J. Dairy Sci. 105:9934–9943
https://doi.org/10.3168/jds.2022-21867

Apparent prevalence and risk factors for udder skin diseases and udder edema in Bavarian dairy herds

L. J. Groh,[1,2]* R. Mansfeld,[2] C. Baumgartner,[3] and U. S. Sorge[2]
[1]Tiergesundheitsdienst Bayern e.V., 85586 Poing, Germany
[2]Klinik für Wiederkäuer mit Ambulanz und Bestandsbetreuung, Tierärztliche Fakultät der Ludwig-Maximilians-Universität München, 85764 Oberschleißheim, Germany
[3]Milchprüfring Bayern e.V., 85283 Wolnzach, Germany

ABSTRACT

The objective of this cross-sectional study was to assess the prevalence and risk factors for teat warts, udder edema, udder thigh dermatitis, and udder cleft dermatitis on Bavarian dairy farms. Udder health and hygiene scores of lactating cows were recorded on 152 farms in Bavaria, Germany. Management practices (e.g., housing, milking systems, and feeding regimens) were assessed with a comprehensive questionnaire. Adjusted prevalence estimates were determined using regression analysis with herd as the random effect. Mann-Whitney U or Fisher's exact on herd level and regression analyses on cow level were performed to determine risk factors. Of the 6,208 cows examined, 4.0% had teat warts, 1.1% udder edema, 0.2% udder thigh dermatitis, and 0.3% udder cleft dermatitis. The apparent median within-herd prevalence was less than 4% for all 4 diseases. Herd-level factors that were associated with the presence of teat warts on a farm were the proportion of cows with poor teat ends as well as conventional milking systems compared with milking robots. At a cow level, teat warts were associated with high somatic cell counts. Herds with poor depth (<5 cm) of bedding material and cows with days in milk less than 60 d had increased odds for udder edema. First-lactating cows had higher odds for udder thigh dermatitis. Freestall housing and comfort rubber mats were identified as risk factors for udder cleft dermatitis on a herd level. In conclusion, although most nonmastitis udder diseases were rarely observed in this study, some herd management practices and cow factors were associated with their presence on a farm or cow level. Future studies are needed to further investigate risk factors for each disease in more detail.

Received January 25, 2022.
Accepted July 29, 2022.
*Corresponding author: grohlucie@googlemail.com

Key words: teat wart, udder edema, udder thigh dermatitis, udder cleft dermatitis, management

INTRODUCTION

When it comes to bovine udder diseases, mastitis comes first and foremost to mind. However, other udder diseases also have to be considered. These include udder edema (**UE**) as well as the skin diseases: teat warts, udder thigh dermatitis (**UTD**), and udder cleft dermatitis (**UCD**). They can be relevant for animal welfare (Okkema and Grandin, 2021) and food safety (Regulation 853/2004, European Commission, 2004).

Though there are many studies on the association of management practices and risk factors for mastitis (Santman-Berends et al., 2016; Hiitiö et al., 2017; Duse et al., 2021), there is scarce information on the prevalence or risk factors of the diseases just mentioned. Therefore, we will discuss the 4 diseases and some of their known risk factors.

Udder and teat warts are predominantly found on teat skin (teat warts) and are small skin nodules caused by *Papillomavirus bovis* (Jarrett et al., 1984; Rai et al., 2011; Kumar et al., 2013). They can grow to the size of a grain of rice or take on secondary and tertiary formations (Kirk and Sischo, 2003). In some cases, they affect the fit of liners and cause difficulties during milking. In severe cases, they may even tear off, the sites may become infected, and, depending on the localization of the lesion, they may even lead to intramammary infections (Kirk and Sischo, 2003; Campo, 2006). To the best of our knowledge, there are no formal studies focusing on risk factors for teat warts. One study (Neijenhuis et al., 2004) reported that changing from conventional to automatic milking systems (**AMS**) reduced the occurrence of teat warts in 15 Dutch herds, and a Japanese study speculated that fly infestation of pastures may be a risk factor for the development of teat warts (Maeda et al., 2007).

Udder edema is the pathological accumulation of fluids in the udder tissue that occurs in about 70% of cows around calving (Morrison et al., 2018). The swelling associated with UE increases the risk of teat and udder injury (Dentine and McDaniel, 1983), as well as UTD (Roy et al., 2012). Furthermore, chronic UE can lead to damage of the suspensory apparatus of the udder (Loppnow, 1959). Morrison et al. (2018) reported an increase in the incidence of clinical mastitis with UE. It also causes difficulties in attaching the milking cluster. Feeding practices, such as the feeding of a highly fermentable diet in the periparturient time (Radostits et al., 2000) or the feeding of large amounts of salt (Lema et al., 1992), can influence the severity of UE.

Udder thigh dermatitis usually develops as a result of UE, due to friction between the udder and the inner thigh, especially in primiparous cows. In more severe cases, the resulting skin lesions can become secondarily infected with bacteria and lead to fever and lameness. Cows in tiestalls have an increased risk of developing UTD due to the reduced opportunity for locomotion compared with cows in loose stalls and straw yards (Roy et al., 2012).

Another type of dermatitis is UCD. Skin lesions form mostly on the cranial udder and in multiparous cows (Persson Waller et al., 2014). Severe cases have been associated with embolic pneumonia (Millar et al., 2017) or even the death of the animal when lesions penetrated the milk vein (Bouma et al., 2016). As in UTD, no single causative infectious agent was identified (Sorge et al., 2019).

The open wounds associated with UTD and UCD may contaminate the milk with blood or pus at harvest and may increase the risk of intramammary infections. According to a recent Swedish study (Ekman et al., 2018), cows housed on comfort mattresses had an increased risk compared with cows housed on other cubicle bedding.

The authors are not aware of any prevalence data for these diseases in Germany. Therefore, the objectives of this study were (1) to determine the prevalence of teat warts, UE, UTD, and UCD on Bavarian dairy farms and (2) to investigate the associations of cow factors and management practices with these diseases.

MATERIALS AND METHODS

Herd Selection

This cross-sectional study was conducted between September 2017 and June 2018 in Bavaria, southern Germany. A list of all Bavarian dairy farms (n = 28,884) was used as the basis for enrollment. The list did not include herd size but only daily milk shipped. The authors assumed that herds producing less than 200 kg milk per day (n = 4,873) had fewer than 10 lactating dairy cows. These herds were excluded. The list of remaining herds (n = 24,011) was quartered based on the amount of daily shipped milk. After randomly assigning a number to each farm, the 4 lists were sorted by random number. The first 200 farms per stratum were selected as the recruitment list, as we were expecting a response rate of 30% and 200 herds was deemed sufficient to recruit 40 herds per stratum. The 4 lists were then split by area code and distributed respectively among the 10 branches of the Bavarian Animal Health Services, covering all Bavarian regions. The herds were then recruited by phone by Bavarian Animal Health Services technicians along the provided lists for each branch. Animal and human ethical guidelines were followed during this study. The sample collection did not require ethical approval under the German animal welfare law.

This study was part of a larger study that primarily focused on the prevalence of mastitis pathogens and management practices in Bavaria. For the main study, up to 100 lactating cows were examined per herd. The 100 cows to be examined in herds with more than 100 cows (n = 3) were randomly selected in advance from a list by the technicians. Because we expected the prevalence of the described diseases to be very low and the sample size was driven by funding restraints for the main study, we did not perform any additional sample size calculation for any of these diseases.

Herd Visit

The farms were visited once by qualified Bavarian Animal Health Services technicians (n = 20) in teams of 2. The detection of udder diseases is part of the daily job of the technicians, and they receive regular training. In addition, they were briefed again before the study with in-class training and information sheets. However, no formal assessment of interobserver agreement was conducted. During the visit, the technicians visually and palpatorically assessed all udders for the aforementioned diseases. A cow was considered positive for teat warts if at least one teat wart was detected, from a raised nodule to larger proliferations on a teat. Udder edema was defined as at least a slight degree of edema, pasty swelling of the udder (i.e., a fingerprint can be seen for a brief moment, or the floor of the udder was too firm for any imprint) without any palpatory or visual signs of inflammation (heat, redness, or pain). A cow was found UCD positive when skin lesions (in the form of crusts, wounds, thickened skin, or exudations of various stages) were observed adjacent to the cranial udder or in the skin fold between the udder halves.

Udder thigh dermatitis was defined as skin lesions between the udder and the inner thigh. The skin lesions could range from superficial skin lesions to deep open wounds, including exudation and smell (Sigmund et al., 1980).

The technicians also assessed teat end condition on a cow level (score 1 to 4, highest score recorded per cow; NMC, 2007), hock lesions (score 1 to 3; NMPF, 2013), udder hygiene (score 1 to 4; Schreiner and Ruegg, 2003), and leg hygiene (score 1 to 4; NMPF, 2013). In addition, a quarter-level California Mastitis Test was performed, and quarter milking samples were taken from all study cows and analyzed for mastitis pathogens (results not shown). Furthermore, a checklist (available upon request) was completed during the farm visit regarding the herd's management practices (e.g., milking routine, dry-off procedures, nutrition, and housing).

Where available, the farmers provided monthly milk test results (DHIA report), the data set of the AMS, or both at the time of visiting and sampling. The monthly DHIA report included the results of the latest test day, providing information on cow data such as lactation number, DIM, breed, and milk parameters (milk protein, fat and urea concentration, test day milk yield, and SCC).

Statistical Analyses

Data were analyzed using SAS 9.4 (SAS Institute Inc.). Alpha was set at 0.05.

First, the data were checked for completeness and plausibility (i.e., unlikely values). Descriptive statistics were performed with PROC MEANS for continuous data and PROC FREQ for categorical data. Based on the call lists (i.e., herd size), the herds were placed into 4 groups, with group 1 having the smallest and group 4 having the largest herds.

Cow-level prevalence analysis was performed using PROC GLMMX with herd as a random effect to account for a farm effect.

On-farm cow data were merged with the monthly DHIA test data, where available. For each disease, variables of the questionnaire, on-farm observations, and the DHIA data were selected to identify risk factors for herd prevalence or disease status of the cow. Possible predictors were chosen based on biologically plausible associations, including known risk factors, as well as other potential associations.

Because of the overall sparsity of cases for the various diseases, the herd-level analysis only allowed for a comparison of individual risk factors between herds with or without disease. Potential risk factors were screened using Mann-Whitney U for continuous data and Fisher's exact test for categorical data. For these analyses, the observed teat end scores greater than or equal to 3 were summarized per herd as 0%, > 0% to 10%, and >10% of cows per herd. Multivariate analyses of potential herd-level risk factors did not converge despite, for example, adjustments in maxiter function.

Cow-level risk factor analysis included only cows from herds in which a particular disease occurred. Analyses were performed per disease to identify potential cow-associated risk factors (predictors), such as lactation number (1, $\geq$2), breed (Simmental, Brown Swiss, other), or milk yield (kg). The variable DIM was dichotomized as $\leq$60 DIM and >60 DIM. Cow SCC was divided into $\leq$100,000 cells/mL and >100,000 cells/mL according to Harmon (1994). Udder and leg hygiene scores were categorized into clean (scores 1 and 2) and dirty (scores 3 and 4). Cow milk yield, milk protein concentration (%), and milk urea concentration (mg/kg) were categorized based on percentiles. An overview of all cow-level factors screened for each disease can be found in Table 3.

Collinearity of predictors was assessed using Spearman rank correlations for continuous or kappa for categorical predictors (PROC FREQ AGREE). If either the correlation coefficient or kappa was greater than 0.6, the variable with less value was excluded. Then identified predictors were included individually in a mixed logistic regression (PROC GLIMMIX) that also included herd as a random effect. Variables with $P < 0.25$ were kept for further analysis in multivariable logistic regression models. Last, a multivariable logistic regression analysis (PROC GLIMMIX) with herd as a random effect was performed using a "quasi-backward" selection—that is, factors (including their interactions) were individually removed or placed back into the model at a later point to assess their effect (alone or as a biologically plausible interaction) on other variables. If a change in coefficient greater than or equal to 20% occurred in other variables, that variable remained in the model as a potential confounder. Otherwise, only variables with $P < 0.05$ remained in the final model. Because only models with one variable remained, no meaningful model comparison (e.g., Akaike information criterion comparison) could be performed.

RESULTS

Herd Description

Based on the lists for each branch, 339 farms were contacted and 156 accepted (response rate = 46%). The larger the farms, the more likely they were to participate. The response rate was 35% for group 1, 41% for group 2, 49% for group 3, and 57% for group 4. Of these, 4 farms backed out before the visit, so that only 152 herds were visited in total. The farms were visited between September 2017 and June 2018, and a total of

Table 1. Description of the Bavarian study herds sorted by group[1]

Variable	Group 1 (n = 38)	Group 2 (n = 37)	Group 3 (n = 39)	Group 4 (n = 38)	Overall (n = 152)	P-value[2]
Herd size, mean ± SD	20 ± 4[d]	31 ± 4[c]	51 ± 6[b]	86 ± 42[a]	48 ± 33	<0.01
Herd size, minimum–maximum	12–26	27–40	41–61	62–327	12–327	
Rolling herd average[3,4] (kg; IQR)	7,199[bc] (6,299–8,095)	7,175[c] (6,484–7,948)	7,901[b] (7,188–8,505)	8,708[a] (8,279–9,116)	7,906 (6,884–8,626)	<0.01
Bulk tank SCC[3,5] (×1,000 cells/mL; IQR)	146 (105–200)	150 (111–189)	138 (102–179)	150 (112–200)	147 (107–190)	0.83
Bulk tank bacterial count[3,5] (×1,000 cfu/mL; IQR)	18 (12–33)	16 (8–24)	12 (8–19)	13 (8–24)	14 (8–23)	0.10
Housing type (% herds)						
Tiestall	86.8[a]	62.2[b]	15.4[c]	2.6[c]	41.5	<0.01
Freestall	13.2[c]	37.8[b]	84.6[a]	97.4[a]	58.5	<0.01
Operating structure (% herds)						
Conventional	89.5	81.1	87.2	94.7	88.2	0.33
Organic	10.5	18.9	12.8	5.3	11.8	0.33
Milking system						
Conventional	100.0[a]	97.3[a]	94.9[a]	71.1[b]	90.8	<0.01
Automatic milking system	0.0[b]	2.7[b]	5.1[b]	28.9[a]	9.2	<0.01
DHIA member (% herds)	71.1[b]	89.2[b]	94.9[a]	89.5[ab]	86.2	0.02
Predominant breed (% herds)						
Simmental	78.9	70.3	82.0	71.0	75.6	0.56
Brown Swiss	13.2	18.9	15.4	5.3	13.1	0.32
Others	7.9[ab]	10.8[ab]	2.6[b]	23.7[a]	11.3	0.03

[a–d]Different superscripts indicate significant differences (P < 0.05) between the means of the different groups (from the largest to the smallest mean).

[1]A list of all Bavarian herds (excluding herds with <200 kg of milk shipped per day) was split into quartiles based on milk shipped daily (group). IQR = interquartile ratio; DHIA = regional DHIA, Landeskuratorium der Erzeugerringe für tierische Veredelung in Bayern e.V. (LKV).

[2]Overall group-level comparison.

[3]Median and 25th to 75th percentile (IQR) reported, the latter in parentheses.

[4]Calculated by dividing the herd performance over the last 365 d by the average number of animals tested per day.

[5]Geometric mean of the preceding 3 mo at the time of the visit.

6,208 cows were evaluated on farm. Table 1 gives an overview of the characteristics of participating herds. Seven farms had more than 90 cows, including 2 with more than 100 cows (n = 111 and n = 121) and 1 with more than 300 cows (n = 327).

Although the majority of cows (5,616/6,208 cows) were from farms with monthly milk testing, only 4,719 cows could be matched to monthly milk recording data.

Apparent Prevalence of Udder Diseases

For the purpose of this article, apparent prevalence will simply be called prevalence.

Teat warts were observed on 55.9% of farms in 4.0% of all cows (95% CI: 3.0% to 5.3%). Among positive herds (n = 85), teat warts were recorded on 432 of the 3,277 cows.

Cows in group 4 were less likely to be diagnosed with warts (2.0%, 95% CI: 1.0% to 3.8%) than those of group 1 (7.0%, 95% CI: 4.6% to 1.05%, P < 0.01) and group 2 (6.5%, 95% CI: 3.9% to 10.9%, P < 0.01). The overall median intraherd prevalence ranged from 0.0% to 60.0% (median: 3.3%). Among herds with positive animals, the intraherd prevalence ranged from 1.5% to 60.0% (median: 9.6%).

Udder edema was observed in 1.1% of the cows (95% CI: 0.8% to 1.4%) on 29.6% of the farms. Among positive herds (n = 45), UE occurred in 79 of the 1,906 cows. The proportion of UE-positive cows did not differ between groups (P = 0.27). The within-herd prevalence ranged from 0.0% to 14.0% (median: 0.0%). Within positive herds, the median within-herd prevalence for UE ranged from 1.5% to 14.0% (median: 4.0%).

Udder thigh dermatitis was observed in 0.2% of all cows (95% CI: 0.1% to 0.4%) in 8.6% of all farms. Of the 666 cows in UTD-positive herds (n = 13), 15 cows were found positive for UTD. No difference in the proportion of UTD-positive cows among the 4 groups was found. The within-herd prevalence ranged from 0.0% to 13.0% (median: 0.0%). Within UTD-positive herds, the median within-herd prevalence ranged from 1.2% to 13.0% (median: 1.9%).

Udder cleft dermatitis was observed in 0.3% of cows (95% CI: 0.2% to 0.5%) in 10.5% of all herds. Among all herds positive for UCD (n = 16), the disease was found in 28 of the 914 cows. The proportion of UCD-positive

Table 2. Association between herd factors and presence of teat warts, udder edema, and udder cleft dermatitis on herd level (present or absent) based on Fisher's exact test ($P < 0.05$)[1]

Disease	Variable	n (+)	n (−)	OR	95% CI	*P*-value
Teat warts		85	67			
	Teat end condition score (≥3), % cows per herd[2]					
	>0–10	26	20	1.79	0.84–3.82	0.18
	>10	25	41	3.88	1.55–9.73	<0.01
	0	33	41	Referent		
	>10			2.16	0.80–5.87	0.15
	>0–10			Referent		
	Milking system					
	Conventional milking	82	57	4.80	1.26–18.20	0.02
	Automated milking	3	10	Referent		
Udder edema		45	107			
	Depth of bedding material (dry cows)[2]					
	>5 cm	4	33	0.22	0.07–0.66	<0.01
	≤5 cm	40	72	Referent		
Udder cleft dermatitis		16	136			
	Housing type					
	Freestall	15	74	12.57	1.61–97.84	<0.01
	Tiestall	1	62	Referent		
	Rubber mats—dry cow housing[2]					
	Plain rubber mats	4	54	1.09	0.26–4.59	>0.99
	Comfort rubber mats	7	15	6.88	1.78–26.63	0.01
	Other[3]	4	59	Referent		
	Comfort rubber mats			6.30	1.63–24.43	0.01
	Plain rubber mats			Referent		

[1]n (+) = number of herds with each condition present; n (−) = number of herds with each condition absent; OR = odds ratio.

[2]Information not available for all herds.

[3]Bedding surface or materials other than mats.

cows did not differ among the 4 groups ($P = 0.39$). The median within-herd prevalence across all herds ranged from 0.0% to 6.2% (median: 0.0%). If UCD was present in a herd, the median within-herd prevalence ranged from 0.9% to 6.2% (median: 3.2%).

Risk Factors for Teat Warts

Herd-Level Risk Factors. At the herd level, conventional milking ($P = 0.02$) and poor teat end condition ($P < 0.01$) were associated with the presence of teat warts on a farm (Table 2). Herds milking with conventional milking systems had almost 5 times the odds of having teat warts in a herd compared with AMS herds. In herds with more than 10% of the cows with a teat end condition score greater than or equal to 3, the odds for teat warts were higher than in herds where no cow had a score greater than or equal to 3.

Cow-Level Risk Factors. A total of 2,359 cows were in 73 teat-wart-positive herds. Because of missing data, only 2,260 cows were included in the final cow-related risk factors model.

At the cow level, univariable mixed-effect regression analysis was first performed for 8 variables (Table 3). Of these, 5 variables (breed, milk yield, cow SCC, teat end condition score, and udder hygiene score) had a $P < 0.25$ and were initially included in the model. After backward selection, only the variable cow SCC ultimately remained in the model ($P < 0.01$, Table 4). Cows with lower SCC also had lower odds of having teat warts than those with SCC > 100,000 cells/mL.

When considering all cows—that is, also those from farms without teat warts—the variables breed and cow SCC remained in the final cow-related risk factors model (results not shown). Brown Swiss cows [odds ratio (**OR**): 2.04, 95% CI: 1.21 to 3.42, $P < 0.01$] and cows of other breeds had increased odds for teat warts compared with Simmental cows (OR: 2.00, 95% CI: 1.16 to 3.49, $P = 0.01$) and cows with low SCC (<100,000 cells/mL) had lower odds compared with cows with SCC > 100,000 (OR: 0.69, 95% CI: 0.53 to 0.89, $P < 0.01$).

Risk Factors for UE

Herd-Level Risk Factors. At the herd level, only one variable was associated with the presence of UE in herds. Herds with a good depth (>5 cm) of bedding

Table 3. Summary of variables screened for association with udder disease (warts, udder edema, udder thigh dermatitis, udder cleft dermatitis) at cow level

Udder disease	Screened variables
Teat warts	Breed,[1] lactation number,[1] DIM,[1,2,3] cow-individual milk yield,[1,3] SCC,[1,3] teat end condition score,[4] UHS,[5,6] LHS[5,7]
Udder edema	Breed, lactation number, DIM, cow-individual milk yield, milk protein concentration[1,3] (%), milk urea concentration[1,3] (mg/dL)
Udder thigh dermatitis	Breed, lactation number, DIM, cow-individual milk yield, UHS, LHS
Udder cleft dermatitis	Breed, lactation number, DIM, cow-individual milk yield, cow SCC, UHS, LHS, hock lesion score[4]

[1]These data are taken from the latest DHIA test day and represent only 1 mo.

[2]Dichotomized as ≤60 DIM and >60 DIM.

[3]Classification based on percentiles.

[4]Score 1 to 3.

[5]Score 1 to 4, dichotomized into clean (scores 1 and 2) and dirty (scores 3 and 4).

[6]UHS = udder hygiene score.

[7]LHS = leg hygiene score.

material for dry cows had reduced odds (OR: 0.22) of UE compared with those with poor bedding depth (Table 2).

Cow-Level Risk Factors. A total of 1,365 cows that came from 40 herds where UE was present were included in the cow-level risk factors analysis.

Six predictor variables were tested in a univariable mixed-effect logistic regression analysis at cow level (Table 4). Four of these variables (lactation number, DIM, cow milk yield, and milk protein concentration) had $P < 0.25$ and were included in a multivariable logistic regression model for cow-level risk factors. The variable DIM remained in the model (Table 4). Cows at the beginning of lactation (d 0 to 60) had 4.9 the odds to experience UE compared with cows in later lactation.

Risk Factors for UTD

Herd-Level Risk Factors. No herd-level risk factor could be identified.

Cow-Level Risk Factors. The 10 UTD-positive herds had a total of 514 cows (512 could be included in the analysis). Six variables were tested for associations with UTD at cow level in univariable mixed-effect regression analysis (Table 4). Of these variables, only one had a $P < 0.25$ (lactation, $P < 0.05$) and therefore remained in the final model. First-lactation animals had almost 4 times the odds to get UTD compared with older cows (Table 4).

Risk Factors for UCD

Herd-Level Risk Factors. Two variables were associated with the occurrence of UCD at herd level (Table 2). Herds with freestalls had 12.6 times the odds of having UCD cases compared with tiestall herds. The odds of having UCD in the herd were increased if dry cows were housed on comfort rubber mats compared with plain rubber mats and no rubber mats for dry cows at all.

Cow-Level Risk Factors. Of all cows, 692 were from 15 UCD-positive herds. Eight variables were evaluated as possible risk factors for UCD in univariable mixed-effect regression analysis (Table 4). Three variables (breed, udder hygiene score, and leg hygiene score) had $P < 0.25$. After backward selection, none remained in the final model.

DISCUSSION

The study was conducted in Bavaria, where almost one-third (28.2%) of German dairy cows are located (Statistisches Bundesamt, 2020). The herd structure of Bavaria varies from that of other German federal states in many ways. For example, the Bavarian-wide herd milk yield was more than 900 kg below the nationwide average at the time of study (LKV Bayern, 2018). This is probably related to the fact that the main breed used was Simmental, a dual-purpose breed. In contrast to other regions of Germany, in Bavaria the Holstein, a pure dairy breed, is the predominant breed (PraeRi, 2020). Herd size is also more than 40% smaller than the national average (LKV Bayern, 2018), and tiestalls are more common compared with other German regions. Therefore, these findings should not be generalized for all of Germany and only represent larger Bavarian dairy herds, as we excluded very small farms with fewer than 10 cows (17% of all farms).

This the first study to investigate the prevalence of teat warts, UE, UTD, and UCD and their risk factors in Germany. Because of the cross-sectional nature of

Table 4. Results of multivariable mixed logistic regression analyses at cow level for cow-related risk factors associated with the udder diseases teat warts (n = 2,260), udder edema (n = 1,365), and udder thigh dermatitis (n = 512), including only cows from herds with the disease present (herd included as random effect)

Disease	Variable	n[1]	Coefficient	SE	OR[2]	95% CI	*P*-value
Teat warts							
	Intercept		−1.76	0.16			<0.01
	Cow SCC (cells/mL)						
	≤100,000	1,340	−0.36	0.13	0.70	0.54–0.90	<0.01
	>100,000	920	Referent				
Edema							
	Intercept		−3.7	0.21			<0.01
	DIM						
	0–60	244	1.59	0.29	4.90	2.79–8.66	<0.01
	>60	1,121	Referent				
Udder thigh dermatitis							
	Intercept		−4.49	0.50			<0.01
	Lactation						
	1	153	1.28	0.65	3.62	1.00–13.07	<0.05
	≥2	359	Referent				

[1]Number of cows per category.

[2]OR = odds ratio.

the study, short-lived diseases or those associated with a particular stage of lactation (e.g., UE) will likely be underrepresented. However, the aim of the study was to provide a first estimate of the apparent prevalence of these diseases in Bavaria, which we achieved.

Prevalence and Risk Factors for Teat Warts

Teat warts were the most commonly found disease in this study. As teat warts can persist for several months (Ohnstad et al., 2007), the likelihood of detecting them in a cross-sectional study is higher than that of detecting shorter-lasting lesions such as UE.

Prevalence data for teat warts are sparse. A retrospective survey study in Egypt found an incidence of 1.65% for teat warts (Nouh et al., 2014), and an older study in Bangladesh found a prevalence of 15.9% (Nooruddin et al., 1997). Neijenhuis et al. (2004) found a prevalence of 21.5% before and 13.4% after changing from conventional to AMS milking in Dutch herds.

The latter findings are consistent with ours, where the odds for teat warts were 5 times higher in herds with conventional milking systems compared with AMS. As the implementation of liner disinfection between cows is more common in AMS, one might assume that the viral transmission via the teat cup liner might be lower. However, this assumption could not be supported with observations in this study, as we were unable to identify associations between milking hygiene parameters (e.g., use of liner disinfection, postdip usage, wearing of single-use gloves during milking, and establishment of milking order) and the prevalence of teat warts.

Herds with poor teat end condition (hyperkeratosis) and cows with higher SCC, an indicator of subclinical mastitis (Dohoo and Meek, 1982), had increased odds for having cows with teat warts in this study. There are several possible explanations for these observations. One is that teat warts could negatively affect the milking process based on poor teat-liner contact and increase the risk of hyperkeratosis and subclinical mastitis due to liner slips (Baxter et al., 1992). Another is that cows with hyperkeratosis and high SCC were more likely to experience a damaged (mucosal) skin barrier or impaired immune system and therefore had an increased susceptibility to papillomaviruses. Although the temporal aspect of this association cannot be answered with a cross-sectional study, skin damage might be a risk factor for teat warts.

Prevalence and Risk Factors for UE

In our study, 1.1% of cows had UE. As per study design, we evaluated cows of all stages of lactation at one point in time, whereas other studies have focused on the high-risk periparturient time period to investigate UE. This explains the much higher UE prevalence reported in studies from the United States (97%; Dentine and McDaniel, 1983) or Canada (70%; Morrison et al., 2018). In our study, cows in early lactation (0 to 60 d) had the highest odds of showing UE, which supports early lactation as a risk factor for UE once more.

At the herd level, a good depth of bedding material for dry cows (means > 5 cm) was associated with UE. Several studies have found that cows prefer soft, compressible lying surfaces (Natzke et al., 1982; Herlin, 1997; Tucker et al., 2003). Whether lying behavior influences lymphatic flow or the development of UE cannot be answered with our data.

Prevalence and Risk Factors for UTD

For UTD, we found the prevalence to be at the low level of 0.2%. Again, because of the study design our reported prevalence was lower than that of other studies. Another German study reported that 1% of heifers and 0.06% of multiparous cows had UTD over a period of 3 years (Sigmund et al., 1980). A French study also had much higher annual UTD incidences of 23% for primiparous and 1.2% for multiparous cows (Roy et al., 2012). Consistent with our results, Roy et al. (2012) also showed that primiparous cows are more frequently affected by UTD compared with multiparous cows. Udder thigh dermatitis usually occurs as a result of friction when the udder is edematous on the inner thigh, and UE also occurs mainly in heifers (Roy et al., 2012; Morrison et al., 2018).

Nevertheless, none of the total 15 UTD-positive cows also had UE in this study. Because UTD usually does not appear until the edema has decreased, UE might have already subsided in the cows affected with UTD in this study. However, it should be emphasized that because of the cross-sectional study design and low number of positive cases (especially for UCD and UTD), the results should be interpreted with caution.

Prevalence and Risk Factors for UCD

The prevalence of UCD, 0.3% of all cows, was clearly below the prevalence in the Netherlands, 5.2% (Olde Riekerink et al., 2014). In Sweden, the prevalence among cows was even higher at 18% (Persson Waller et al., 2014) and 28% (Ekman et al., 2018). Although Persson Waller et al. (2014) found breed to be a risk factor for UCD, breed was not associated with UCD in our study. In the Swedish studies, the Swedish Holstein and Swedish Red breeds were predominantly sampled, whereas Simmental was mostly sampled in our study. This could contribute to this discrepancy.

At the herd level, the use of comfort (padded) rubber mats during the dry period was identified as a risk factor for UCD during lactation. Compared with farms that had plain rubber mats or completely different bedding for dry cows, the odds for UCD were increased. These findings are consistent with the study of Ekman et al. (2018), who found comfort rubber mattresses as a risk factor for UCD compared with normal rubber mats.

Ekman et al. (2018) speculated that comfort rubber mattresses are more likely to cause heat and moisture buildup, and that the mats' deformability decreases over time. Subsequently, feces and urine may accumulate and cause skin barrier damage when the cow is lying down.

Methodological Considerations

The farms were contacted from telephone lists, and participation was voluntary. The question arises as to why a farm agrees to participate or not. In this study, 54% of farms declined. One could speculate that smaller farms are more likely to know what can be found in their herds and therefore do not want to participate.

The prevalence of the diseases was unknown beforehand, and these data were collected as part of a different study. Therefore, no formal sample size calculation was conducted for each disease, but the sample size was deemed meaningful even for these rare diseases. However, despite a low effective sample size for some diseases (including missing DHIA data for some herds), we were able to identify some risk factors.

Furthermore, 20 trained technicians visited the herds and collected the data. Though they are regularly trained on disease identification and sample collection, no interobserver variability was assessed, and misclassification or detection bias will not be completely avoidable. However, the technicians were in teams of 2 on each farm to look for diseases, which should improve the interobserver agreement as unclear cases would have been examined by 2 people who were specifically looking for these lesions.

Disease definitions may vary from those used by other studies. This may result in different detection rates. The diseases are sometimes only vaguely defined in other studies (e.g., Roy et al., 2012; Morrison et al., 2018). For example, Morrison et al. (2018) had an adspectoral scoring system for UE but no more precise definition based on palpation. Both overestimation and underestimation may occur. For example, UE may not be diagnosed visually alone, and palpation to check the consistency of the udder tissue is an important part of the diagnosis. Some teat warts could be mistaken for udder pox, but this could have only been confirmed with absolute accuracy by laboratory analysis.

Seasonal influences were not considered in our study. The majority of farms (n = 117) were visited between March and May, including 73 farms in April alone, and none in midsummer (July or August). For this reason, risk factors influenced by season (e.g., grazing) were ignored.

CONCLUSIONS

This is the first study in southern Germany about the prevalence and risk factors of various udder diseases other than mastitis—namely, teat warts, UE, UCD, and UTD. The diseases were rarely detected in the study cows. The most common disease was teat warts (in 4.0% of all cows). The risk factors identified for teat warts were conventional milking on the herd level and cow SCC on the cow level. Poor depth of bedding material was associated with UE on the herd level and early DIM on the cow level. Freestall housing and the use of comfort rubber mats in the dry period were identified as risk factors for UCD on the herd level. Cows in first lactation had increased odds for UTD compared with cows in later lactations. Further studies that examine each disease in depth should identify additional risk factors.

ACKNOWLEDGMENTS

We thank the farmers for their participation and the Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (Munich, Germany), as well as the Bayerischen Tierseuchenkasse (Munich, Germany) for the financial support of this study. L. J. Groh: data analysis, manuscript preparation. R. Mansfeld and C. Baumgartner: manuscript review. U. S. Sorge: study design, data collection, and funding acquisition. The authors have not stated any conflicts of interest.

REFERENCES

Baxter, J. D., G. W. Rogers, S. B. Spencer, and R. J. Eberhart. 1992. The effect of milking machine liner slip on new intramammary infections. J. Dairy Sci. 75:1015–1018. https://doi.org/10.3168/jds.S0022-0302(92)77844-8.

Bouma, A., M. Nielen, E. van Soest, S. Sietsma, J. van den Broek, T. Dijkstra, and T. van Werven. 2016. Longitudinal study of udder cleft dermatitis in 5 Dutch dairy cattle herds. J. Dairy Sci. 99:4487–4495. https://doi.org/10.3168/jds.2015-9774.

Campo, M. S. 2006. Bovine papillomavirus: Old system, new lessons? Pages 373–387 in Papillomavirus Biology: From Natural History to Vaccine and Beyond. M. S. Campo, ed. Caister Academic Press, Glasgow, UK.

Dentine, M. R., and B. T. McDaniel. 1983. Variation of edema scores from herd-year, age, calving month, and sire. J. Dairy Sci. 66:2391–2399. https://doi.org/10.3168/jds.S0022-0302(83)82097-9.

Dohoo, I. R., and A. H. Meek. 1982. Somatic cell counts in bovine milk. Can. Vet. J. 23:119–125.

Duse, A., K. Persson-Waller, and K. Pedersen. 2021. Microbial aetiology, antibiotic susceptibility and pathogen-specific risk factors for udder pathogens from clinical mastitis in dairy cows. Animals (Basel) 11:2113. https://doi.org/10.3390/ani11072113.

Ekman, L., A.-K. Nyman, H. Landin, U. Magnusson, and K. P. Waller. 2018. Mild and severe udder cleft dermatitis—Prevalence and risk factors in Swedish dairy herds. J. Dairy Sci. 101:556–571. https://doi.org/10.3168/jds.2017-13133.

European Commission. 2004. Regulation 853/2004 of Apr. 29, 2004, Laying Down Specific Hygiene Rules for on the Hygiene of Foodstuffs, 2004 O.J. (L 139/55) (EC).

Harmon, R. J. 1994. Physiology of mastitis and factors affecting somatic cell counts. J. Dairy Sci. 77:2103–2112. https://doi.org/10.3168/jds.S0022-0302(94)77153-8.

Herlin, A. H. 1997. Comparison of lying area surfaces for dairy cows by preference, hygiene and lying down behavior. Swedish J. Agric. Res. 27:189–196.

Hiitiö, H., J. Vakkamäki, H. Simojoki, T. Autio, J. Junnila, S. Pelkonen, and S. Pyörälä. 2017. Prevalence of subclinical mastitis in Finnish dairy cows: Changes during recent decades and impact of cow and herd factors. Acta Vet. Scand. 59:22. https://doi.org/10.1186/s13028-017-0288-x.

Jarrett, W. F. H., M. S. Campo, B. W. O'Neil, H. M. Laird, and L. W. Coggins. 1984. A novel bovine papillomavirus (BPV-6) causing true epithelial papillomas of the mammary gland skin: A member of a proposed new BPV subgroup. Virology 136:255–264. https://doi.org/10.1016/0042-6822(84)90162-4.

Kirk, J. H., and W. M. Sischo. 2003. Case report: An investigation of dairy cow teat lesions and clinical mastitis. Bov. Pract. 37:30–34. https://doi.org/10.21423/bovine-vol37no1p30-34.

Kumar, P., B. L. Jangir, G. Saikumar, and R. Somvanshi. 2013. Co-infection of bovine papillomavirus type-1 and -10 in teat warts of dairy cattle. Vet. Med. 60:475–480. https://doi.org/10.1111/j.1865-1682.2012.01361.x.

Lema, M., W. B. Tucker, M. Aslam, I. S. Shin, P. Le Ruyet, and G. D. Adams. 1992. Influence of calcium chloride fed prepartum on severity of edema and lactational performance of dairy heifers. J. Dairy Sci. 75:2388–2393. https://doi.org/10.3168/jds.S0022-0302(92)78000-X.

LKV Bayern. 2018. Milchleistungsprüfung in Bayern. Landeskuratorium der Erzeugerringe für tierische Veredelung in Bayern e.V. Accessed Dec. 4, 2021. https://www.lkv.bayern.de/wp-content/uploads/2021/01/mlp_jahresbericht2018-1.pdf.

Loppnow, H. 1959. Über die verschiedenen Formen des Euterödems, ihre Entstehung und ihre Folgen. Zentralbl Veterinarmed 6:46–67. https://doi.org/10.1111/j.1439-0442.1959.tb00565.x.

Maeda, Y., T. Shibahara, Y. Wada, K. Kadota, T. Kanno, I. Uchida, and S. Hatama. 2007. An outbreak of teat papillomatosis in cattle caused by bovine papilloma virus (BPV) type 6 and unclassified BPVs. Vet. Microbiol. 121:242–248. https://doi.org/10.1016/j.vetmic.2006.12.015.

Millar, M., A. Foster, J. Bradshaw, A. Turner, R. Blowey, N. Evans, and G. Hateley. 2017. Embolic pneumonia in adult dairy cattle associated with udder cleft dermatitis. Vet. Rec. 180:205–206. https://doi.org/10.1136/vr.j954.

Morrison, E. I., T. J. DeVries, and S. J. LeBlanc. 2018. Short communication: Associations of udder edema with health, milk yield, and reproduction in dairy cows in early lactation. J. Dairy Sci. 101:9521–9526. https://doi.org/10.3168/jds.2018-14539.

Natzke, R. P., D. R. Bray, and R. W. Everett. 1982. Cow preference for free stall surface material. J. Dairy Sci. 65:146–153. https://doi.org/10.3168/jds.S0022-0302(82)82163-2.

Neijenhuis, F., O. C. Bos, O. C. Sampimon, J. Poelarends, J. E. Hillerton, C. Fossing, and J. Dearing. 2004. Changes in teat condition in Dutch herds converting from conventional to automated milking. Pages 141–147 in Automatic Milking—A Better Understanding. A. Meijering, H. Hogeveen, and C. J. A. M. de Koning, ed. Wageningen Academic Publishers, Wageningen, the Netherlands.

NMC (National Mastitis Council). 2007. Guidelines for evaluating teat skin condition. Accessed Dec. 4, 2021. http://www.nmconline.org/wp-content/uploads/2016/09/Guidelines-for-Evaluating.pdf.

NMPF (National Milk Producers Federation). 2013. Animal care reference manual. Accessed Dec. 4, 2021. https://www.nmpf.org/wp-content/uploads/2015/08/FARM_manual_2013_WEB.pdf.

Nooruddin, M., M. S. Rahman, and M. M. Rahman. 1997. Prevalence and distribution of teat papillomatosis in crossbred and exotic dairy cows. Bangladesh Vet. 14:5–7.

Nouh, S., A. Korittum, M. Elkammar, and W. Barakat. 2014. Retrospective study of the surgical affections of the teat in dairy cows of army farms and their successful treatment. Alex. J. Vet. Sci. 40:65–76. https://doi.org/10.5455/ajvs.45201.

Ohnstad, I., G. A. Mein, J. R. Baines, M. D. Rasmussen, R. Farnsworth, B. Pocknee, T. C. Hemling, and J. E. Hillerton. 2007. Addressing teat condition problems. Pages 188–199 in Natl. Mastitis Counc. Annu. Mtg. Proc., San Antonio, TX. Natl. Mastitis Counc. Inc., New Prague, MN.

Okkema, C., and T. Grandin. 2021. Graduate student literature review: Udder edema in dairy cattle—A possible emerging animal welfare issue. J. Dairy Sci. 104:7334–7341. https://doi.org/10.3168/jds.2020-19353.

Olde Riekerink, R. G. M., K. van Amersfort, O. C. Sampimon, G. A. Hooijer, and T. J. G. M. Lam. 2014. Short communication: Prevalence, risk factors, and a field scoring system for udder cleft dermatitis in Dutch dairy herds. J. Dairy Sci. 97:5007–5011. https://doi.org/10.3168/jds.2013-7651.

Persson Waller, K., M. Bengtsson, and A.-K. Nyman. 2014. Prevalence and risk factors for udder cleft dermatitis in dairy cattle. J. Dairy Sci. 97:310–318. https://doi.org/10.3168/jds.2013-7186.

PraeRi. 2020. Tiergesundheit, Hygiene und Biosicherheit in deutschen Milchkuhbetrieben—Eine Prävalenzstudie (PraeRi). Abschlussbericht. Accessed Dec. 4, 2021. https://ibei.tiho-hannover.de/praeri/uploads/report/Abschlussbericht_komplett_2020_06_30_korr_2020_10_22.pdf.

Radostits, O. M., I. G. Mayhew, and D. M. Houston. 2000. Veterinary Clinical Examination and Diagnosis. Saunders.

Rai, G. K., M. Saxena, V. Singh, R. Somvanshi, and B. Sharma. 2011. Identification of bovine papilloma virus 10 in teat warts of cattle by DNase-SISPA. Vet. Microbiol. 147:416–419. https://doi.org/10.1016/j.vetmic.2010.07.015.

Roy, C., J.-L. Roque, P.-M. François, A. Ferrieres, and D. Raboisson. 2012. Investigation of the aetiology of udder-thigh dermatitis in French dairy cattle. Vet. J. 193:274–276. https://doi.org/10.1016/j.tvjl.2011.09.023.

Santman-Berends, I. M. G. A., J. M. Swinkels, T. J. G. M. Lam, J. Keurentjes, and G. van Schaik. 2016. Evaluation of udder health parameters and risk factors for clinical mastitis in Dutch dairy herds in the context of a restricted antimicrobial usage policy. J. Dairy Sci. 99:2930–2939. https://doi.org/10.3168/jds.2015-10398.

Schreiner, D. A., and P. L. Ruegg. 2003. Relationship between udder and leg hygiene scores and subclinical mastitis. J. Dairy Sci. 86:3460–3465. https://doi.org/10.3168/jds.S0022-0302(03)73950-2.

Sigmund, H. M., W. Klee, and H. Schels. 1980. Udder-thigh dermatitis of cattle: Epidemiological, clinical and bacteriological investigations. Bov. Pract. 18:18–23. https://doi.org/10.21423/bovine-vol1983no18p18-23.

Sorge, U. S., E. M. Binger, J. Schefers, and P. J. Plummer. 2019. Short communication: Metagenomic evaluation of skin biopsies of udder sores in dairy cows. J. Dairy Sci. 102:11470–11475. https://doi.org/10.3168/jds.2018-15863.

Statistisches Bundesamt. 2020. Destatis. Viehbestand—Fachserie 3 Reihe 4.1. Accessed Dec. 4, 2021. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Tiere-Tierische-Erzeugung/Publikationen/Downloads-Tiere-und-tierische-Erzeugung/viehbestand-2030410205314.pdf;=publicationFile.

Tucker, C. B., D. M. Weary, and D. Fraser. 2003. Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. J. Dairy Sci. 86:521–529. https://doi.org/10.3168/jds.S0022-0302(03)73630-3.

ORCIDS

L. J. Groh https://orcid.org/0000-0001-8588-755X
R. Mansfeld https://orcid.org/0000-0002-7448-9246
C. Baumgartner https://orcid.org/0000-0002-3725-8414
U. S. Sorge https://orcid.org/0000-0002-7709-4282