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Healthy cows, happy farmers? Exploring the dynamics of mastitis and farmer well-being

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ABSTRACT

Clinical mastitis, a prevalent production disease in the dairy industry, causes significant pain and swelling in dairy cows' udders. Although previous research highlights a symbiotic relationship between humans and animals, particularly in terms of health, this study investigates how animal health, specifically clinical mastitis, influences farmers' well-being. Acknowledging farmers' pivotal role in mitigating animal health problems, we examined the human-animal relationship by exploring how dairy cow health relates to the psychological well-being of dairy farmers. This was performed by investigating the connection between animal and farmer health and whether it is mediated by farmers' perceptions of mastitis as a production disease and their sense of control over the situation. For the current study, we combined and matched data from a large questionnaire study covering dairy farmer's well-being (n = 356) with data on dairy cow herd health. For statistical analyses we used the PROCESS macro (ver. 4.2) for serial multiple mediator analysis, an analysis that allows for the estimation of the effect of multiple mediators in a causal chain. We found that farmers' well-being is indirectly related to animal health when mediated through their illness perception and perceived self-efficacy, underscoring the importance of cultivating awareness and control over mastitis occurrences. For these estimations, we controlled for the effect of farm size, expected income from dairy production, marital status, and cohabitation status of the farmer, as well as age and gender. Our results indicate that maintaining healthy animals with minimal mastitis incidents, coupled with farmers' perceived self-efficacy, is positively related with farmer well-being.

Key words: human-animal relationship, illness perception, self-efficacy, dairy farmer

INTRODUCTION

Dairy farming is considered to foster a unique human-animal relationship (Waiblinger and Lürzel, 2023) due to the relatively long life and production span of a dairy cow. Unlike the relationship with companion animals, the relationship between the farmer and dairy cows is also accompanied by a utilitarian function, most often expressed in commercial terms (Bock et al., 2007). In comparison to other livestock, a dairy cow is kept for a long time and across lactations involving regular, intense, and long-term human-animal contact, promoting relationships not only with individual cows but also across generations (Waiblinger et al., 2006; Waiblinger and Lürzel, 2023). Previous research has suggested that the human-animal relationship is believed to have a positive effect, with mutually beneficial effects on the health and well-being of both humans and animals (Mota-Rojas et al., 2020; Prato-Previde et al., 2022). However, contradictory results exist, suggesting that the relationship may vary from highly positive to highly negative outcomes (Herzog, 2011; Andrade and Anneberg, 2014).

The concept of the human-animal relationship aligns with the "One Welfare" framework (Pinillos et al., 2016), within the concept of "One Health." The One Welfare framework "describes the interrelationships between animal welfare, human well-being, and the physical and social environment" in which the health and welfare of animals should not be considered in isolation from humans (Pinillos, 2018). Dairy cows, like any other production animal, are dependent on the farmers because farmers are the ones determining the living conditions that ultimately affect animal health (Kauppinen et al., 2010). The relationship between animals and humans has increasingly been recognized as interconnected, with research suggesting that the health and well-being of animals are often reflective of the mental and physical health of the farmers who care for them (Andrade and Anneberg, 2014; King et al., 2021; Steen et al., 2025). On the one hand, farmers play a critical role in shaping the welfare and health

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of their animals; thus, farmer health is thought to be essential for sustaining animal health and productivity (Hemsworth and Coleman, 2010; Kauppinen et al., 2010; Kauppinen et al., 2012; Hansen and Østerås, 2019). Furthermore, farming is consistently reported as one of the most physically dangerous (Hounsome et al., 2012) and mentally stressful occupations worldwide (Daghagh Yazd et al., 2019). Although contrary results exist, studies have reported higher prevalence of mental illness in comparison to the general population (Younker and Radunovich, 2021; Proctor and Hopkins, 2023), underscoring the demanding nature of their work and the potential relationship with animal welfare. Most of the previous research related to farmers' health has focused on aspects of stress, suicide, and depression, and to some extent on other health dimensions, such as anxiety, burnout, and overall resilience among farmers (Kallioniemi et al., 2016; Klingelschmidt et al., 2018; Hagen et al., 2019). Given the complex interplay between human and animal well-being in agricultural settings, there is a particularly strong need for deeper insights into this relationship to promote both human and animal welfare more effectively.

Production and livestock animals such as dairy cows are at high risk for impaired health due to several characteristics of the cow, such as age and genetics, production level, environmental conditions, nutrition, and housing. This is why disease control and prevention are crucial in livestock management (Ruegg, 2017; Bhakat et al., 2020; Autio et al., 2021).In this study, we give specific focus to mastitis in the dairy cow, one of the most common diseases in dairy cows, which causes inflammation in the cow's udder (Krishnamoorthy et al., 2021). As a production disease, mastitis is one of the most common reasons for antibiotic use in the dairy industry (e.g., Swinkels et al., 2015; Jamali et al., 2018; Lardé et al., 2021). It is also one of the most important cow health disorders in terms of economic cost on dairy farms because it increases time used for labor, increases medical and veterinary costs, and reduces the payment for the milk delivered to the dairies (Hogeveen et al., 2019). Mastitis is more or less constantly present in a dairy herd in varying degrees, as indicated by the bulk milk SCC (**BMSCC**) identified in the milk. This means that continuous and proactive efforts are needed to control the current situation and prevent future cases (Jamali et al., 2018; Shock et al., 2020). Due to high variability in BMSCC, farmers are continuously exposed to the psychological stress and need for preparedness related to outbreaks to keep the animals healthy, as well as to ensure the farm's financial results (DeLong et al., 2017; Jamali et al., 2018; Shock et al., 2020).

The objective of this study was to examine how dairy cow health, as indicated by BMSCC, relates to the psychological well-being of dairy farmers. We assessed farmers' well-being using the validated Satisfaction with Life Scale (Diener et al., 1985; Hultell and Gustavsson, 2008), based on questionnaire data from Swedish dairy farmers. Additionally, we aimed to explore whether farmers' illness perception (their view of mastitis occurrence on their own farms) and self-efficacy (their sense of control over managing farm health) mediate the relationship between animal health and farmer well-being. In relation to most previous literature on farmers' health, we focus on a health measure that is oriented toward positive outcomes. A focus on positive health aspects could aid in understanding what enhances farmers' well-being and what enables some to thrive despite significant stress.

MATERIALS AND METHODS

Conceptual Framework

Using the Self-regulation model of illness (Leventhal, 1984; Leventhal et al., 2001; Cameron and Leventhal, 2003), we predicted that farmers' illness perception would mediate the relationship between animal health and farmers' well-being and would also affect farmers perceived self-efficacy. Self-efficacy, beyond the feeling of control, is also suggested to function as a coping strategy that may increase farmers' ability to handle the situation and increase farmers' own well-being (Lown, 2011; O'Sullivan, 2011; Azizli et al., 2015). The human-animal relationship is a complex and multifaceted matter in which empathy and attachment play an important role in whether positive effects occur due to the bond developed between the human and the animal (Prato-Previde et al., 2022). To increase our understanding and to explore this, we used a serial multiple mediator model framework, which allowed us to test the relationship between animal health and human well-being directly. We also included other possible indicators that may affect that relationship (Hayes and Preacher, 2013; Hayes and Rockwood, 2017; Hayes, 2018).

Previous literature has suggested that the representation of an illness and future coping behavior are key aspects of how humans approach and understand illness. According to the theory of the self-regulation model of illness (Leventhal, 1984; Leventhal et al., 2001; Cameron and Leventhal, 2003), also described as the common sense model, in which an individual's perception and experience of symptoms and emotions when facing a health threat or diagnosis guide people to understand the cause of the illness and whether it can be cured or controlled. The assessment and perception of the illness are believed to affect emotional outcomes such as well-being (Diefenbach and Leventhal, 1996; Heijmans, 1998; Scharloo et al., 1998). Concerning the farming situation, as well

as dairy farmers' approach toward mastitis in their dairy cows, the model suggests that farmers themselves must create their understanding and interpretation of mastitis, what it means for the animal in terms of symptoms and signs, and the probable causes to understand how and if they can control or treat it. Previous studies, in the more general literature related to human health and caregiving, have found that illness beliefs of spouses significantly affect patients' functioning and well-being (Heijmans et al., 1999; JoÃo Figueiras and Weinman, 2003). Others have shown, for both individuals and caregivers, that having a better understanding of an illness and a high self-efficacy are positively related to better compliance to treatment and to improved health-related outcomes in illness (Griva et al., 2000; Zelber-Sagi et al., 2017). When comparing the experience of illness, studies have shown that caregivers generally tend to interpret and report more negative effects of illness in comparison to the patients themselves as a result of the burden of care (Clipp and George, 1992). We adopt this framework for our study, expecting to find similarities in the relationship between the farmer and their dairy cows as those between caregivers and patients.

Assuming that the dairy farmer develops a relationship with the dairy cow over time, it can be expected that the relationship has a positive effect in terms of both health outcomes in the dairy cows and on the farmers themselves. Individual relationships between the farmers and the animals may create awareness that allows farmers to notice behavioral changes or signs in the animal health at an early stage. Earlier detection and treatment of the cows may have a positive effect both in terms of well-being and reduced stress in farmers, because animal health is improved and the financial impact on the farm may be lowered.

Psychological research has further pointed to the importance of individual perception of control over a situation, which has a huge effect on the general well-being of individuals because it may function as a coping strategy. Self-efficacy beliefs are suggested to provide the foundation for human motivation, well-being, and personal accomplishment (Bandura, 1977, 2011; Kuijer and De Ridder, 2003; Bisschop et al., 2004; Wright and Perrone, 2010; O'Sullivan, 2011; Azizli et al., 2015). People with high self-efficacy tend to exhibit strong capability when approaching difficult tasks, cope with life demands, and recover quickly from setbacks (Lown, 2011; O'Sullivan, 2011; Azizli et al., 2015). For dairy farmers, the perceived burden of mastitis, and its effect on both animal health and farmer well-being, is likely closely related to the characteristics of the individual. This suggests that farmers' perception of being able to handle the situation in terms of perceived control, as well as their representation of mastitis as an animal health problem (Shock et al., 2020), has an effect on the farmer's well-being. In particular, farmers perceiving themselves as being able to control mastitis could increase their feeling of self-efficacy, which may have a positive effect on the health and well-being of the animals. However, existing research has so far not focused on these relationships and the current understanding of how farmers' subjective well-being can be predicted from the animal health situation on the farm. This is important from the perspective of understanding how farmers' vulnerability to poor subjective well-being is derived from animal health problems and how strengthening their self-efficacy can help improve their subjective well-being, which, in turn, may improve animal health and welfare.

Data and Summary Statistics

This study used data from a larger questionnaire study that was part of a larger multidisciplinary research project (Lind et al., 2019, 2023). The questionnaire included pretested and validated instruments (e.g., Hultell and Gustavsson, 2008; Lind et al., 2019), including questions developed by researchers with expert knowledge of mastitis in dairy cows, working together with researchers with expert knowledge of psychometric testing. The instruments were not pretested in the conventional sense, but significant experience on how to set questions for the target group was derived from previous work by members of the research group (e.g., Hansson et al., 2012).

All Swedish full-time farmers specializing in dairy production during 2015 were eligible for inclusion in the study. Names, phone numbers, and addresses of a random sample were obtained from a register of all Swedish farmers administered by Statistics Sweden (Örebro, Sweden). At the end of 2015, a total of 4,039 Swedish farms were registered as active specialist dairy farms. From the total population of active farms, Statistics Sweden performed a random selection of 1,200 farms for whom we received contact information. The 1,200 farmers running these farms were invited to participate in the present study and asked to complete an online questionnaire between April and June 2016. Online data collection was considered appropriate because 98% of the Swedish population is assumed to have access to the internet in their home (Internetstiftelsen, 2019). Farmers who were unwilling to use the online questionnaire were provided with the option to submit their responses using a hard copy version. To ensure the farmers' anonymity, the survey was conducted by a third party specializing in survey data collection (IPSOS Sweden, Stockholm) on behalf of the research group. The research group obtained unidentified data from the completed questionnaires. The study was approved by the Uppsala Regional Ethics Board (Dnr 2016/075).

During the data collection, the survey company kept track of nonrespondents and reasons for not participating in the questionnaire. Together with the collected data, the research group received the information that during the data collection process 143 farmers declined to participate due to time constraints, 40 no longer matched the target group (they had retired or sold their dairy cattle), 3 declined to participate due to reasons of illness, 42 declined to participate for other reasons, and 62 farmers could not be reached for a reminder due to a lack of contact details. This gave us a sample of 910 possible respondents. Before sending out the questionnaire, sample size estimations were performed based on the total population of Swedish dairy farmers and assuming a margin of error of 5% and a CI of 95%, expecting a response rate of 30%. According to our estimations, at least 351 participants were needed and as part of our contract with IPSOS Sweden, they reminded farmers about the questionnaire until that requirement was fulfilled. In total 356 (32.4%) respondents (42 of whom used the hard copy version) participated in the questionnaire. The questionnaire required 30 to 40 min to complete, and as a token of appreciation after completing the questionnaire each participating farmer was sent 2 lottery tickets.

For each respondent, data used as Y in the model (i.e., BMSCC) was retrieved by matching it with Swedish Dairy Association (**SDA**) register records. The matching was performed after collecting the survey data. To ensure farmers' anonymity to the research group, a coded key containing each farmer's unique ID, and information of the participant's name and address was sent from IPSOS to the SDA, allowing them to create a database containing only data on herd health. A file with herd health information and the key was then sent to the research group, allowing us to merge the 2 datasets. Farmers participating in the Dairy Cow Recording Scheme have given SDA their approval to use their unique data for research, provided that it is used anonymously. Because our sample consisted of a random sample of all dairy farms in Sweden, we were not able to match data for all participating farms because only 80% of them are associated with the SDA. Due to this, 51 farms were excluded, leaving us with a total sample of 305 farms before data screening.

Data Screening and Preparation

A case and variable screening was performed on the sample of 305 farmers before the analyses. An additional 29 farmers were excluded because they (1) were considered outliers when exploring Mahalanobis Distance, Cook's Distance, and Centered Leverage Value for the included variables or (2) did not have data for all 3 yr (2014–2016) of BMSCC from the SDA database. This left us with a final sample of 276 participants. The oldest participating farmer was 91 yr old, which was considered unexpected but still plausible as the average age of Swedish farmers is generally high and that the questionnaire was distributed to registered owners. Demographic information for the 276 remaining participants is given in Table 1.

Table 1. Demographics of the 276 participating farmers and their dairy herds

Parameter	Value[1]
Age, yr (SD)[2]	64.1 (11.4)
Share of male respondents	75.7
Number of dairy cows (SD)[3]	109.7 (143.1)
Agricultural education[4]	53.6
Married/partner	89.9
Cohabitation	94.2
Share of income from milk production to household income	
<25%	5.1
25%–49%	17.8
50%–74%	26.1
75%–99%	34.8
100%	16.3
Perception of herd health[5]	
Very low	8.0
Low	38.4
Medium	43.1
High	10.1
Very high	0.4

[1]All numbers are reported as percentages unless stated otherwise.
[2]In 2015, the median age of Swedish farmers was 55–59 yr (Statistics Sweden, 2015).
[3]In 2015, the average Swedish dairy herd was 74 cows, although more than 50% of herds had more than 100 dairy cows (Statistics Sweden, 2015).
[4]Reported as a percentage of farmers holding any type of education specific to agriculture.
[5]Farmers subjectively evaluated levels of SCC on the farm.

Factor and Serial Multiple Mediator Analysis

Exploratory factor analysis (**EFA**) was used to reduce the total number of items used to measure the Satisfaction with Life Scale (**SWLS**), Mastitis Prevention Self-Efficacy Scale (**MPSES**), perceived herd health, and BMSCC into latent variables, each representing a factor, as indicated by our proposed model (see Figure 1). Because we believe that all measured variables included in the analysis are related to every latent variable, EFA was considered to be the most appropriate approach. Using EFA enabled a reduction of the data (all individual items) to a smaller set of summary variables (each representing a latent variable) to enable us to explore the underlying theoretical structure of the phenomena by examining the covariation among the items. To allow for correlation between the factors, Promax rotation was used. After retrieving a clean pattern matrix, item loadings for each of the latent variables were created. For BMSCC, mean

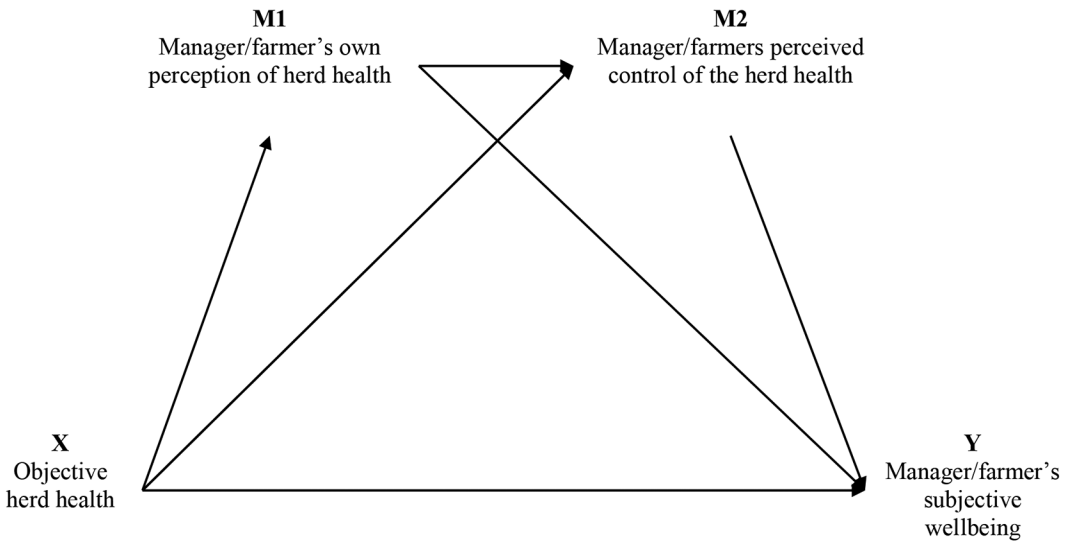

Figure 1. Proposed theoretical model representing the suggested relationship between each of the variables and mediators; arrows indicate the causal chain tested in the serial multiple mediator analysis.

values were calculated to represent the total mean across all 3 yr. For SWLS, the items were calculated to a total score, following previous studies. Farmer perception of herd health was used as a single item. The MPSES was calculated to a total score indicating farmers self-efficacy. The latent variables identified were thereafter used in further analyses.

The PROCESS macro version 4.2 (Hayes and Preacher, 2013; Hayes, 2018; Hayes and Rockwood, 2017) for SPSS was used for a serial multiple mediator (**SMM**) analysis. Serial multiple mediator allows for the estimation of the effect of multiple mediators in a causal chain. For the macro, the mediators (*perception of herd health* as M1 and *perceived control of the herd health* as M2) were arranged in a sequence, such that M1 is before M2. This allows for simultaneous estimation of the separate effects of X on M1, X on M2, X on Y, M1 on M2, M1 on Y, and M2 on Y (Hayes and Rockwood 2017). Using this approach allows us to test the individual relationship between animal health (X) on farmers' well-being (Y) and at the same time estimate the effect of farmers illness perception (M1) and self-efficacy (M2). The method links the mediators with a specified direction of causal flow, leading to the creation of paths between mediators, as shown in Figure 1, to be able to see how they would affect each other. Serial multiple mediator analysis allows for a test of the combined effects of all proposed mediators (here referred to as M1 and M2) to be carried out (i.e., the total indirect effect), allows for multiple mediators to be examined, and reports the individual effects of each mediator while controlling for the others, meaning any significant mediation effects are unique.

Multiple mediator analysis (Hayes and Rockwood, 2017) has been used in previous studies in psychology (Pot-Kolder et al., 2018; Miranda et al., 2019), epidemiology (Zhao et al., 2018), and economics (Onubi et al., 2020), but none have, to our knowledge, used it in the context of the relationship between farm animals and farmers, especially not when considering health and the pathways that we consider.

PROCESS was used for testing the effects on the dependent variable *farmers subjective well-being* (Y) using the following settings: the predefined Model 6 (see Figure 1 for schematic overview) using the setting for 5,000 bootstraps, a confidence level of 95%, and *BMSCC* (X) as the independent variable. In the final model, covariates were accounted for. The regression coefficients from the models were standardized to allow for comparison of the relative magnitude of the effects of different explanatory variables in the path model. The analysis was performed using SPSS version 26 (SPSS, IBM Corp., IBM SPSS Statistics for Windows, Version 26.0, Armonk, NY).

Application to the SMM Analysis

Previous literature suggests that human-animal relationships can have positive effects on health and well-being for both humans and animals (Hansen and Østerås, 2019; Waiblinger and Lürzel, 2023). We draw on this conceptual framework to motivate our mediation analysis (see the visualization of how the concepts are connected in Figure 1). Although we recognize that the channels through which animal health and farmers' well-being affect each other are many and varied, our approach

considers farmers' perception of mastitis as a production disease and specifically the prevalence of mastitis on the farm and each farmer's perceived domain-specific self-efficacy as the main mediating factors for the following reasons. First, these mediators are important predictors for how the farmers are expected to approach and interpret the situation on the farm (Svensson et al., 2019; Regan et al., 2021; Lind et al., 2023). Second, given that farmers' perception of mastitis as a production disease may vary as a result of different thresholds (i.e., given that the BMSCC can fluctuate and that there are wide differences between farms), the point at which farmers consider the BMSCC problematic or at what threshold they are penalized by the processors (Jansen et al., 2009; Jansen, 2010; Troendle et al., 2017) may, in turn, affect how and if farmers perceive their capability to be able to handle the situation.

Specific to the present study, the behavior of the farmers was expected to change according to the prevalence of mastitis to reduce or minimize the health risk (Leventhal et al., 1997, 2001). This was assumed to directly affect farmers' perception of the situation, in terms of whether the occurrence of mastitis on the farm needed additional effort or whether it was necessary to act. The expected coping strategies followed by the farmers were assumed to be represented in terms of domain-specific self-efficacy in our model, because this represents the evaluation of how well the farmers perceive themselves as able to control and handle the situation concerning mastitis among their dairy cows. This means that self-efficacy functions as a mediator between animal health and farmers' well-being because it represents farmers' perceived ability to cope with the situation.

By using domain-specific self-efficacy, we took into consideration how farmers perceive themselves as being able to handle the specific situation regarding mastitis and its effect on farmers' well-being, because this may work as a motivator for how the farmer undertakes the required preventive care activities. The perception of the situation on its own may also promote farmers' motivation to work with the situation, as well as working as direct feedback on farmers' previous accomplishments in mastitis prevention. This may, in turn, improve or worsen farmers' perception of self-efficacy, which ultimately may affect farmers' well-being and animal health.

Given that people's beliefs in their individual and collective efficacy can be developed in various ways, one of the most effective and productive ways of reaching a strong sense of efficacy is through mastery experiences (Bandura, 2000, 2023). In the case of farming, farmers perceiving themselves as able to control mastitis will increase their feeling of self-efficacy when feeling successful, which may in turn also affect the health of the animals and their own well-being. Assuming that farmers develop a relationship with their dairy cows (Waiblinger and Lürzel, 2023) and that this relationship has positive effects on health (Kauppinen et al., 2010; Hansen and Østerås, 2019), it is reasonable to assume that animals suffering from mastitis may ultimately affect farmers' general perception of their well-being. To summarize, the aim is to explore whether farmers' well-being is affected by animal health by taking into consideration how this may be mediated through farmers' perception of the occurrence of mastitis, together with their feeling of control (see Figure 1 for our proposed theoretical model). By using a multiple mediator model, we can explore the causal flow from X to Y by also including mediators that are instigated by X and then causally influence Y.

Explanatory and Outcome Variables

We used BMSCC as an objective measure of herd health. The BMSCC used in our study was based on individual cow test-day information on milk yield and SCC, rather than on the BMSCC in the milk delivered to the dairy. The BMSCC was thus based on milk sampling performed by the farmers monthly and analyzed by the SDA. The milk sampling was performed for each dairy cow and matched using a unique bar code, allowing the farmers to monitor all animals on the farm. Using this type of BMSCC ensures that all cows on the farm are included, in comparison to the BMSCC from milk delivered to the dairy, in which milk from cows with high SCC may have been separated. The arithmetic mean for the BMSCC for the 3 yr closest to the year of the survey (2014, 2015, and 2016) was used and included in the analyses. Using 3 yr of BMSCC allowed us to assess the general herd health level and not to be greatly influenced by a single bad year.

Farmers' subjective well-being, without differentiating between different domains, was measured using the SWLS. The SWLS is a short, 5-item, 7-point Likert-style response-scale instrument designed to measure global cognitive judgments of satisfaction with one's life (Diener et al., 1985). The SWLS has been used extensively as a measure for the life satisfaction components of subjective well-being. Scores on the SWLS have been shown to correlate well with measures of mental health (Guney et al., 2010). In the area of health psychology, the SWLS has been used to measure the subjective quality of the lives of people experiencing serious health concerns (Pavot and Diener, 2008) but has also been used for the general population (Glaesmer et al., 2011). The SWLS measures individual cognitive judgment about overall life satisfaction without differentiating between different domains (Diener et al., 1985; Erdogan et al., 2012). The instrument has previously been successfully used on farmers (Judd et al., 2006). Using the SWLS gave us the ability

to explore farmers' overall life satisfaction and whether this may be affected by animal health on the farm. For the SWLS, a score of 20 represents a neutral point on the scale. Scores between 5 and 9 indicate the respondent is extremely dissatisfied with life, whereas scores between 31 and 35 indicate the respondent is extremely satisfied (Diener et al., 1985). For the present study, the validated Swedish version was used (Hultell and Gustavsson, 2008) for which we identified a Cronbach α of 0.89 for the present sample. All items are presented in Supplemental Table S1 (see Notes).

Mediators

Perception of herd health was domain-specific, expressing the farmers' perception of the level of the BMSCC on their farm. One single item question on a 5-point Likert scale ("How would you describe the level of somatic cell count in the herd in 2015?" 1= very low to 5 = very high). The question was included because it was considered to be an important aspect in shaping the human-animal bond and because it may function as an indicator of whether farmers consider additional action to be needed for animals' health and welfare. The decision to ask for farmers' evaluation of the situation of the previous year, rather than the year when the survey was made, was taken because it would guide the farmers to think about the situation over a long time rather than monthly.

The MPSES was used to operationalize the perceived control of herd health. The MPSES was developed based on a corresponding scale to the General Self-efficacy Scale (Schwarzer and Fuchs, 1996; Löve et al., 2012). It consisted of 10 items describing dairy farmers' feelings of confidence about being able to prevent mastitis, reduce incidence of mastitis, and control the situation on the farm (Lind et al., 2019). Example items from this measure are as follows: "If problems arise in my herd and my dairy cows suffer from mastitis, I can always manage to find an appropriate measure if I try hard enough" and "Thanks to my resourcefulness, I know how to handle even surprising situations related to mastitis that can occur in my herd." Each of the statements was rated on a 4-point scale (1 = not at all, 4 = exactly true). A Cronbach α of 0.90 was identified for the present sample. All items of the MPSES are presented in Supplemental Table S2 (see Notes).

Control Variables

Several self-reported background variables were used as covariates in the proposed model because these are believed to affect the outcome of herd health (X in the proposed model), farmers' well-being (Y), or both.

Number of Dairy Cows. Each participant was asked to give the number of dairy cows in the herd. The variable was included because it can be expected that a larger herd means a decrease in the feeling of control over the situation and less possibility of spending time with individual animals, meaning a higher risk for unnoticed illness.

Contribution of Dairy Production to Household Income. The participant was asked how dependent their total household income was on dairy production. The variable was coded into 5 categories (1: less than 25%; 2: 25%–49%; 3: 50%–74%; 4: 75%–99%, and 5: 100%). The variable was included because it is expected that farms with a large proportion of their income from dairy production are more dependent on a healthier herd, meaning farmers' well-being may be more affected by mastitis.

Marital Status. The variable was included because having a spouse or being in a romantic relationship may function as social support, which in turn can increase subjective well-being (Holt-Lunstad et al., 2008; Braithwaite and Holt-Lunstad, 2017).

Cohabitation. Living together with someone can function as a buffer, leading to increased social support, which can help in promoting health and as a protector of well-being (Dush and Amato, 2005; Eckermann, 2015).

Farmer Age. Subjective well-being and health are closely related, and the link could become increasingly important at older ages (Steptoe et al., 2015).

Gender. Gender was used because it may affect overall subjective well-being, although inconsistent results exist across studies (Tesch-Römer et al., 2008; Hsu, 2010; Carmel, 2019).

RESULTS

The EFA was performed as a first step to explore and identify the latent variables used in our hypothesized model. The EFA was used to ensure that each of the variables is theoretically related to each other (i.e., that all 5 items on the SWLS, in our proposed model, are in fact loaded onto the same factor).

As a first step, all items were included in the EFA to ensure that they loaded onto the theoretically correct variables. The items capturing farmers' perception of herd health (subjectively evaluated BMSCC in the herd) loaded onto the same factor as the objective measure of herd health (recorded as BMSCC). Due to this loading, and because we wanted to separate objective herd health status from the farmers' perception of health, the variable for the perception of herd health was removed from the EFA and was included at a later step as a single item in the SMM. The EFA was performed until we arrived at a clean pattern matrix showing good adequacy (see Table 2 for factor loadings). All items had a loading amplitude of at least 0.5, except one item on the domain-specific

measure MPSES (factor loading of 0.41). The reliability analysis for all 3 factors identified in the EFA had a Cronbach α above 0.8, which is considered to be an acceptable level (Taber, 2018). The factor analysis was then used as the basis for creating the latent variables representing the variables X, Y, M1, and M2 in our SMM (see Figure 1 for the theoretical model and Table 2 for an overview of the items used for each factor).

Figure 2 and Table 3 show the results of the SMM analysis; all statistically significant results are marked in bold text in the table or lines in the figure. The SMM model proposed that herd health influenced farmers' perception of the herd health situation ($P < 0.001$), which in turn was associated with farmers' perceived control ($P < 0.05$) and farmer's subjective well-being ($P < 0.001$). The SMM model revealed individual associations between the mediators on its own, showing that farmers' perception (M1) influenced farmers' perceived control (M2). However, we could not establish that objective herd health was directly associated with the farmer's subjective well-being alone ($P = 0.430$). All findings remained, and with very similar coefficients, even after controlling for the covariates (the number of cows, income from dairy production, marital status, cohabitation, age, and gender; see Table 3).

Table 2. Factors were extracted using EFA with maximum likelihood and Promax rotation[1]

	Factor		
	M2	Y	X
Item	MPSES (α = 0.899)	SWLS (α = 0.894)	BMSCC (α = 0.870)
MPSES item 1	0.594		
MPSES item 2	0.414		
MPSES item 3	0.557		
MPSES item 4	0.754		
MPSES item 5	0.820		
MPSES item 6	0.739		
MPSES item 7	0.803		
MPSES item 8	0.827		
MPSES item 9	0.772		
MPSES item 10	0.595		
SWLS item 1		0.832	
SWLS item 2		0.821	
SWLS item 3		0.859	
SWLS item 4		0.825	
SWLS item 5		0.681	
BMSCC for the year 2014			0.816
BMSCC for the year 2015			0.890
BMSCC for the year 2016			0.789

[1]In total, 3 factors were identified and constituted the latent variables. The Chronbach α for each factor is presented in parentheses. The analysis included 285 farmers. MPSES = Mastitis Prevention Self-Efficacy Scale; SWLS = Satisfaction with Life Scale; BMSCC = bulk milk SCC.

DISCUSSION

With this study, we aimed to explore the human-animal relationship using mastitis in dairy cows and dairy farmers' well-being as an example. Numerous studies have shown that the bond developed between humans and animals can have positive effects on health in both (Waiblinger et al., 2006; Hansen and Østerås, 2019; Waiblinger and Lürzel, 2023). In this study, we take the perspective of how the occurrence of one of the most common production diseases in dairy farming, mastitis, affects dairy farmers' perceived well-being. By using this perspective, findings from our study provide novel insights into the role of farmers' perception of the situation, here measured as illness perception, in terms of the human-animal relationship, as well as the importance of farmers feeling able to handle this situation, measured as self-efficacy. From our results, we did not see a direct association between the health situation on the farm (i.e., the occurrence of mastitis as measured through test milk samplings) and farmers' subjectively reported well-being.

The human-animal relationship is complex and so is the effect that humans and animals can have on each other. Previous studies have reported that empathy and attachment are both related to the quality of human-animal relationships (Waiblinger and Lürzel, 2023). This would suggest that a lack of empathy or feeling of attachment could be an explanatory variable when no relation is found between the health of animals and humans. This has partly been used to explain previous studies on animal abuse and cruelty (Andrade and Anneberg, 2014; Devitt et al., 2015). Considering our results, we see that for the health of the animals to affect the farmer, they need to have an understanding of the situation (i.e., illness perception) and to have a feeling of being able to handle the situation and approach it (i.e., self-efficacy). This means farmers need to make sense of and respond to health problems in the herd by creating an understanding or representation of the disease and how they can or should treat it. These findings are in line with the theory of the self-regulation model of illness (Diefenbach and Leventhal, 1996; Leventhal et al., 1997; Heijmans, 1998; Scharloo et al., 1998). Recent studies have suggested that illness perception plays a key role as a motivator for undertaking the required self-care activities (Chong et al., 2020). In the case of farming, it can be expected that when farmers are made aware of the situation, it probably evokes a reaction followed by a strategy on how to approach it. How to treat and handle a situation is then largely dependent on how equipped the farmers perceive themselves to be to be able to handle the situation. Whether the farmer decides to act or not may also be a case of priority on the farm (Svensson et al., 2019). Illness perception has, in humans, been suggested to evoke beliefs about the ability to cure and the controllability of

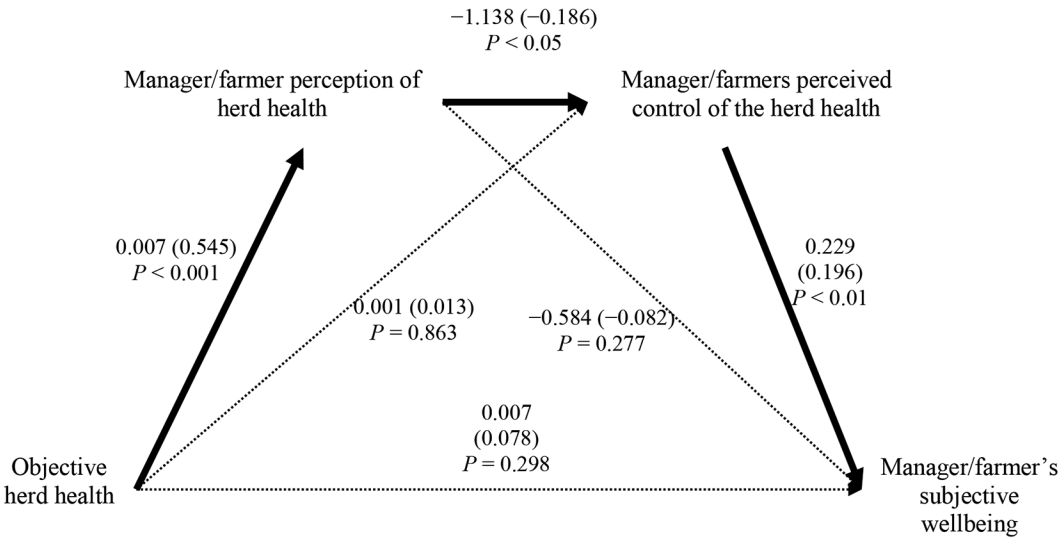

Figure 2. Coefficients (standardized coefficients in brackets) and *P*-value were identified in the SMM analysis. For the model, R^2, including all covariates, was 0.078. A total of 276 farmers were included. Thick lines represent significant associations.

the condition, as well as affecting the perceived severity (Orbell et al., 2008; Zhang et al., 2016; Lee et al., 2019). In farming, similar reactions are to be expected. In human medicine, findings have suggested that facing a disease without knowledge of how to cope with and adapt to it increases the risk of falling into a "psychological limbo" in which one does not know what to do (Orbell et al., 2008), which would probably increase the stress load.

Our results imply that participating farmers are well aware of the situation on the farm, as shown in the relationship between objectively measured BMSCC and their perception of the situation. Our findings on farmers' perception of the situation, here referred to as their perception of the general occurrence of mastitis, may partly be explained by 2 factors: (1) farmers have easy access to the BMSCC through platforms like "My Farm," which is provided by the SDA and all participating farmers have access to; and (2) some of the farmers included in our sample probably have access to more advanced sensor systems that give early warnings for detecting changes in animal health during milking. Use of either of these kinds of instruments and systems has increased over the years, which has led to improved awareness of the situation and has likely increased the feeling of control in farmers (Berckmans, 2014; Jelinski et al., 2020; Stone, 2020). Because we did not ask the farmers if and how they used this kind of information, we cannot control for this effect or explore it further. Furthermore, what is considered a high versus low level of BMSCC is probably a combined result of the social norm, set by the surroundings of which the farmers are a part, and thresholds set by the dairy industry (Swinkels et al., 2015; Shock et al., 2020; Lind et al., 2023). In Sweden, advisory agencies encourage dairy farmers to maintain a BMSCC below 150,000 cells/mL, a level well below the 300,000 cells/mL threshold at which dairy processors impose penalties. Although the average SCC has decreased over the past 20 yr, it was relatively high during the years 2015 and 2016 at 249,000 cells/mL, suggesting that many cows in Swedish herds had elevated SCC levels, likely due to subclinical or clinical mastitis (Växa, 2017).

Given that the human-animal relationship between the dairy farmer and the dairy cow is symbolized by a utility function, in which the farmers are dependent on the dairy cow producing milk, adds a unique layer to the relationship (Bock et al., 2007). In cases where farmers only consider the cow as a means of production but do not develop a caring relationship with the animal, we would not likely have identified any of the relationships presented here. De-individualizing animals, by treating them as a collective entity and labeling them with a code is a common approach to adopt in intense farming to prevent developing familiarity, relationships, and even attachment to them (Serpell, 1999; Hamilton and McCabe, 2016). In the Swedish context, dairy farms are continuously growing in size, increasing the number of animals on the farms, with the direct result of an increased distance between the farmer and the animals. The number of smaller dairy farms has also dropped sharply due to hardship in surviving the competitiveness in the

Table 3. Regression coefficients, standardized coefficients (Stand. coeff.), SE, and model summary information for the objective herd health status influence on farmers subjective well-being using an SMM model[1]

	M1 (Perception of herd health)				M2 (Perceived control)				Y (Farmer's subjective well-being)			
Model parameter	Regression Coeff.	Stand. Coeff.	SE	*P*-value	Regression Coeff.	Stand. Coeff.	SE	*P*-value	Regression Coeff.	Stand. Coeff.	SE	*P*-value
Model without covariates												
X (objective herd health)	**0.007**	**0.579**	**0.001**	**<0.001**	−0.002	−0.031	0.005	0.667	0.005	0.057	0.006	0.430
M1 (perception of herd health)					**−1.037**	**−0.169**	**0.446**	**<0.05**	−0.637	−0.089	0.523	0.224
M2 (perceived control)									**0.229**	**0.196**	**0.070**	**<0.001**
Constant	0.878		0.149	<0.001	32.400		1.167	<0.001	19.480		2.648	<0.01
	$R^2 = 0.335$				$R^2 = 0.036$				$R^2 = 0.047$			
	$F(274) = 137.950$, $P < 0.001$				$F(273) = 5.076$, $P < 0.01$				$F(272) = 4.515$, $P < 0.01$			
Model with covariates[2]												
X (objective herd health)	**0.007**	**0.545**	**0.001**	**<0.001**	0.001	0.013	0.006	0.863	0.007	0.078	0.006	0.298
M1 (perception of herd health)					**−1.138**	**−0.186**	**0.453**	**<0.05**	−0.584	−0.082	0.536	0.277
M2 (perceived control)									**0.229**	**0.196**	**0.072**	**<0.01**
Constant	0.497		0.339	0.144	26.658		2.524	<0.001	17. 727		3.517	<0.001
	$R^2 = 0.372$				$R^2 = 0.083$				$R^2 = 0.078$			
	$F(268) = 22.\ 6987$, $P < 0.001$				$F(267) = 3.019$, $P < 0.01$				$F(266) = 2.517$, $P < 0.01$			

[1]Significant results are marked in bold.

[2]Covariates = number of dairy cows, income from dairy production, marital status, age, gender, cohabitation.

market and maintaining viability (Karlsson et al., 2023). Structural change may, in the long run, affect the human-animal relationship and the possibility of maintaining an individual relationship between the farmer and the dairy cow. The quality of the human-animal relationship plays a central role in defining the welfare of the animals, a relationship that needs continual positive contact to maintain high quality across the lifespan of the animal (Waiblinger and Lürzel, 2023).

This survey was distributed in 2016 and conditions for dairy farming have in many countries changed since then. For instance, the milk quota in EU was abolished in 2015 and there have been changes in regional and national regulations (i.e., in terms of biodiversity protection, ensuring animal welfare; see e.g., Jongeneel and Gonzalez-Martinez, 2022). This may, in turn, have had effects on the dairy management at the farm level including farmers' health and welfare decisions for their animals. However, the milk quota never put an effective production constraint on Swedish dairy production (Swedish Board of Agriculture, 2016). Also, the Swedish regulations and animal welfare standards were, at the time of the study, considerably stricter than in other EU member states, but these have become more similar because of EU legislation (European Commission, 2024). Therefore, this study still provides valid and valuable insights into how relations between animal health and farmers' well-being affect one another and highlights the importance of taking a holistic approach when considering animal health and welfare and farmers health in livestock production. Indeed, through this study, we were able to combine data covering both the well-being of the farmers and objective data on the herd health offering a unique insight into this relationship.

This study makes 3 main contributions to the existing literature. First, it contributes to the field of One Welfare, considering how human and animal welfare may be associated with each other. Second, it extends previous literature on illness perception commonly used in human medicine and caregiving to incorporate the perspective of the human-animal relationship. Finally, we add to the discussion on farmer well-being and the importance of also considering positive health aspects because they can add to the understanding of farmers' overall well-being and contribute to future studies on how farmers can thrive despite significant stress.

CONCLUSIONS

Our study contributes to understanding the human-animal relationship by examining the link between dairy cow health, indicated by BMSCC, and dairy farmers' psychological well-being, measured using the SWLS. Our findings suggest that farmers' perceptions of illness and self-efficacy are significant mediators in this relationship. Specifically, when farmers feel more in control over managing mastitis on their farms, both their well-being and animal health outcomes may improve. These insights can guide targeted strategies to support mental health and animal care practices on dairy farms, enhancing outcomes for both farmers and their animals.

NOTES

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Nonstandard abbreviations used: BMSCC = bulk milk SCC; EFA = exploratory factor analysis; M1 = perception of herd health; M2 = perceived control of herd health; MPSES = Mastitis Prevention Self-Efficacy Scale; SDA = Swedish Dairy Association; SMM = serial multiple mediator; SWLS = Satisfaction with Life Scale.

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