities of VoAWL for the final model are shown in Figure 1. The figure shows the probability of VoAWL for the different combinations of variables included in the final model, for example, a herd with a high bulk tank SCC (⩾250 000 cells/ml) and <25 recorded annual veterinary treatments/100 cow years would have an estimated probability of VoAWL at welfare inspections of ~70% if the standard deviation in milk yield among second parity cows was 3000 kg.

Table 2 *Descriptive results for the qualitative explanatory variables and their distribution among herds with and without violations of animal welfare legislation (VoAWL) and sensitivity (Se) and specificity (Sp) estimates, and the positive (PPV) and negative predictive values (NPV) for the given explanatory variables*

				Herds with VoAWL			
Variables	Level	Problem	Herds (%)	Yes (%)	No (%)	Se/Sp (%)	PPV/NPV (%)
			73 (100)	23 (32)	50 (68)		
Annual veterinary treatments	⩽25 treatments	Yes	13 (18)	7 (54)	6 (46)	34/73	54/73
	>25 treatments	No	50 (82)	16 (32)	44 (68)		
Bulk tank somatic cell count	⩾250 000 cells/ml	Yes	28 (38)	12 (43)	16 (57)	52/68	43/76
	<250 000 cells/ml	No	45 (62)	11 (24)	34 (76)		
Abattoir remarks	No remarks	Yes	20 (27)	3 (15)	17 (85)	13/66	15/62
	Remarks	No	53 (73)	20 (38)	33 (62)		

Table 3 *Risk estimates (ORs) for the dichotomized explanatory variables from a univariable logistic screening for associations with VoAWL in 73 Danish dairy herds*

Variables	Levels	OR	95% Confidence limits	*P*-value
Bulk tank somatic cell count	High (⩾250 000)	1.8	[0.9; 3.42]	0.17
	Low (<250 000)	1		
Veterinary treatment records	Low (⩽25)	2.2	[1.16; 4.13]	0.07
	High (>25)	1		
Abattoir remarks	No remarks	2.5	[0.84; 7.55]	0.11
	Remarks	1		

OR = odds ratio; VoAWL = violations of animal welfare legislation.

Table 4 *Parameter estimates, s.e., odds ratios (OR), 95% confidence intervals of OR and* P*-values for explanatory variables in the final model for the prediction of violations in animal welfare legislation in 73 Danish dairy herds*

Variables	Levels	Estimate (s.e.)	OR	95% CI of OR	*P*-value
Intercept		– 5.8 (1.8)			
Standard deviation in ECM of first lactation cows/1000 kg ECM increase		1.4 (0.5)	4.0	[1.5; 12.4]	0.008
Annual veterinary treatments	⩽25 recorded treatments	2.2 (0.8)	9.0	[2.0; 48.3]	0.006
	>25 recorded treatments	0	1		
Bulk tank somatic cell count	⩾250 000 cells/ml	1.2 (0.6)	3.2	[1.0; 11.0]	0.055
	<250 000 cells/ml	0	1		

ECM = energy corrected milk.

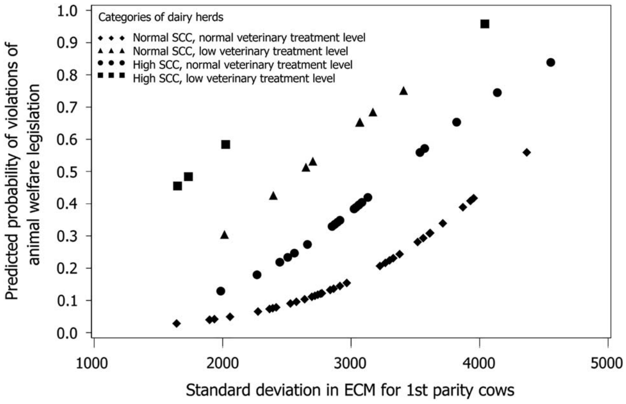

Figure 1 The predicted probabilities of herds having violations in animal welfare legislation based on their levels of three explanatory variables from the final model, including the standard deviation in milk yield (kg energy corrected milk (ECM)) for first parity cows based on the qualitative variables' high levels of bulk tank somatic cell count (high SCC $\geqslant$ 250 000 cells/ml) or normal range (normal SCC < 250 000 cells/ml), low levels of veterinary treatments ($\leqslant$25 annual recordings/100 cow years) and normal level of veterinary treatments (>25 annual recordings/100 cow years).

Discussion

The study aimed at identifying predictor variables easily extractable from routine registrations within the DCD to be used in the identification of herds with an increased risk of VoAWL at welfare inspections. The present study identified a limited number of variables associated with VoAWL. Because this study had a cross-sectional study design, the detected associations do not necessarily imply causal relationships between the significant variables and the outcome. As the associations are more likely to reflect management aspects than animal welfare, caution should be exerted when including these as future predictors for animal welfare. Future field validation of the predictive power of the model is therefore warranted.

Four variables were considered in the multivariable model. Abattoir remarks were excluded, as only three problem herds also had unrealistically low abattoir remarks (no remarks). The final model from the present study differed from previous prediction models. DeVries (2013) reported variables related to demographics (e.g. herd size, distribution of age groups and mortality), milk composition and yield, management and fertility being the most frequently included explanatory variables in final prediction models for single animal-based measures, not an overall composite welfare definition. Mortality of cows <60 days in milk was the most frequently included variable in the final models. Two Swedish studies used the same data set to investigate the predictive potential of identifying herds with poor welfare (Sandgren *et al*., 2009) and herds with good welfare (Nyman *et al*., 2011). Here, Sandgren *et al.* (2009) identified late ongoing artificial insemination (>120 days), heifers not inseminated at 17 months of age and calf mortality (aged 2 to 8 months) for the classification of herds with poor welfare at a sensitivity of 62%. However, herds with good welfare, on the other hand, could be classified at a higher sensitivity of 96% based on the same two fertility measures, cow mortality, stillbirth rates, and incidences of mastitis and feed-related diseases. The main reason for the discrepancies between the present study and previous studies might be found in the differences of the underlying welfare definition.

Assessment of the variation in milk parameters as predictors of VoAWL

The association to increased variation in milk yield for lactation groups within a herd and increased bulk tank SCC with VoAWL might be explained by farmers not performing well on feeding, dry cow management, calving management and milking practices, or controlling high levels of lameness, which subsequently are associated with less uniform milk yields and higher SCC. Known management-related risk factors for high SCC are short post-milking standing time (Watters *et al*., 2013), metabolic diseases (Nyman *et al*., 2008) and hygiene aspects (Barkema *et al*., 1999).

Assessment of the number of veterinary treatment records as a predictor of VoAWL

Neither a decrease in the number of recorded veterinary treatments nor the dichotomized low treatment level were significantly associated (both $P = 0.07$) with VoAWL. However, the dichotomized variable contributed significantly to the multivariable model, indicating an interaction between the variables all being managerial aspects. The low number of veterinary treatment records could reflect the farmers' treatment threshold, which is in line with findings by Kielland *et al.* (2009) showing that farmers with low empathy scores towards cattle also ranked painful conditions lower than farmers with a positive attitude and high empathy scores. In addition, farmers with positive attitudes also had better cow welfare because of lower prevalence of skin lesions. Furthermore, a suspiciously low number of veterinary treatment records in the database may occur, if farmers do not record treatments, which again can be associated with unorganized herd health management that also affects other aspects of the herd welfare level, such as detection and removal or management of sick animals or cattle that should be euthanized. Since 2008, Danish herds participating in the Module 2 of the mandatory Herd Health Programme for herds with more than 100 cows have been able to initiate treatments of individual cows according to herd-specific diagnoses established by the herd veterinarian (DVFA homepage). Depending on the number of calvings per month, either weekly or fortnightly veterinary visits are required.

Kelly *et al.* (2011) investigated key performance indicators from the Irish Department of Agriculture, Fisheries and Food's national databases on livestock herds to characterize 18 case cattle herds with recorded farm animal welfare incidents. Four indicators were identified including late registration of calves, carcase disposal by use of on-farm burial, increased transport of animals to incineration plants over time and records of movements of animals to herds unknown. These indicators correspond very well to accessible data from the DVFA and late registration of calves and mortality rate have been used as risk parameters for sampling in previous Danish welfare inspections.

Assessment of the proportion of abattoir remarks as a predictor of VoAWL

A 10% decrease in proportion of abattoir remarks yielded a 4.4 times higher odds of VoAWL in the univariable analysis. However, dichotomization of the variable left only three herds with no abattoir remarks and VoAWL. Furthermore, the proportion of abattoir remarks is a variable that is not only influenced by herd management but also by the abattoirs, and therefore this was assessed as an unsuitable variable for prediction of herds with VoAWL.

Nonetheless, the potential association between VoAWL and low number of abattoir remarks did not show increases in abattoir remarks as a risk but a decrease in abattoir remarks as a potential risk, which was much unexpected. A speculation might be that farmers with ongoing animal welfare problems do not send injured or recently ill animals to slaughter either because they risk fines for delivering animals in a poor health condition, or because these cows are not suited for transportation or actually die on farm either assisted or unassisted.

Neither herd size nor mortality showed any significant associations with VoAWL in the present study. The lack of agreement between the present findings and previous studies is most likely to be found in the differences of the outcome definition – whether animal welfare is defined by minimum legislative standards or by direct observations of the animals (animal-based welfare assessment). Although control of compliance with the minimum standards for housing and management deal with an indirect welfare definition, for example, assessing potential risk factors, the animal-based approach yields a more explicit welfare definition, which also enables the quantification of animal welfare. The current sample only considered herds with more than 100 cows, whereas the official surveillance scheme may target herds from as little as 10 animals/herd. However, there are no official results indicating what herd size group might be overrepresented in the non-compliant group found in the official control. The use of privately owned routinely collected data has not been used in the official welfare inspection so far. Nonetheless, the incorporation of these parameters might have potential to identify more true case herds and thereby improve the efficiency of the welfare inspections.

Outcome of interest as an animal welfare indicator

It should be stressed that the present study did not investigate the actual prevalence of poor animal welfare as a complex entity. The official animal welfare inspection is not assessing animal welfare *per se*, but is controlling compliance with current animal welfare legislation. Hence, it could be possible for a herd with VoAWL to have low prevalences of clinical or behavioural poor welfare measures. Results might have been different, if the outcome definition had been based upon animal-based measures instead. Previous risk factor studies have only investigated single components of animal welfare like animal-based measures, for example, lameness prevalence (Alban *et al.*, 1996; Green *et al.*, 2002; Haskell *et al.*, 2006; Dippel *et al.*, 2009), hock lesions (Rutherford *et al.*, 2008; Kielland *et al.*, 2009) or mortality (Thomsen *et al.*, 2004; Alvåsen *et al.*, 2012). Although other studies have evaluated register data performance in predicting herd animal welfare, there have been major differences in the case definition of animal welfare. DeVries (2013) used similar range of register data to predict the single welfare measures included in the Welfare Quality® (WQ®) protocol (Keeling, 2009), but no associations between the register data and the overall WQ® score were made. It would be notoriously difficult to obtain meaningful register-based predictors of a poor WQ® score, because the score in itself is a composite number based on many different observations and evaluations weighted on different scales.

However, welfare assessment and welfare inspection are fundamentally different. This is due to substantial differences in whether the aim is a quantitative welfare evaluation, as performed in a large-scale cross-sectional welfare assessment systems or whether it is to control minimum requirements settled within legislation. Where the welfare assessment defines the welfare level based on a very explicit welfare definition combined into, for example, an animal welfare index, the inspection is based upon proxies for welfare often regarding resource-based measures as risk factors for animal welfare.

Conclusion

The present study identified the variation in milk yield in first and second parity cows, a suspiciously low number ($\leqslant$25) of veterinary treatment records/100 cow years and bulk tank milk SCC $\geqslant$250 000 cells/ml as significant predictors of dairy herds with welfare problems expressed as non-compliance with animal welfare legislation based on the presence of sick or weak animals not being housed accordingly. However, as risk factors are highly dependent on the welfare definition there is a need for further investigation of possible risk factors for animal welfare covering more than just minimum legislative standards.

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