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The relationship between common data-based indicators and the welfare of Swiss dairy herds

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The assessment of dairy cow welfare has become increasingly important in recent years. Welfare assessments that use animal-based indicators, which are considered the most direct indicators, are time consuming and therefore not feasible for assessments on a large number of farms. One approach to reducing this effort is the use of data-based indicators (DBIs) calculated from routine herd data. The aim of this study was to explore the relationship between common DBIs and the welfare of 35 dairy herds to evaluate the feasibility of a data-based welfare prediction method. For this purpose, the WelfareQuality[®] (WQ) protocol was used to assess the welfare of dairy cows on 35 Swiss farms, for each of which 10 commonly used DBIs were calculated from herd data. Spearman's rank correlations were used to investigate the relationship between DBIs and WQ criteria and measurements. The study found only a few statistically weak associations between DBIs and animal welfare, with no associations for measurements or criteria of resting comfort and appropriate behavior. Thus, the multidimensional welfare definition is insufficiently covered, and the present publication does not support the approach of a purely data-based prediction of dairy welfare status at the farm level. Instead, the regular calculation of DBIs that are indicative of isolated animal welfare problems or metrics of animal health could allow monitoring of these specific areas of animal welfare.

KEYWORDS

herd records, welfare assessment, routine herd data, national database, herd health, animal based measures

Introduction

In recent years, the valid assessment of farm animal welfare has become increasingly important for a growing number of stakeholders. Farmers benefit from animal welfare assessments for self-control, benchmarking their performance, or as advisory tools (1, 2). Market organizations, retailers, and organic farming associations employ welfare

assessments by external auditors to ensure compliance with their welfare standards (3, 4) and federal institutions assess the fulfillment of legal welfare requirements and minimum welfare standards (1, 5). However, animal welfare is a complex, multidimensional concept that includes biological functions, animal behavior, and affective state (6). Because of its complexity, animal welfare itself cannot be measured directly but must be reflected by a variety of indicators that represent its multidimensionality (7). The indicators used for on-farm welfare assessments can be divided into two main types: input- and outcome-based indicators. Resource- and management-based indicators are used to survey the environment and the management that affect the animals (input-based). In contrast, animal-based indicators (ABIs) are collected directly from the animal and can thus indicate how the animal copes with the influencing factors (outcome-based) (1, 8). Therefore, ABIs are considered to reflect welfare more directly, leading to an increasing preference for ABIs over input-based indicators (9). Probably the most comprehensive welfare assessment protocol for various livestock species is the approach developed by the WelfareQuality[®] (WQ) project (10, 11). The WQ protocol for dairy cows includes 27 indicators that are mostly animal-based and complemented by input-based indicators only in areas where no suitable ABIs are available (12). However, conducting on-farm surveys, especially the assessment of animal-based indicators, is very time-consuming. Approximately 6 h are required to survey a herd of 60 cows using the WQ protocol (13). To survey larger numbers of farms, such as for monitoring animal welfare at the population level, alternatives must be found to allow a quick and cost-effective assessment (14).

Given the challenge of alternative approaches to assessing animal welfare, various attempts have been made to make animal welfare assessments on large numbers of farms more feasible or to shorten the duration of surveys. One way to accomplish this is to integrate routinely collected herd data into animal welfare monitoring, which could replace ABIs (8) or enable data-driven risk screening that could reduce the number of farm visits (15). Herd data collected directly from animals, such as somatic cell counts in milk, can be considered indirect animal-based indicators (16) or data-based welfare indicators (DBIs). Whereas traditional welfare assessments, such as the WQ protocol, usually include only a few DBIs, some research has aimed to predict farm-level welfare status based solely on DBIs (14, 15, 17–19). In this way, a data-based screening should be created that could limit on-farm surveys to high-risk farms.

A precondition for a wide use of DBIs, for example within the framework of national monitoring, is the availability of data of sufficient quality from as many farms as possible (20). This approach seems particularly suitable for dairy farms, as, due to European legislation, a large amount of routine herd data are available. For example, cattle must be individually identifiable, and data on birth, movement, and death must be collected and stored in national databases (21). Furthermore, analyses of

bulk milk delivered for food production must be carried out on a regular basis (22). These data are supplemented by milking records of individual animals obtained monthly by breeding or producer organizations in many countries (23).

In addition to the availability of the data, it is necessary that the DBI is related to the animal welfare of the farm to use a DBI to predict animal welfare (20). Based on the results of previous work, the aim of this study was to investigate the relationship between common data-based indicators and the welfare of Swiss dairy herds in order to assess the potential of data-based indicators to estimate the animal welfare of Swiss dairy herds. For this purpose, an on-farm survey was conducted on 35 Swiss dairy farms. The animal welfare status was assessed using the WQ's criteria and measurements and subsequently examined for its association with 10 selected DBIs calculated from herd data.

Materials and methods

Farms and animals

Farm visits were conducted on Swiss dairy farms from January 2020 to March 2021. To recruit farms, farmers interested in previous studies or recommended by other farmers were contacted by telephone. Thirty-seven farmers agreed to participate and fulfilled the condition of having at least 16 lactating dairy cows at the time of the planned farm visit. The farms were visited once during the winter housing period between January and March (22 farms in 2020, 15 farms in 2021), after the cows had been mainly housed indoors for a minimum of 2 months. Of the 37 farms visited, 35 farms with a complete on-farm welfare assessment delivered valid values and were included in the analyses.

The mean annual herd size was 47 dairy cows (range 16–136). Twenty farms had a free stall barn, and on 15 farms cows were kept in tie-stalls. Seven farms were run according to certified organic standards (Bio Suisse). All tie-stall farms participated in the Swiss animal welfare program RAUS (24), which requires regular outdoor exercise during winter and pasturing in summer. All loose housing farms participated in the Swiss animal welfare program BTS (24), which requires a comfortable lying area separated from the feeding area. In addition, 18 of the 20 loose housing farms participated in the RAUS program.

Assessment of farm animal welfare status using the WQ protocol

The welfare status of the herds was surveyed by conducting the entire WQ protocol for dairy cattle (12). All assessments were carried out by the first author, who had previous experience

TABLE 1 Overview of WelfareQuality[®] principles, criteria, and measurements as well as the expressions at herd level used for the analysis [Table modified from (12)].

	Criteria	WQ indicators	Measurements/herd-level expressions used for analysis	
Principle: Good feeding	1. Absence of prolonged hunger	Body condition score	% BCS very lean % BCS fat [†]	
	2. Absence of prolonged thirst	Water provision (number, length of water troughs/bowls)		
		Cleanliness of water points	*	
		Water flow	*	
Principle: Good housing	3. Comfort around resting	Functioning of water points	*	
		Time needed to lie down	Mean time to lie down	
		Animals colliding with housing equipment during lying down	% Collisions with stalls	
		Animals lying outside the lying area	% Lying outside lying area	
		Cleanliness of udder	% Dirty udders	
		Cleanliness of flank/upper legs	% Dirty hindquarters	
	4. Thermal comfort	Cleanliness of lower legs	% Dirty legs	
		No measure developed yet		
	5. Ease of movement	Presence of tethering	*	
		Access to outdoor loafing area or pasture	*	
	6. Absence of injuries	Lameness		% Not lame [†] % Moderately lame % Severely lame
			Integument alterations	% Cows without skin alterations [†] % Cows with hairless patches % Cows with severe skin alterations
7. Absence of disease		Coughing	Frequency of coughing (coughs/cow/15 min)	
Principle: Good health		Nasal discharge	% Nasal discharge	
		Ocular discharge	% Ocular discharge	
		Hampered respiration	% Hampered respiration	
		Diarrhea	% Diarrhea	
		Vulvar discharge	% Vulvar discharge	
		Milk somatic cell count	% Mastitis	
		Mortality	% Mortality	
		Dystocia	% Dystocia	
		Downer cows	% Downer cows	
		8. Absence of pain induced by management procedures	Disbudding/dehorning	*
	Tail docking		*	
	Principle: Appropriate behavior	9. Expression of social behaviors	Agonistic behaviors	Frequency of head butts (head butts/cow/h) Frequency of displacements and other agonistic interactions (interactions/cow/h)

(Continued)

TABLE 1 (Continued)

Criteria	WQ indicators	Measurements/herd-level expressions used for analysis
10. Expression of other behaviors	Access to pasture	*
11. Good human-animal relationship	Avoidance distance	*
12. Positive emotional state	Qualitative behavior assessment	*

† WQ protocol foresees survey and evaluation at herd level, but not inclusion in calculation of indicators and criteria.

* Exclusively considered as criteria score, individual measurements not taken into account for analyzes.

in dairy farming and the handling of cows. The proper application of the WQ was trained in a 3-day course given by an official trainer of the WQ consortium and routinized on three test farms, which were not included in the data analysis.

Farm visits started at the end of morning milking or, alternatively, at morning feeding, when the cows were at the feeding table. All measurements were collected following the guidelines of the WQ protocol. This involved direct observations of the herd, examinations of individual animals and husbandry conditions, and an interview with the farm manager. Additional information was derived from the farm records.

According to the guidelines of the WQ protocol (12), the on-farm measurements were expressed as herd-level prevalence or frequencies on a continuous scale and aggregated into WQ criteria scores ranging from 0 to 100. As the WQ does not currently include a measurement of thermal comfort, this criterion was not considered (see Table 1).

Calculation of data-based indicators used as animal welfare indicators

For the present study, DBIs were investigated that have already been used as animal welfare indicators or that are considered to be relevant for this purpose. In addition, the DBIs had to be calculable using data routinely available in Switzerland. To identify the DBIs, results from previous scientific literature (25) were used. These DBIs were supplemented with DBIs that are currently being used in other animal welfare projects or assessments, such as Q-check (26) or AssureWel (27), even if no peer-reviewed reports have yet been published for these projects or assessments. All DBIs fitting the criteria (routinely available, identified in scientific literature, or used in other projects) are listed in Table 2.

All farm-specific data were obtained with the consent of the farm managers. For each farm, data on cattle identification and registration were obtained from the Swiss animal movement database. Where available, data on bulk milk analysis were obtained from the national milk quality database dbmilch, and data on cow-individual milk analysis were retrieved from the breeding associations. From the data sets, the 10 selected DBIs

were calculated for an annual period prior to the farm visit (see Table 2). As two farms did not supply milk for human consumption and were therefore not subjected to mandatory bulk milk analysis, the variable mean number of somatic cells in bulk milk (BMSCC) was calculated for 33 farms. Three farms did not participate in the monthly milk recording of individual cows; thus, DBIs derived from the monthly milk analyzes could only be calculated for 32 farms [cows with SCC < 1,00,000 cells/ml (%), cows with SCC > 2,00,000 cells/ml (%), cows with SCC > 4,00,000 cells/ml (%), cows with milk fat-to-protein ratio < 1.0 in 0–60 days in milk (%), cows with milk fat-to-protein ratio > 1.5 in 0–60 days in milk (%)].

Statistical methods

All analyzes were performed in R version 3.6.3 (32). Descriptive analyzes included the scores of the criteria except for the criterion *thermal comfort*. Furthermore, for criteria with more than one animal-based measurement specified in the WQ, the individual measurements, aggregated at the herd level were included in the analyzes (in particular for the criteria *absence of prolonged hunger*, *comfort around resting*, *absence of injuries*, *absence of disease*, and *expression of social behaviors*). This included also measurements that were collected and evaluated at the herd level as specified in the WQ but are not intended to be used in the calculations of indicators and scores (e.g., % fat cows, etc.) (see Table 1). The distribution of WQ measurements, WQ criteria, and calculated DBIs was described using minima, maxima, upper and lower quartiles, means, and medians.

To assess potential associations between DBIs and WQ measurements or criteria, we used Spearman rank correlations on each pair of DBI and either the WQ measurements or criteria. Spearman ranks were chosen because the farm results were not normally distributed in the criteria and measurements. The Spearman rank correlations were corrected for tied values. For the criteria *absence of prolonged thirst*, *ease of movement*, and *absence of pain induced by management procedures*, farm results were each grouped in three ranks. These three criteria differ from the other criteria in that their assessment in the WQ is not obtained on a continuous scale. Instead, decision trees were

TABLE 2 Data-based indicators, and their calculations and data sources used for the present study and reasons for the inclusion in the analyzes.

Data-based indicators	Definition and description	Data source	Reason for inclusion in the analyzes
Cow mortality (%)	$\frac{\text{Dead and euthanized cows}}{\text{Herd size (total number of cows)}} \times 100$	Data on identification and registration, Swiss animal movement database	Use as a data-based animal welfare indicator (12, 26–29)
Culled cows in 0–60 DIM (%)	$\frac{\text{Culled cows in 0–60 DIM}}{\text{Total culled cows}} \times 100$		Potential indicator of health problems in early lactation (30)
Stillbirths (%)	$\frac{\text{Stillborn, euthanized and dead calves up to 48 h}}{\text{Total number of calves born}} \times 100$		Use of similar data-based animal welfare indicators (26, 27)
Mean productive lifespan (months)	Mean timespan between the day of first calving and day of culling of all the cows culled during the 1-year period		Use as a data-based animal welfare indicator (26, 28)
Cows with SCC < 1,00,000 cells/ml (%)	$\frac{\text{Cows with SCC} < 1,00,000 \text{ cells/ml}}{\text{Total number of cows sampled}} \times 100$	Monthly milk testing, breeding organizations	Recommended indicator for veterinary herd management (31)
Cows with SCC > 2,00,000 cells/ml (%)	$\frac{\text{Cows with SCC} > 2,00,000 \text{ cells/ml}}{\text{Total number of cows sampled}} \times 100$		
Cows with SCC > 4,00,000 cells/ml (%)	$\frac{\text{Cows with SCC} > 4,00,000 \text{ cells/ml}}{\text{Total number of cows sampled}} \times 100$		Use as a data-based animal welfare indicator (12, 26, 28)
Milk FPR < 1.0 in 0–60 DIM (%)	$\frac{\text{Cows with FPR} < 1.0 \text{ in 0–60 DIM}}{\text{Total number of cows in 0–60 DIM}} \times 100$		Use of comparable data-based animal welfare indicators (26, 28)
Milk FPR > 1.5 in 0–60 DIM (%)	$\frac{\text{Cows with FPR} > 1.5 \text{ in 0–60 DIM}}{\text{Total number of cows in 0–60 DIM}} \times 100$		
Mean BMSCC (cells/ml)	Arithmetic mean of BMSCC	Routine milk analyses of milk delivered for food production	Use as a data-based animal welfare indicator (29), availability for all milk-supplying farms.

All indicators were calculated for a 1-year period in advance of the welfare assessment.

DIM, days in milk; SCC, milk somatic cell count; FPR, fat-to-protein ratio; BMSCC, bulk milk somatic cell count.

used to compile the measurements into a limited number of possible scores. The limited number of ranks achieved led to the exclusion of the criteria *absence of prolonged thirst, ease of movement, and absence of pain induced by management procedures* from the subsequent analyzes. Furthermore, the farm results for the measurements *% hampered respiration, % nasal discharge, and % collisions with stalls* were grouped on a limited number of different ranks, which led to their exclusion from further analyzes. In total, the relationship between the DBIs and eight criteria scores and 23 measurements were analyzed.

As the number of pairwise comparisons increases the risk of false positive results, the obtained *p*-values were adjusted using Benjamini and Hochberg's false discovery rate adjustment (33). Because adjusting for false positives inadvertently increases the risk for false negatives, we carefully assessed all associations with an unadjusted *p*-value ≤ 0.05 based on plausibility, the correlation coefficient, and the unadjusted and adjusted *p*-value.

Results

Results of the welfare assessment and the calculation of data-based indicators

Descriptive results for farm animal welfare expressed as criteria of the WQ protocol are displayed in Figure 1, while

results for the evaluated WQ measurements can be found in Supplementary Table 1. Descriptive statistics for the DBIs as calculated from herd data are shown in Table 3.

Associations between animal welfare and data-based indicators

The initial Spearman rank analysis revealed associations based on uncorrected *p*-values between the DBIs and 7 of 23 analyzed WQ measurements, as well as 2 of 8 analyzed WQ criteria (Table 4). WQ measurements found to be associated with DBIs were predominantly indicators of animal health, as was the criterion *freedom from disease*. Furthermore, the criterion *absence of hunger* and the corresponding measurement *% cows very lean* were associated with the DBI cows with a milk fat-to-protein ratio > 1.5 in 0–60 DIM (%). Out of the five analyzed measurements of the criterion *comfort around resting*, the *percentage of cows with dirty udders* was associated with the mean productive lifespan. No association could be shown for measurements or criteria related to the principle of *appropriate behavior*.

Correction of the *p*-values to multiple analyzes confirmed five associations with a *p*-value < 0.05 at a high level of confidence. After correction, the associations between the

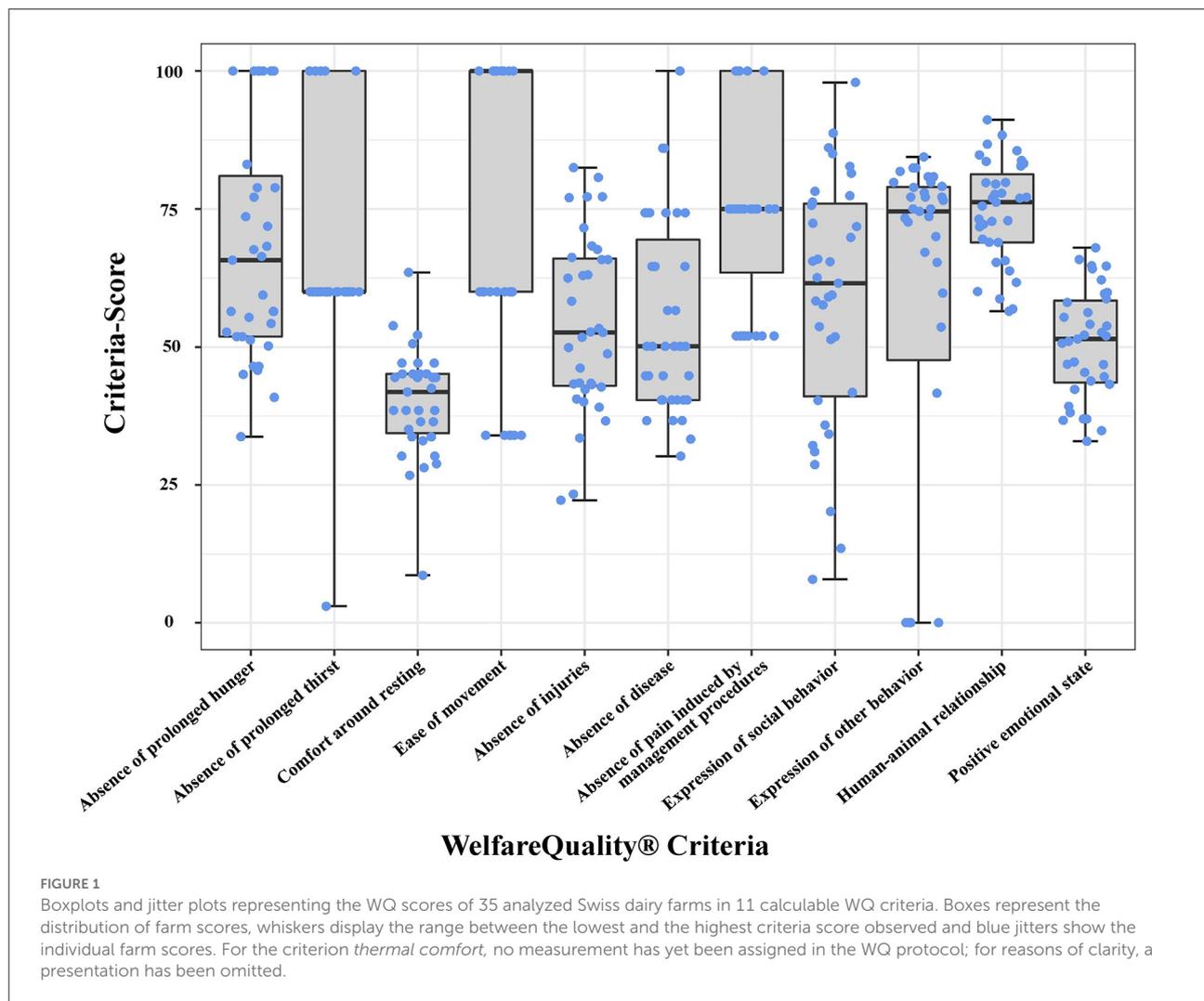


TABLE 3 Descriptive statistics from 10 common data-based indicators calculated from 35 Swiss dairy farms for a 1-year period in advance of the welfare assessments.

Data-based indicators	Min	1st Quartile	Median	Mean	3rd Quartile	Max	Farms with lacking data
Cow mortality (%)	0.00	0.00	2.65	2.51	3.85	10.70	
Culled cows in 0–60 DIM (%)	0.00	0.00	2.65	4.12	4.51	18.94	
Stillbirths (%)	0.00	3.30	6.45	6.43	8.33	18.18	
Mean productive lifespan (months)	791.00	1136.00	1492.00	1498.00	1724.00	2876.00	
Cows with SCC < 1,00,000 cells/ml (%)	30.57	52.13	61.22	58.43	63.40	80.80	3
Cows with SCC > 2,00,000 cells/ml (%)	8.00	14.73	19.23	19.68	24.39	32.18	3
Cows with SCC > 4,00,000 cells/ml (%)	3.09	5.43	7.95	8.49	11.55	16.06	3
Milk FPR < 1.0 in 0–60 DIM (%)	0.00	6.27	11.06	11.93	16.58	29.66	3
Milk FPR > 1.5 in 0–60 DIM (%)	1.30	4.91	11.46	13.51	20.03	35.67	3
Mean BMSCC (cells/ml)	64640.00	108292.00	133792.00	138645.00	161500.00	229815.00	2

DIM, days in milk; SCC, milk somatic cell count; FPR, fat-to-protein ratio; BMSCC, bulk milk somatic cell count.

TABLE 4 Associations between measurements and criteria of the WelfareQuality[®]-Protocol and data-based indicators. Associations with an adjusted $p < 0.05$ are highlighted in gray.

WelfareQuality criteria or measurements	Data-based indicators	<i>r</i>	<i>p</i> -Value	<i>p</i> .adj
Absence of prolonged hunger	Milk FPR > 1.5 in 0–60 DIM (%)	−0.38	0.030	0.638
Absence of disease	Stillbirths (%)	−0.37	0.029	0.638
% BCS very lean	Cows with FPR > 1.5 in 0–60 DIM (%)	0.38	0.030	0.638
% Dirty udders	Mean productive lifespan (months)	0.38	0.024	0.638
% Not lame	Culled cows in 0–60 DIM (%)	−0.39	0.020	0.638
% Mastitis	Cows with SCC < 1,00,000 cells/ml (%)	−0.57	0.001	0.039
	Cows with SCC > 2,00,000 cells/ml (%)	0.79	< 0.001	< 0.001
	Cows with SCC > 4,00,000 cells/ml (%)	0.75	< 0.001	< 0.001
	Mean BMSCC (cells/ml)	0.40	0.022	0.638
% Mortality	Cow mortality (%)	0.57	< 0.001	0.032
	Cows with SCC < 1,00,000 cells/ml (%)	0.42	0.017	0.638
	Cows with SCC > 2,00,000 cells/ml (%)	−0.36	0.046	0.835
% Dystocia	Cow mortality (%)	0.55	0.001	0.039
% Downer cows	Cows with SCC > 2,00,000 cells/ml (%)	0.37	0.039	0.761
	Cows with SCC > 4,00,000 cells/ml (%)	0.50	0.004	0.190
	Mean BMSCC (cells/ml)	0.38	0.031	0.638
	Stillbirths (%)	0.39	0.020	0.638

DIM, days in milk; SCC, milk somatic cell count; FPR, fat-to-protein ratio; BMSCC, bulk milk somatic cell count.

measurement % *mastitis* and the DBIs based on the cow-specific SCC as well as the associations between the WQ measurements % *mortality* and % *dystocia* and the DBI cow mortality % yielded a p -value < 0.05.

Discussion

To identify the potential benefits of DBIs for monitoring herd-level welfare, the aim of the present study was to determine the relationship between 10 commonly used DBIs and animal welfare, expressed in terms of WQ measures and criteria. Overall, the results of the present study suggest that only a few criteria or indicators measured with the WQ are associated with the tested DBIs. The analyzes revealed statistically reliable and at the same time strong associations of the DBIs for only the WQ measurements % *mastitis*, % *mortality* and % *dystocia*. The two WQ measurements % *mastitis* and % *mortality* are both collected from herd data and are thus already data-based indicators. Therefore, these associations are of limited use for the monitoring of dairy welfare.

In addition, associations shown in the initial Spearman-Rank analyzes could also be valuable for predicting animal welfare status, although most of these associations were eliminated after correction for multiple associations. This comes from the fact that the correction used to adjust for multiple analyzes inadvertently increases the risk of false-negative associations. Hence, associations found in the initial analysis

that were not significant after correction of the p -values may also be worth further investigation. Among these associations, most were found between DBIs and WQ measurements used as indicators of animal health. Only one association with a measurement of the criterion *comfort around resting* was shown, whereas associations with measurements or criteria of the principle *appropriate behavior* were lacking completely.

One might wonder why the present study showed only a few relationships between DBIs and animal based measurements in comparison to previous work (14, 15, 18, 34). One reason could be the number and selection of DBIs included. For our study, a reduced approach that did not include fertility or milk yield data was used, although those DBIs were found to be associated with animal welfare in other studies (14, 15, 18, 34). These data were omitted, as only the DBIs that were calculable for most Swiss dairy farms and allowing for comparisons between farms were included. The milk yield could have limited the comparability between farms due to the diverse intensity levels of Swiss milk production (e.g., localization of the farm in valley or mountain regions, conventional or organic production, production for drink milk or cheese, the use of dual-purpose or high-yield breeds).

In addition, for both reproduction data and milk yield, the relationship to herd welfare is unclear (35, 36), with a direct link strongly questioned (37). Furthermore, even previous studies examining broad sets of DBIs were unable to predict all criteria of animal welfare. In 2011, a review observed that only a few studies reported relationships between DBIs and measurements

of resting comfort and animal behavior (38). On one hand, this was explained by a general lack of studies examining correlations between DBIs and behavior or resting comfort, as was also reported recently (25). On the other hand, the potential of herd data to detect problems in resting comfort and behavior was questioned (38). Indeed, even among the studies that included behavioral parameters, the number of associations between DBIs and animal welfare was low compared to other parameters (14, 15, 34). Hence, the lack of relationships between DBIs and measurements of behavior or comfort of resting might be due to the nature of the DBIs. With the exception of the mean productive lifespan, the DBIs included in the present study are closely related to animal health or describe risk factors for impaired animal health. In contrast, none of the DBIs has a strong direct relationship with animal behavior or resting comfort. Whereas the considered DBIs and the health-related measurements could be linked by common factors (e.g., health management), resting comfort and animal behavior were likely to have no common link with selected DBIs.

Our study was intended as a preliminary investigation to determine relationships between DBIs and animal welfare to estimate the predictive potential of DBIs for animal welfare at the herd level. Regarding the methodology used, one may question why criteria and herd-level measurements were used to express the welfare status of herds rather than the overall score. The overall score was omitted as it results from a multi-step weighted aggregation of measurements, which partly allows the compensation of different welfare aspects (39). However, the weighted and compensating aggregation is questioned in animal welfare research, as it has been shown that the overall score is strongly influenced by only few measurements (11, 40, 41). Furthermore, the weightings, which were determined partly based on expert opinion (39), have not been adjusted to reflect changes in agriculture and changing attitudes toward animal welfare.

Concerning the statistical methodology, the present study investigated univariate relationships between DBIs and welfare measurements and criteria. This approach derives from current efforts to routinely evaluate a range of DBIs that are not aggregated into predictive models (26). Furthermore, the approach was chosen to facilitate comparison with previous studies on DBIs that also initially analyzed univariate associations between DBIs and animal-based measures (14, 15, 18, 34). It should be noted that, based on the information provided, none of these studies adjusted the univariate associations for the presence of multiple analyzes. The results of the present study suggest that univariate relationships between DBIs and welfare measurements and criteria obtained without correction for multiple testing should be interpreted with caution.

It is clear that replicating the present study with more farms, possibly targeting farms with suspected good or poorer

animal welfare status or a random selection of farms, would increase the reliability of the results. Nonetheless, in connection with the results from the literature, conclusions can be drawn for the predictive potential of DBIs. The predominantly statistically weak associations of the tested DBIs with only a few measurements of WQ indicate that the tested DBIs are not sufficient to comprehensively predict animal welfare. Given the inadequate coverage of behavioral measurements and indicators of resting comfort, it is questionable whether additional DBIs could complete the predictability of dairy herd welfare status as described by the WQ. This is in line with previous studies which—despite finding a number of associations between DBI and welfare measurements—concluded that associations found were limited (34) and DBIs could only identify problem herds with moderate accuracy rather than estimate the welfare status on the farms (14, 15, 18). Since both the currently used animal welfare definitions (6) and the Swiss Animal Welfare Act (42) require a multidimensional definition including species-appropriate behavior and adequate husbandry, we doubt the applicability of DBIs to predict animal welfare in its multidimensionality in the near future.

Nevertheless, DBIs should not be generally considered inappropriate for the monitoring of dairy cow welfare at the herd level. All 10 variables investigated in the present study are used in veterinary medicine or herd monitoring to gain insights into herd-level animal health status (43, 44). Moreover, increased cow mortality (45) or a high stillbirth rate (46) can themselves be considered animal welfare issues. For example, applying current alarm thresholds to the DBI % cow mortality [4–5% cows (47, 48)] would classify about 14% of the study farms as at-risk for the welfare problem of high cow mortality. Thus, the more welfare issues that can be captured using data, the more direct DBIs could be applied to identify farms at risk. However, since only a limited number of animal welfare issues can currently be monitored directly by data screening, it must be clear that good performance in these parameters does not necessarily reflect a sufficient herd welfare status.

Conclusions

This study demonstrated few associations between DBIs and animal welfare as measured by the WQ protocol. The associations shown for DBIs were predominantly statistically weak and emerged for a limited number of criteria and herd-level measurements of the WQ, with no associations identified with resting comfort or appropriate behavior. Thus, as DBIs were not able to adequately reflect the multidimensionality of animal welfare, the study suggests that the potential of DBIs is to provide information on specific welfare aspects rather than to provide a comprehensive predictive tool for dairy welfare status at the herd level.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The animal study was reviewed and approved by Cantonal Veterinary Office Thurgau and the Ethical committee for animal experiments of the Cantonal Veterinary Office Zurich. Written informed consent was obtained from the owners for the participation of their animals in this study.

Author contributions

BT and J-BB: conceptualization and funding acquisition and funding acquisition. BL: investigation and writing—original draft preparation. BL and DS: formal analysis. BT, J-BB, DS, and SZ: review and editing. J-BB: supervision. All authors have read and agreed to the submitted version of the manuscript.

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References

1. Main DCJ, Kent J, Wemelsfelder F, Ofner E, Tuytens F. Applications for methods of on-farm welfare assessment. *Anim Welf.* (2003) 12:523–8.
2. Zapf R, Schultheiß U, Knierim U, Brinkmann J, Schrader L. Assessing farm animal welfare—guidelines for on-farm self-assessment. *Landtechnik.* (2017) 72:214–20. doi: 10.15150/LT.2017.3166
3. Main DCJ, Webster AJF, Green LE. Animal welfare assessment in farm assurance schemes. *Acta Agric Scand A Anim Sci.* (2010) 51:108–113. doi: 10.1080/090647001316923171
4. Rushen J, Butterworth A, Swanson JC. Animal behavior and wellbeing symposium: farm animal welfare assurance: science and application. *J Anim Sci.* (2011) 89:1219–28. doi: 10.2527/jas.2010-3589
5. Sørensen JT, Fraser D. On-farm welfare assessment for regulatory purposes: issues and possible solutions. *Livest Sci.* (2010) 131:1–7. doi: 10.1016/j.livsci.2010.02.025
6. Fraser D. Understanding animal welfare. *Acta Vet Scand.* (2008) 50:S1. doi: 10.1186/1751-0147-50-S1-S1
7. Fraser D. Science, values and animal welfare: exploring the 'inextricable connection'. *Anim Welf.* (1995) 4:103–17.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fvets.2022.991363/full#supplementary-material>

8. EFSA Panel on Animal Health and Welfare (AHAW). Statement on the use of animal-based measures to assess the welfare of animals. *EFSA J.* (2012) 10:2767. doi: 10.2903/j.efsa.2012.2767
9. Webster AJF, Main DCJ, Whay HR. Welfare assessment: indices from clinical observation. *Anim Welf.* (2004) 13:93–8.
10. van Eerdenburg FJCM, di Giacinto AM, Hulsen J, Snel B, Stegeman JA. A new, practical animal welfare assessment for dairy farmers. *Animals.* (2021) 11:881. doi: 10.3390/ani11030881
11. de Graaf S, Ampe B, Winckler C, Radeski M, Mounier L, Kirchner MK, et al. Trained-user opinion about welfare quality measures and integrated scoring of dairy cattle welfare. *J Dairy Sci.* (2017) 100:6376–88. doi: 10.3168/jds.2016-12255
12. WelfareQuality[®]. *Welfare Quality[®] Assessment Protocol for Cattle*. Lelystad: Welfare Quality[®] Consortium (2009). Available online at: http://www.welfarequalitynetwork.net/media/1088/cattle_protocol_without_veal_calves.pdf (accessed September 3, 2021).

13. Knierim U, Winckler C. On-farm welfare assessment in cattle: validity, reliability and feasibility issues and future perspectives with special regard to the welfare quality[®] approach. *Anim Welf.* (2009) 18:451–8.
14. de Vries M, Bokkers EAM, van Schaik G, Engel B, Dijkstra T, de Boer IJM. Exploring the value of routinely collected herd data for estimating dairy cattle welfare. *J Dairy Sci.* (2014) 97:715–30. doi: 10.3168/jds.2013-6585
15. de Vries M, Bokkers EAM, van Schaik G, Engel B, Dijkstra T, de Boer IJM. Improving the time efficiency of identifying dairy herds with poorer welfare in a population. *J Dairy Sci.* (2016) 99:8282–96. doi: 10.3168/jds.2015-9979
16. EFSA Panel on Animal Health and Welfare (AHAW). Scientific opinion on the use of animal-based measures to assess welfare of dairy cows. *EFSA J.* (2012) 10:2554. doi: 10.2903/j.efsa.2012.2554
17. Nyman AK, Lindberg A, Sandgren CH. Can pre-collected register data be used to identify dairy herds with good cattle welfare? *Acta Vet Scand.* (2011) 53:1–6. doi: 10.1186/1751-0147-53-S1-S8
18. Sandgren CH, Lindberg A, Keeling LJ. Using a national dairy database to identify herds with poor welfare. *Anim Welf.* (2009) 18:523–32.
19. Krug C, Haskell MJ, Nunes T, Stilwell G. Creating a model to detect dairy cattle farms with poor welfare using a national database. *Prev Vet Med.* (2015) 122:280–6. doi: 10.1016/j.prevetmed.2015.10.014
20. Thomsen PT, Houe H. Cow mortality as an indicator of animal welfare in dairy herds. *Res Vet Sci.* (2018) 119:239–43. doi: 10.1016/j.rvsc.2018.06.021
21. Regulation (EC) No 1760/2000 of the European Parliament and of the Council of 17 July 2000 Establishing a System for the Identification and Registration of Bovine Animals and Regarding the Labeling of Beef and Beef Products and Repealing Council Regulation (EC) No 820/97. (2000). Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000R1760&from=EN> (accessed June 13, 2022).
22. Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 Laying Down Specific Hygiene Rules for Food of Animal Origin. (2004). Available online: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:139:0055:0205:en:PDF> (accessed June 13, 2022).
23. ICAR. *Yearly Survey on the Situation of Milk Recording Systems (Years 2016, 2017 and 2018) in ICAR Member Countries for Cow, Sheep and Goats.* (2019). Available online at: <https://www.icar.org/wp-content/uploads/2019/07/Survey-on-milk-recording-systems-in-cows-sheep-and-goats-2016-2017-and-2018.pdf> (accessed June 13, 2022).
24. Federal Council of Switzerland. *Verordnung über die Direktzahlungen an die Landwirtschaft.* (2013). Available online at: <https://www.fedlex.admin.ch/eli/cc/2013/765/de> (accessed July 10, 2022).
25. Lutz B, Zwyygart S, Rufener C, Burla JB, Thomann B, Stucki D. Data-based variables used as indicators of dairy cow welfare at farm level: a review. *Animals.* (2021) 11:3458. doi: 10.3390/ani11123458
26. DLQ. *Q Check—Tierwohl in der Milchviehhaltung mit System. DLQ-Richtlinie 2.0 -Definitionen und Berechnungen von Indikatoren und zugehörigen Vergleichswerten zur Durchführung der betrieblichen Eigenkontrolle und des nationalen Tierwohlmonitoring. LKV Bayern.* (2020). Available online at: <https://infothek.q-check.org/wp-content/uploads/2020/06/DLQ-Richtlinie2.0.pdf> (accessed May 10, 2022).
27. AssureWel. *Dairy Welfare Outcome Assessment Protocol.* (2018). Available online at: http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol_2018.pdf (accessed July 10, 2022).
28. Brinkmann J, Cimer K, March S, Ivemeyer S, Pelzer A, Schultheiss U, et al. *Tierschutzindikatoren: Leitfaden für die Praxis—Rind.* 2nd ed. Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft eV (KTBL) (2020).
29. Bertocchi L, Fusi F. *Guidelines for the Assessment of Welfare and Biosecurity in Dairy Cattle in Loose Housing Systems.* 1st ed. Brescia: Centro di Referenza Nazionale per il Benessere Animale (CRENBA) (2014).
30. Dechow CD, Goodling RC. Mortality, culling by sixty days in milk, and production profiles in high- and low-survival Pennsylvania herds. *J Dairy Sci.* (2008) 91:4630–9. doi: 10.3168/jds.2008-1337
31. Fachgruppe “Milchhygiene” Arbeitsgruppe Sachverständigenausschuss Subklinische Mastitis. *Leitlinien Bekämpfung der Mastitis des Rindes als Bestandsproblem.* 5th ed. In: Fehlings K, Hamann J, Klawonn W, Knapstein K, Mansfeld R, Wittkowski G, Zschöck M, editors. Gießen: DVG Service GmbH. (2012).
32. R Core Team. *R: A Language and Environment for Statistical Computing.* R Foundation for Statistical Computing, Vienna, Austria. (2020). Available online at: <http://www.r-project.org/index.html>
33. Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J R Stat Soc Ser B Methodol.* (1995) 57:289–300. doi: 10.1111/j.2517-6161.1995.tb02031.x
34. Otten ND, Rousing T, Houe H, Thomsen PT, Sørensen JT. Comparison of animal welfare indices in dairy herds based on different sources of data. *Anim Welf.* (2016) 25:207–15. doi: 10.1120/09627286.25.2.207
35. Coignard M, Guatteo R, Veissier I, Lehébel A, Hoogveld C, Mounier L, et al. Does milk yield reflect the level of welfare in dairy herds? *Vet J.* (2014) 199:184–7. doi: 10.1016/j.tvjl.2013.10.011
36. Grimard B, de Boyer des Roches A, Coignard M, Lehébel A, Chuiton A, Mounier L, et al. Relationships between welfare and reproductive performance in French dairy herds. *Vet J.* (2019) 248:1–7. doi: 10.1016/j.tvjl.2019.03.006
37. Ritter C, Beaver A, von Keyserlingk MAG. The complex relationship between welfare and reproduction in cattle. *Reprod Domest Anim.* (2019) 54 Suppl 3:29–37. doi: 10.1111/rda.13464
38. de Vries M, Bokkers EAM, Dijkstra T, van Schaik G, de Boer IJM. Invited review: associations between variables of routine herd data and dairy cattle welfare indicators. *J Dairy Sci.* (2011) 94:3213–28. doi: 10.3168/jds.2011-4169
39. Botreau R, Bracke MBM, Perny P, Butterworth A, Capdeville J, van Reenen CG, et al. Aggregation of measures to produce an overall assessment of animal welfare. Part 2: analysis of constraints. *Animal.* (2007) 1:1188–97. doi: 10.1017/S1751731107000547
40. Heath CAE, Browne WJ, Mullan S, Main DCJ. Navigating the iceberg: reducing the number of parameters within the welfare quality[®] assessment protocol for dairy cows. *Animal.* (2014) 8:1978–86. doi: 10.1017/S1751731114002018
41. de Vries M, Bokkers EAM, van Schaik G, Botreau R, Engel B, Dijkstra T, et al. Evaluating results of the welfare quality multi-criteria evaluation model for classification of dairy cattle welfare at the herd level. *J Dairy Sci.* (2013) 96:6264–73. doi: 10.3168/jds.2012-6129
42. Federal Assembly of the Swiss Confederation. *Animal Welfare Act. Art. 3b.* (2005). Available online at: <https://www.fedlex.admin.ch/eli/cc/2008/414/en> (accessed May 10, 2022).
43. Green M, Bradley A, Breen J, Higgins H, Hudson C, Huxley J, et al. *Dairy Herd Health.* Wallingford, CT: CABI Publishing (2012). doi: 10.1079/9781845939977.0001
44. de Kruif A, Mansfeld R, Hoedemaker M. *Tierärztliche Bestandsbetreuung beim Milchrind.* 3rd ed. Stuttgart: Enke Verlag. (2014).
45. Otten ND, Toft N, Thomsen PT, Houe H. Evaluation of the performance of register data as indicators for dairy herds with high lameness prevalence. *Acta Vet Scand.* (2019) 61:1–9. doi: 10.1186/s13028-019-0484-y
46. Mee JF. Why do so many calves die on modern dairy farms and what can we do about calf welfare in the future? *Animals.* (2013) 3:1036–57. doi: 10.3390/ani3041036
47. Laevens H, Deluyker H, Schukken YH, de Meulemeester L, Vandermeersch R, de Muëlenaere E, et al. Influence of parity and stage of lactation on the somatic cell count in bacteriologically negative dairy cows. *J Dairy Sci.* (1997) 80:3219–26. doi: 10.3168/jds.S0022-0302(97)76295-7
48. Brinkmann J, March S, Cimer K, Schultheiß U, Zapf R. *Tierschutzindikatoren für Milchkühe: Vorschläge zu Ziel- und Alarmwerten für die betriebliche Eigenkontrolle.* (2020). Available online at: https://literatur.thuenen.de/digbib_extern/dn062462.pdf (accessed July 10, 2022).