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Connecting farmer mental health with cow health and welfare on dairy farms using robotic milking systems

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Abstract

The objective of this exploratory, preliminary study was to survey dairy farmers using robotic milking systems to better understand their mental health and potential connections to their cow health and welfare. Only farms using robotic milking systems in Ontario, Canada were visited for collection of data on management practices, cow welfare, and milk production and quality. Those farmers also completed an online survey that included validated psychometric scales used to assess resilience, stress, anxiety, and depression; results from 28 farms were analysed. Thirty cows per farm (or 30% for herds > 100 milking cows) were scored for body condition (five-point scale: 1 = thin to 5 = over-conditioned) and lameness (five-point scale: 1 = sound to 5 = lame); cows with a Body Condition Score ≤ 2.5 and lameness score ≥ 4 were defined as under-conditioned and severely lame, respectively. Farmer stress was positively associated with severe lameness prevalence, was greater for females vs males, and was greater for those feeding manually vs using an automated feeder. Anxiety and depression were greater for females vs males, and for those working alone, feeding manually, and with lesser milk protein percentage. Anxiety was also positively associated with the prevalence of severe lameness. Resilience was greater for those with automated feeding systems, but tended to be negatively associated with milk yield per robot and positively associated with milk somatic cell count. This is the first study to identify associations between farmer well-being and cow lameness, udder health, and milk yield. With future research, we can better understand this relationship to improve the well-being of both agricultural animals and their caretakers.

Keywords: *animal welfare, automation, dairy cow welfare, lameness, mental health, One Welfare*

Introduction

Animal welfare has been ranked as the top management priority for Canadian dairy farmers (Bauman *et al* 2016). For some, the interest in animal welfare is tied to their inherent love of cows while, for others, it may be to improve production and efficiency, or to comply with animal care requirements. Regardless of their motivation, animal welfare is on farmers' minds, along with many other sources of stress and anxiety. Not only is farming one of the most physically dangerous (Hounsome *et al* 2012) and mentally stressful occupations worldwide (Kerby 1992), but farmers also have higher rates of depression and related suicide compared with other occupational groups of similar socioeconomic status (Gregoire 2002; Milner *et al* 2013). In a recent national survey of farmer mental health across Canada (Jones-Bitton *et al* 2019), it was reported that farmers have high levels of stress, anxiety, depression, and burn-out, which exceed that of other occupational groups and population norms. Additionally, farmers had lower emotional resilience than the norm. Therefore, those farmers may be more susceptible to the effects of chronic stress, such as physical and mental illness (Jones-Bitton *et al* 2019).

With ongoing challenges in the field of animal welfare, there is the added challenge of farmers experiencing high levels of stress and poor mental health. In fact, there may be a strong connection between farmer mental health and the welfare of their animals. This connection aligns with the 'One Welfare' approach (Pinillos *et al* 2016; Galindo *et al* 2017), related to 'One Health.' The One Welfare framework "describes the interrelationships between animal welfare, human well-being, and the physical and social environment" (Pinillos 2018). This approach may be particularly relevant in relationships between humans and domesticated animals. For example, farmers who were previously involved in animal welfare incidents have been reported to struggle with mental health-related problems, such as depression, alcoholism, social problems, and stress (Kelly *et al* 2011; Devitt *et al* 2014). Furthermore, farmers experiencing both economic and psychiatric problems have been demonstrated to be at the highest risk of being convicted of animal neglect (Andrade & Anneberg 2014). Animal hoarding is another example of poor animal welfare associ-

ated with poor mental health (Thobaben 2006; Nathanson 2009). In contrast, it is hypothesised that farmers with a good quality of life and mental health are better equipped to care for their animals, but there are currently little data to support this idea. Previous research has been focused on case studies of farmers involved in animal welfare incidents, without representing the entire range of farms present, ranging from poor to excellent animal welfare.

With so much attention placed on animal welfare, the perspective of farmers often goes underrepresented, even though it is they who care for the animals daily and have the most direct impact on animal welfare (Kauppinen *et al* 2010). Therefore, it may be that the best way to improve animal welfare is to focus also on improving the well-being of the farmer (Kauppinen *et al* 2012). Thus, the objective of this exploratory, preliminary study was to identify factors associated with farmer mental health, such as management practices, milk production and quality and, particularly, measures of cow welfare. We hypothesised that scores indicative of better mental health would be associated with better animal welfare, in this case, the biological health and function pillar of animal welfare (Fraser 2008), specifically focusing on milk production, lameness, body condition, and udder health.

Materials and methods

Between May and October 2019, we visited dairy farms using robotic milking systems in Ontario to identify factors associated with milk production and cow health (Matson *et al* 2020). During farm visits, we conducted a survey of management practices and recorded aspects of barn design. Milk production per cow and per robot were recorded continuously and collected from the computer system at each farm for approximately six months prior to the farm visit. The study design was approved by the University of Guelph Animal Care Committee (AUP#3963) and Research Ethics Board (REB#19-05-011, linked to REB#19-01-012), and animal use complied with the guidelines of the Canadian Council on Animal Care (2009).

Surveying farmer mental health

To survey farmer mental health, we invited farmers to complete an online survey using Qualtrics (Provo, Utah, USA). The survey was completed by 34 farmers and took approximately 10 min for each person to complete. Each participant received a $C10 gift certificate for participating. Inclusion criteria were: working with dairy cows on a farm using a robotic milking system in Ontario; participating in milk recording; being 18 years of age or older; and being able to read and write in English. Informed written consent was obtained prior to starting the questionnaire. Based on previous surveys of farmer stress, personality, and attitudes towards animal welfare (Booth & Lloyd 1999; Hanna *et al* 2009; Kauppinen *et al* 2010), we expected 30 to 43% of farmers to complete the survey (ie 23 to 33 surveys). The *post hoc* sample size determined for this study ranged from 21 to 50, using previous mental health disorder prevalence estimates ranging from 9 to 33% (from Jones-Bitton *et al* 2019 and the current study), at a 90% confidence level, and 10% allowable error (Dohoo *et al* 2012). Given that the objective of our study was to identify associations between mental health and cow welfare, and not necessarily to accurately identify the prevalence of health disorders in farmers or cows, we considered our sample size to be acceptable for the purposes of this study.

The survey (see Appendix I in the supplementary material to papers published in *Animal Welfare*: https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material) included validated psychometric scales to identify levels of perceived stress (Cohen *et al* 1983), anxiety and depression (Zigmond & Snaith 1983), and emotional resilience (Connor & Davidson 2003; Campbell-Sills & Stein 2007). These questionnares have been previously used by researchers to assess the mental health of Canadian farmers of many commodity groups, as well as American, Australian, French, Norwegian and UK farmers (Jones-Bitton *et al* 2019). The Perceived Stress Scale (Cohen *et al* 1983) contains ten questions relating to the respondents' feelings regarding how often they were upset by unexpected events, felt nervous or stressed, felt confident about handling problems, and were able to cope with responsibilities or control irritations over the past month. Each question is scored from 0 to 4 and summed for an overall score out of 40, where a greater score indicates a higher level of perceived stress. The original Connor-Davidson Resilience Scale (Connor & Davidson 2003) uses 25 questions to assess resilience, or the ability of a person to cope or thrive despite hardships, over the past month. We used a refined version of the scale (Campbell-Sills & Stein 2007), using ten questions demonstrated to have good internal consistency and construct validity. Those ten questions assessed whether farmers were feeling able to adapt to change, able to bounce back after illness or hardship, confident about achieving goals despite obstacles, and able to not be discouraged by failure. Each question had a score of 0 to 4 and scores were summed to get an overall score of 40, where a greater score indicates greater resilience. The Hospital Anxiety and Depression Scale (Cohen *et al* 1983) contains 14 questions used to score respondents' feelings over the past week. Seven questions were scored from 0 to 3 for both anxiety and depression; the maximum score for each was out of 21, with scores $\geq$ 11 out of 21 indicating cases of probable anxiety or depression (Bartram *et al* 2009). To assess anxiety, questions were focused on feeling tense or wound up, frightened, worried, relaxed, restless, or panicked. Depression was assessed based on whether farmers were able to enjoy or laugh at things, felt cheerful or slowed down, or had lost interest in their appearance. Also included were some basic demographic questions and those about participants' responsibilities on the farm (ie the percentage of responsibility assigned to them, other farmworkers, list of chores, age group, sex, relationship status). As 16, 6, and 12 respondents were responsible for 0–50, 51–75, and 76–100% of the workload, respectively, we grouped these responses into two categories for social environment, separating those who worked mostly alone (n = 12) and those who did not work alone (n = 18).

Survey results were summed by sections to calculate a score for each outcome variable (stress, anxiety, depression,

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resilience) as per their respective protocols (Cohen *et al* 1983; Zigmond & Snaith 1983; Campbell-Sills & Stein 2007). Of the 34 surveyed farms, two milked non-Holstein breeds and we removed their responses due to substantial differences in milk production and components related to breed. From four of the farms, two surveys were submitted by two different people (eight farmers). For three of these farms (six farmers) — because both participants per farm were of the same gender and had identical workloads — we averaged their scores, which were rather similar, to become three survey responses. In the remaining farm (two farmers), one participant was responsible for the majority of the workload and, therefore, we used that individual's response and removed the other. Therefore, subtracting two non-Holstein farms and four duplicate responses per farm from the original 34 survey responses gave us a total of 28 farms to analyse.

Surveying animal welfare

To survey animal welfare, we focused on lameness and mastitis as they are two of the main production diseases in the dairy industry with considerable economic and welfare implications and are ranked as the top two disease priorities by Canadian farmers and veterinarians (Bauman *et al* 2016). Milk components and somatic cell count (SCC) data were collected by a Dairy Herd Improvement Association (Lactanet, Guelph, ON, Canada) approximately once per month for six months before the farm visit. High SCC is indicative of poor udder health in cows with mastitis. Other animal-based measures of cow welfare included body condition and lameness scoring conducted by one trained observer at all farms. Body Condition Score (BCS) was determined using a five-point scale, at increments of 0.25, as described by Wildman *et al* (1982). Cows with BCS $\leq$ 2.5 and $\geq$ 3.5 were classified as under- and over-conditioned, respectively. Lameness (gait) was scored using a five-point numerical rating system (NRS), at increments of 1.0 (Flower & Weary 2006). Lameness scoring was performed from a clear posterior side angle while cows took at least six steps on flat flooring only while walking, and not when stumbling, falling, defaecating, urinating, or restricted from free movement by a nearby cow (Flower & Weary 2006). Cows with NRS $\geq$ 3 and $\geq$ 4 were classified as clinically and severely lame, respectively. At each farm, we scored a minimum of 30 cows (or 30% for herds > 100 milking cows) to ensure a representative sample of cows were scored (Endres *et al* 2014). We used systematic random sampling to select individuals by only including every nth cow, based on the number of cows needed relative to the total number of cows in each pen. This ensured that cows were selected proportionately from all parts within a pen (ie those lying down, feeding, standing idly, and so on). In cases of farms housing milking cows in more than one pen, a proportionate number of cows per pen were selected to ensure that a representative and random sample was achieved; this included cows separated into smaller treatment per separation pens. Based on these results, we calculated the prevalence of under-conditioned, over-conditioned, clinically lame, and severely lame cows for each farm.

Table 1 Categorical variables describing survey participants included in analyses (n = 28).

Variable	Number of farmers
Age group	
18–29	5
30–44	11
45–64	9
Not available	3
Sex	
Female	6
Male	22
Social environment[1]	
Mostly alone	11
Not alone	17
Feeding method[2]	
Automated	7
Manual	21

[1] Those who worked mostly alone performed 76–100% of the farm work themselves, whereas those not working alone were responsible for 0–75% of farm chores.

[2] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both.

Statistical analysis

Prior to analyses, all data were screened for normality and outliers using the UNIVARIATE procedure of SAS (SAS Institute 2013). Transformations were applied to normalise data that did not follow a normal distribution. The percentage of over-conditioned cows was transformed by taking the natural logarithm. Due to having values of zero, the prevalence of severe lameness and under-conditioned cows were transformed by taking the natural logarithm of the (value +1). Using the MIXED procedure of SAS (SAS Institute 2013), we evaluated associations of various predictor variables with outcome variables (stress, anxiety, depression, and resilience scores) in mixed-effect linear regression models. Farm was considered a random effect. Degrees of freedom for fixed effects were estimated using the Kenward-Roger option in the MODEL statement. Predictor variables offered to models were chosen based on data available from records and the management survey that pertained to the farmer experience and cow welfare based on previous literature and conversations with farmers. Categorical predictor variables (Table 1) tested were sex (female vs male), social environment (working mostly alone vs not alone), age group (18 to 29, 30 to 44, 45 to

Table 2 Continuous variables describing farms and survey results included in analyses.

Variable	Mean (± SD)	Min–max	N
Number of lactating cows	76 (± 32)	45–161	28
Milk yield (kg per cow per day)	36.6 (± 5.3)	24.7–48.1	28
Milk yield (kg per robot per day)	1,643 (± 406)	826–2,332	28
Number of cows per robot	45 (± 10)	27–60	28
Milk fat content (%)	4.03 (± 0.15)	3.79–4.29	28
Milk protein content (%)	3.36 (± 0.08)	3.19–3.48	28
Milk SCC (× 1,000 cells ml^{-1})	187 (± 65)	77–347	26
Prevalence of clinical lameness[1]	26.5 (± 9.9)	10.0–40.0	27
Prevalence of severe lameness[1]	2.4 (± 3.1)	0.0–10.0	27
Percentage of under-conditioned cows[2]	5.6 (± 6.0)	0.0–23.3	27
Percentage of over-conditioned cows[2]	11.4 (± 8.1)	0.0–27.5	27
Total perceived stress score[3]	16.8 (± 6.6)	6.0–32.0	28
Total anxiety score[4]	7.3 (± 3.9)	1.0–14.0	27
Total depression score[4]	5.4 (± 3.5)	1.0–13.0	27
Total resilience score[5]	28.4 (± 5.0)	19.0–38.0	27

[1] Cows with a lameness score ≥ 3 and ≥ 4 out of 5 were classified as clinically and severely lame, respectively;
[2] Cows with Body Condition Score ≤ 2.5 and ≥ 3.5 out of 5 were classified as under- and over-conditioned, respectively;
[3] The Perceived Stress Scale (Cohen *et al* 1983) uses ten questions scored from 0 to 4 to determine respondents' perceived stress over the last month out of 40;
[4] The Hospital Anxiety and Depression Scale (Cohen *et al* 1983) uses seven questions for anxiety, and seven for depression scored from 0 to 3, to score respondents' feelings over the past week (each out of 21);
[5] We used a refined version of the Connor-Davidson Resilience Scale (Connor & Davidson 2003) with ten questions (Campbell-Sills & Stein 2007) scored from 0 to 4 to determine respondents' resilience over the past month out of 40.

64 years old), and feeding method (manual vs automated feeder) (ie conveyer or automated delivery system). Continuous predictor variables (Table 2) tested were the number of lactating cows, milk yield per cow, milk yield per robot, cows per robot, prevalence of clinical lameness, prevalence of severe lameness, percentage of under-conditioned cows, percentage of over-conditioned cows, milk fat content (%), milk protein content (%), and SCC. We initially screened various independent variables individually as fixed effects, with sex treated as a covariate, due to strong differences reported in the literature (Jones-Bitton *et al* 2019). We did not account for month in our analysis because there were no monthly differences in cow welfare or production variables, nor in the mental health measures. Only variables with $P < 0.25$ were offered to multivariable models (Dohoo *et al* 2012). We analysed Pearson correlation coefficients between independent variables (CORR procedure of SAS) to determine if any variables were correlated ($r > 0.6$). Manual backward step-wise elimination was used to remove any variables with $P > 0.10$; those retained were deemed significant at $P \leq 0.10$.

Results

Variables offered to the multivariable model for perceived stress (Table 3) were milk yield per cow, prevalence of severe lameness, percentage of under-conditioned cows, milk protein percentage, SCC, sex, and feeding method. After backward step-wise elimination, perceived stress was positively associated with the prevalence of severe lameness and was reduced for those using automated feeding systems, while also being greater for females compared with males (Table 4).

Variables offered to the multivariable model for anxiety were milk yield per cow, the prevalence of severe lameness, milk protein percentage, feeding method, sex, and social environment (Table 5). Variables retained in the final multivariable model for anxiety were the prevalence of severe lameness (positive association), milk protein percentage (negative association), feeding method (lesser anxiety with automated feeders), and social environment (greater anxiety if working mostly alone), as well as sex (greater anxiety for females) (Table 6).

Variables offered to the multivariable model for depression were milk yield per cow, milk protein percentage, feeding method, sex, and social environment (Table 7). In the final multivariable model, depression was negatively associated with milk protein percentage, and was greater for females, those feeding manually, and working mostly alone (Table 8).

Variables offered to the multivariable model for resilience were milk yield per robot, the percentage of under-conditioned cows, milk protein percentage, SCC, sex, and feeding method (Table 9). Variables retained in the final multivariable model were milk yield per robot (negative association), milk SCC (positive association), and feeding method (greater resilience for those with automated feeders) (Table 10).

Various associations between predictor variables were identified when assessing potential correlations. Milk SCC was associated with milk yield per cow ($r = –0.55$; $P = 0.004$), clinical lameness prevalence ($r = 0.47$; $P = 0.02$), severe lameness prevalence ($r = 0.47$;

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Table 3 Individual predictor variables tested for associations with farmer stress[1] (n = 28).

Variable	β[2]	SE	*P*-value
Number of lactating cows	–0.04	0.56	0.9
Cows per robot	0.01	0.12	0.9
Milk yield (kg per cow per day)	–0.37	0.21	0.09
Milk yield (kg per robot per day)	–0.002	0.16	1.0
Milk fat content (%)	–6.37	7.94	0.4
Milk protein content (%)	–26.6	14.0	0.07
Milk SCC (× 1,000 cells ml^{-1})	0.005	0.0	< 0.001
Prevalence of clinical lameness[3]	0.13	0.13	0.3
Prevalence of severe lameness[3]	2.01	1.25	0.12
Percentage of under-conditioned cows[4]	0.73	0.0	< 0.001
Percentage of over-conditioned cows[4]	–25.1	31.9	0.4
Age group			
18–29	–0.79	4.91	0.6
30–44	–3.06	2.92	
45–64	Referent	–	
Social environment[5]			
Mostly alone	2.86	20.63	0.9
Not alone	Referent	–	
Feeding method[6]			
Automated	–4.42	2.54	0.09
Manual	Referent	–	
Sex[7]			
Female	6.78	2.77	0.02
Male	Referent	–	

[1] Measured using the Perceived Stress Scale (Cohen *et al* 1983) which contains ten questions relating to the respondents' feelings over the past month, scoring each question from 0 to 4 and summing them to get an overall score out of 40, where a greater score indicates a higher level of perceived stress;
[2] Estimated regression coefficients;
[3] Cows with a lameness score ≥ 3 and ≥ 4 out of 5 were classified as clinically and severely lame, respectively;
[4] Cows with Body Condition Score ≤ 2.5 and ≥ 3.5 out of 5 were classified as under- and over-conditioned, respectively;
[5] Those who worked mostly alone performed 76–100% of the farm work themselves, whereas those not working alone were responsible for 0–75% of farm chores;
[6] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both;
[7] Sex was treated as a covariate.

$P = 0.02$), and the percentage of under-conditioned cows ($r = 0.46$; $P = 0.02$). The prevalence of clinical lameness was associated with milk yield per cow ($r = –0.44$; $P = 0.02$) and prevalence of severe lameness ($r = 0.35$; $P = 0.07$). The prevalence of severe lameness was associated with the percentage of under-conditioned cows ($r = 0.51$; $P = 0.007$).

Discussion

After assessing management practices, farmer mental health, and cow health, we analysed associations between those variables to identify relationships between farmer mental health and cow welfare. Overall, improved mental health of dairy farmers using robotic milking systems was associated with a lower prevalence of severe lameness and

Table 4 Multivariable models of factors associated with farmer stress[1] (n = 28).

Variable	β[2]	95% CI[3]	SE	*P*-value
Intercept	14.9	12.0–18.7	1.6	< 0.001
Prevalence of severe lameness[4]	2.89	0.52–5.27	1.15	0.02
Feeding method[5]				
Automated	–6.52	(–1.68)–(–11.37)	2.34	0.01
Manual	Referent	–	–	
Sex				
Female	7.31	2.26–12.36	2.44	0.007
Male	Referent	–	–	

[1] Measured using the Perceived Stress Scale (Cohen *et al* 1983) which contains ten questions relating to the respondents' feelings over the past month, scoring each question from 0 to 4 and summing them to get an overall score out of 40, where a greater score indicates a higher level of perceived stress;
[2] Estimated regression coefficients;
[3] Confidence interval;
[4] Cows with a lameness score ≥ 4 out of 5 were classified as severely lame;
[5] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both.

greater milk protein percentage. Further, mental health scores differed by feeding method (better mental health for those using automated feeding systems vs feeding manually), social environment (better mental health for those working with others vs mostly working alone), and sex (better mental health for males vs females). While this associative study is unable to make statements regarding cause and effect, we can examine these associations in two ways: i) human well-being affecting animal health and production; and/or ii) animal health and production influencing mental health. Firstly, it is possible that farmers with poor mental health struggle with routine barn chores, herd management, and barn cleanliness, leading to thin cows with poor hoof health, udder health, and production. In contrast, those with better mental health may be more efficient or motivated in the barn, and better able to manage their cows' health and environment. There are many studies linking low body condition to lameness (Bicalho *et al* 2009; Lim *et al* 2015; Westin *et al* 2016), poor cow hygiene to lameness (Dembele *et al* 2006), and poor stall hygiene with mastitis (DeVries *et al* 2012), although we did not measure cow hygiene in this study and this would be beneficial in future research. Secondly, farms with < 10% severe lameness prevalence have greater average corrected milk production per year and greater profitability margin per cow over replacement cost (Villettaz Robichaud *et al* 2018). Granted that there are many other factors involved besides finances, it is possible that, if farmers are making more money, there are fewer financial stressors on them and this may have a positive impact on their mental health. Farms with a lower prevalence of lameness are associated with producing more milk per cow and more milk per robotic milking unit (King *et al* 2016). Farms with lower levels of lameness also have improved overall technical efficiency (Barnes *et al* 2011); with fewer cases of lameness to treat and a lower replacement rate, input costs are reduced while profits are increased (ie milk yield relative to feed costs), which could potentially lower stress and improve mental health. Although there have been no studies conducted in Canada to specifically investigate this relationship, the connection between farmer stress and finances is pervasive worldwide, from increased input costs and debt to market prices, taxes, and irregular cash flow (Yazd *et al* 2019). Farm profitability has previously been associated with greater well-being and reduced distress among Australian farmers and irrigators (Peel *et al* 2015). Financial factors like market prices and taxes were cited as 'very stressful' by over half of surveyed farmers in Northern Carolina (USA) (Kearney *et al* 2014). On the other hand, those struggling to produce enough milk may have greater costs relative to their income, which may cause stress and impair their mental health. It is also possible that farmers feel that their herd's health and performance are a reflection of their work and performance as a farmer; this, in combination with feelings related to results of animal care assessments, may also impact their mental health positively or negatively. However, as this was an associative study, with data from 28 farms, we cannot draw any strong conclusions as to whether the relationship is causal, cyclical, or merely associative, and further research is needed to fully elucidate this relationship in many farming scenarios. Future research should also include measures of barn and cow hygiene, as well as many other measures relating to the farmer, such as personality, attitudes, and behaviour.

Researchers have previously explored associations between farmer personality traits, behaviour, and attitudes towards animal welfare and measures of animal welfare (health,

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Table 5 Individual predictor variables tested for associations with farmer anxiety[1] (n = 27).

Variable	β[2]	SE	*P*-value
Number of lactating cows	–0.02	0.02	0.4
Cows per robot	0.05	0.07	0.4
Milk yield (kg per cow per day)	–0.25	0.13	0.06
Milk yield (kg per robot per day)	4.5×10^{-5}	0.002	1.0
Milk fat content (%)	–4.34	4.52	0.3
Milk protein content (%)	–18.10	7.56	0.02
Milk SCC (× 1,000 cells ml^{-1})	0.001	0.01	0.9
Prevalence of clinical lameness[3]	0.001	0.08	1.0
Prevalence of severe lameness[3]	1.64	0.68	0.02
Percentage of under-conditioned cows[4]	0.70	0.70	0.3
Percentage of over-conditioned cows[4]	–17.2	18.2	0.4
Age group			
18–29	1.88	2.79	0.8
30–44	0.09	1.64	
45–64	Referent	–	
Social environment[5]			
Mostly alone	2.59	1.26	0.05
Not alone	Referent	–	
Feeding method[6]			
Automated	–2.51	1.42	0.09
Manual	Referent	–	
Sex[7]			
Female	5.06	1.66	0.006
Male	Referent	–	

[1] Measured using the Hospital Anxiety and Depression Scale (Cohen *et al* 1983) which contains seven questions used to score respondents' feelings over the past week. Responses were scored from 0 to 3; the maximum score for each was out of 21, with scores ≥ 11 out of 21 indicating cases of probable anxiety (Bartram *et al* 2009);
[2] Estimated regression coefficients;
[3] Cows with a lameness score ≥ 3 and ≥ 4 out of 5 were classified as clinically and severely lame, respectively;
[4] Cows with Body Condition Score ≤ 2.5 and ≥ 3.5 out of 5 were classified as under- and over-conditioned, respectively;
[5] Those who worked mostly alone performed 76–100% of the farm work themselves, whereas those not working alone were responsible for 0–75% of farm chores;
[6] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both;
[7] Sex was treated as a covariate.

production, behaviour). In dairy farming, specifically, researchers have identified many factors related to dairy cattle health, welfare, productivity, farm management, veterinary costs, and cow behaviour (for a review, see Adler *et al* 2019). In one study, farmer attitudes toward, and the use of, positive and neutral vocal interactions during milking were the strongest factors among human-animal relationship variables to explain deviation in the prevalence of lame cows (Rouha-Mulleder *et al* 2009). Relating that to our study, it is possible that farmers with greater stress or anxiety are more likely to rush cows and cause injuries, or that moving lame cows requires more motivation or force and farmers become accustomed to that behaviour. These associations are not just observed in dairy herds, but also in swine production (Kaupinnen *et al* 2010, 2012); those researchers assessed farmer attitudes towards animal

Table 6 Multivariable results of factors associated with farmer anxiety[1] (n = 27).

Variable	β[2]	95% CI[3]	SE	*P*-value
Intercept	45.5	4.7–90.6	20.6	0.04
Prevalence of severe lameness[4]	1.48	0.24–2.71	0.59	0.02
Milk protein (%)	–12.02	(–24.74)–0.70	6.10	0.06
Social environment[5]				0.07
Mostly alone	2.05	(–0.20)–4.30	1.08	
Not alone	Referent	–	–	
Feeding method[6]				0.005
Automated	–3.59	(–1.23)–(–5.94)	1.13	
Manual	Referent	–	–	
Sex				< 0.001
Female	5.75	3.14–8.35	1.25	
Male	Referent	–	–	

[1] Measured using the Hospital Anxiety and Depression Scale (Cohen *et al* 1983) which contains seven questions used to score respondents' feelings over the past week. Responses were scored from 0 to 3; the maximum score for each was out of 21, with scores ≥ 11 out of 21 indicating cases of probable anxiety (Bartram *et al* 2009);
[2] Estimated regression coefficients;
[3] Confidence interval;
[4] Cows with a lameness score ≥ 3 and ≥ 4 out of 5 were classified as clinically and severely lame, respectively;
[5] Those who worked mostly alone performed 76–100% of the farm work themselves, whereas those working not alone were responsible for 0–75% of farm chores;
[6] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both.

welfare and the importance and ease of various methods to improve welfare. According to farmers in that study, taking care of their own well-being ranked as the most important way to improve animal welfare, but it was the most difficult action to put into practice (Kaupinnen *et al* 2010). While that study identified ways to improve farmer well-being (ie enough leisure time, holidays, time to complete work without rushing, investing in their well-being), those authors did not measure farmer well-being in any capacity, nor could they analyse the association between farmer and animal well-being. Another factor affecting animal welfare decisions made by farmers may be their satisfaction with the delivery of information. After herd health visits with their veterinarian, farmers were more prepared to adopt their veterinarian's recommendations if they had a positive vet-client interaction (Ritter *et al* 2019); therefore, it is very important to consider the social aspects of animal care and the farmer's point of view if attempting to influence their actions towards improving animal health.

While the environmental pillar is key to achieving 'One Welfare', it is beyond the scope of this study and future research efforts should incorporate this third element as well. For example, in terms of the immediate environment, both cows and farmers using robotic milking systems live and work in a very different social and physical environment compared with those in conventional parlour or tie-stall herds. Future studies could be focused on the differences in animal welfare and human well-being between different types of dairies. On a larger scale, working towards environmental sustainability and reducing the negative impacts of climate variability and environmental degradation also contribute to food security and farm sustainability, benefiting human health and well-being. For example, pesticide exposure in both developed and developing countries has been associated with farmer mental health, while in developed countries and Australia in particular, climate variability has had a great impact on farmers (for a review, see Yazd *et al* 2019). The weather has also been cited by US farmers as a great source of stress (Kearney *et al* 2014). Additionally, there are connections between the health of the environment and that of domesticated and wild animals. For example, forest coverage in silvopastoral farms not only supports more native and specialist species of bats, rodents, and birds, it also improves cattle welfare through provision of shade and lower temperatures, leading to better body condition, fewer skin alterations, more stable social hierarchies, and increased productivity (meat production per hectare) compared with monocultured landscapes or those with lower forest cover (Améndola *et al* 2016; Galindo *et al* 2017; Mancera *et al* 2018).

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Table 7 Individual predictor variables tested for associations with farmer depression[1] (n = 27).

Variable	β[2]	SE	*P*-value
Number of lactating cows	–0.01	0.02	0.6
Cows per robot	0.027	0.069	0.7
Milk yield (kg per cow per day)	–0.18	0.14	0.21
Milk yield (kg per robot per day)	–0.0002	0.002	0.9
Milk fat content (%)	–4.79	4.65	0.3
Milk protein content (%)	–22.9	7.3	0.005
Milk SCC (× 1,000 cells ml^{-1})	–0.007	0.010	0.5
Prevalence of clinical lameness[3]	–0.005	0.08	0.9
Prevalence of severe lameness[3]	0.80	0.76	0.3
Percentage of under-conditioned cows[4]	0.001	0.74	1.0
Percentage of over-conditioned cows[4]	–19.3	18.7	0.3
Age group			0.9
18–29	–0.73	2.96	
30–44	–0.62	1.73	
45–64	Referent	–	
Social environment[5]			0.03
Mostly alone	2.92	1.28	
Not alone	Referent	–	
Feeding method[6]			0.11
Automated	–2.42	1.48	
Manual	Referent	–	
Sex[7]			0.16
Female	2.47	1.72	
Male	Referent	–	

[1] Measured using the Hospital Anxiety and Depression Scale (Cohen *et al* 1983) which contains seven questions used to score respondents' feelings over the past week. Responses were scored from 0 to 3; the maximum score for each was out of 21, with scores ≥ 11 out of 21 indicating cases of probable depression (Bartram *et al* 2009);
[2] Estimated regression coefficients;
[3] Cows with a lameness score ≥ 3 and ≥ 4 out of 5 were classified as clinically and severely lame, respectively;
[4] Cows with Body Condition Score ≤ 2.5 and ≥ 3.5 out of 5 were classified as under- and over-conditioned, respectively;
[5] Those who worked mostly alone performed 76–100% of the farm work themselves, whereas those working not alone were responsible for 0–75% of farm chores;
[6] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both;
[7] Sex was treated as a covariate.

Furthermore, farmer mental health may also influence the uptake of environmental stewardship practices; Hounsome and Edwards (2006) demonstrated that Welsh farmers of unknown commodity groups who adopted agri-environmental programmes had better self-reported mental health than non-adopters, although they used different scales to assess mental health than in our study. Similar to the current study, those researchers also used backward step-wise elimination with several predictor variables and reported associative results without causation, finding that poor mental health was involved with low adoption of environmental stewardship programmes (Hounsome & Edwards 2006). In the current study, we found that poor mental health may be related to low adoption of animal welfare stewardship, and therefore, promoting mental health may be one tool to improve animal welfare on-farm.

Table 8 Multivariable results of factors associated with farmer depression[1] (n = 27).

Variable	β[2]	95% CI[3]	SE	*P*-value
Intercept	71.8	31.0–115.5	20.4	0.002
Milk protein (%)	–20.1	(–7.5)–(–32.6)	6.1	0.003
Social environment[4]				0.005
Mostly alone	3.13	1.05–5.21	1.00	
Not alone	Referent	–	–	
Feeding method[5]				0.02
Automated	–2.79	(–0.50)–(–5.08)	1.10	
Manual	Referent	–	–	
Sex				0.05
Female	2.56	(–0.04)–5.15	1.25	
Male	Referent	–	–	

[1] Measured using the Hospital Anxiety and Depression Scale (Cohen *et al* 1983) which contains seven questions used to score respondents' feelings over the past week. Responses were scored from 0 to 3; the maximum score for each was out of 21, with scores ≥ 11 out of 21 indicating cases of probable depression (Bartram *et al* 2009);
[2] Estimated regression coefficients;
[3] Confidence interval;
[4] Those who worked mostly alone performed 76–100% of the farm work themselves, whereas those working not alone were responsible for 0–75% of farm chores;
[5] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both.

Regarding farmers' physical health, however, Hounsome and Edwards (2006) reported the reverse relationship when looking at the physical health of farmers and their adoption of agri-environmental programmes, whereby those with poor physical health were less likely to adopt these programmes. Therefore, even when considering the generally poorer mental health of younger farmers compared with the poor physical health of older farmers in that study, those who were older and had poor mental health were less likely to be adopters (Hounsome & Edwards 2006). While we did not assess physical health in the current study, it would be interesting to see if the physical health of farmers relates to cow health. Previous research has linked the physical and mental health of farmers (for a review, see Yazd *et al* 2019). In a Canadian study, many farmers who have switched to using robotic milking systems highlighted that their work was less physically demanding and they ranked this as the second major improvement to their quality of life; some farmers even noted improvements in their physical health and reductions in neck and back issues (Tse *et al* 2018). Perhaps being in less pain combined with more time flexibility could give farmers the energy and ability to focus on other chores to improve cow welfare.

Comparing our results with those of Jones-Bitton *et al* (2019), it may be that the surveyed dairy farmers with robotic milking systems were slightly less stressed than the average Canadian farmer. Tse *et al* (2018) demonstrated this in a survey where farmers strongly agreed that having robotic milking systems improved their quality of life and that of their cows, gave them more time flexibility, and meant less physically demanding work. Furthermore, farmers reported being able to spend more time with their families, resting, and performing other tasks (Tse *et al* 2018). Our results also demonstrate the potential for automated feeding systems to have a protective effect on all four measures of mental health, perhaps due to a similar reduction in time and labour spent mixing and delivering feed to cows, freeing up time for other chores and family. When comparing our 34 respondents with the results of Jones-Bitton *et al* (2019), we had a similar composition of male and female participants and slightly lower rates of probable anxiety (27 vs 33%) and probable depression (9 vs 15%). Males in our study had lower average perceived stress scores (15.0 vs 18.3 out of 40), rates of probable depression (8 vs 12.5%), and rates of probable anxiety (16 vs 29%). Within our female participants (n = 8), 62.5% had probable anxiety, and 12.5% had probable depression, compared with 43 and 19%, respectively, reported by Jones-Bitton *et al* (2019). However, given that our study only included eight female participants, it is not appropriate to make broad statements about the significance of those findings. Jones-Bitton *et al* (2019) used a 25-point scale to assess resilience, and we used a ten-point scale, but when we scale our results to match their methods, we get a very similar average resilience score for all participants (72.0 vs 71.1). Females in our study reported similar resilience to the average female Canadian farmer (68.1 vs 69.5), and males had similar resilience (73.3 vs 71.8) to the average male Canadian farmer as reported by Jones-Bitton *et al* (2019).

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Table 9 Individual predictor variables tested for associations with farmer resilience[1] (n = 27).

Variable	β[2]	SE	*P*-value
Number of lactating cows	0.020	0.031	0.5
Cows per robot	–0.087	1.87	1.0
Milk yield (kg per cow per day)	–0.22	0.20	0.3
Milk yield (kg per robot per day)	–0.004	0.002	0.10
Milk fat content (%)	–1.15	6.81	0.9
Milk protein content (%)	20.3	11.7	0.10
Milk SCC (× 1,000 cells ml^{-1})	0.036	0.014	0.02
Prevalence of clinical lameness[3]	0.057	0.11	0.6
Prevalence of severe lameness[3]	0.20	1.11	0.9
Percentage of under-conditioned cows[4]	2.13	0.95	0.04
Percentage of over-conditioned cows[4]	–4.97	27.38	0.9
Age group			0.3
18–29	3.76	3.93	
30–44	–2.73	2.30	
45–64	Referent	–	
Social environment[5]			0.3
Mostly alone	–1.99	1.99	
Not alone	Referent	–	
Feeding method[6]			0.01
Automated	5.30	1.95	
Manual	Referent	–	
Sex[7]			0.2
Female	–3.05	2.46	
Male	Referent	–	

[1] Measured using a refined version of the Connor-Davidson Resilience Scale (Connor & Davidson 2003; Campbell-Sills & Stein 2007), using ten questions to assess resilience, or the ability of a person to cope or thrive despite hardships, over the past month. Each question had a score of 0 to 4 and scores were summed to get an overall score of 40, where a greater score indicates greater resilience;
[2] Estimated regression coefficients;
[3] Cows with a lameness score $\geq$ 3 and $\geq$ 4 out of 5 were classified as clinically and severely lame, respectively;
[4] Cows with Body Condition Score $\leq$ 2.5 and $\geq$ 3.5 out of 5 were classified as under- and over-conditioned, respectively;
[5] Those who worked mostly alone performed 76–100% of the farm work themselves, whereas those working not alone were responsible for 0–75% of farm chores;
[6] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both;
[7] Sex was treated as a covariate.

While it is possible that farmers with more free time or better mental health were more likely to complete our survey, that should also apply to the results of Jones-Bitton *et al* (2019), making our findings comparable. Furthermore, farmers who have mental health disorders may be more motivated or less willing to complete this type of survey. However, farms in this study also represented the age, sex, and lameness prevalence of the average robotic dairy farm in Ontario (King *et al* 2016; Matson *et al* 2020).

This preliminary study allowed us to make the first ever analysis connecting cow welfare to farmer well-being in dairy herds using robotic milking systems. While this study was associative and included a moderate sample size, this was deemed sufficient for our purpose of connecting human well-being and animal welfare. This study highlights the potential for these concepts to be associated and future research can target whether farmer health and well-being are universally related to animal health and welfare in

Table 10 Multivariable results of factors associated with farmer resilience[1] (n = 27).

Variable	β[2]	95% CI[3]	SE	*P*-value
Intercept	29.9	21.1–40.6	4.4	< 0.001
Feeding method[4]				0.03
Automated	4.55	0.47–8.63	1.96	
Manual	Referent	–	–	
Milk SCC (× 1,000 cells ml^{-1})	0.025	(–0.002)–0.052	0.013	0.07
Milk yield (kg per robot per day)	–0.004	(–0.0084)–0.0001	0.002	0.06
Sex				0.2
Female	–2.56	(–6.76)–1.63	2.01	
Male	Referent	–	–	

[1] Measured using a refined version of the Connor-Davidson Resilience Scale (Connor & Davidson 2003; Campbell-Sills & Stein 2007), using ten questions to assess resilience, or the ability of a person to cope or thrive despite hardships, over the past month. Each question had a score of 0 to 4 and scores were summed to get an overall score of 40, where a greater score indicates greater resilience;
[2] Estimated regression coefficients;
[3] Confidence interval;
[4] Manual feeding implies mixing and delivering feed in a tractor whereas automated feeding involves using an automated feed mixing or delivery system (such as an autonomous robot or conveyer) or a combination of both.

different contexts, and if the relationships are causal, cyclical, or associative, and if other factors are involved, such as farmer personality type, attitudes towards animal welfare, education level, and so on.

Animal welfare implications

We identified associations between farmer well-being and cow welfare, specifically health and production. Using the 'One Welfare Approach' to improve the health of agricultural animals and their human caretakers, we must consider all dimensions of life on the farm and consider the perspective of farmers to truly create truly sustainable farms.

Conclusion

In summary, although this exploratory, pilot study had a limited sample size and was not able to establish causation, cow health and production were among the factors associated with farmer mental health. Greater stress and anxiety were associated with an increasing prevalence of severe lameness and were greater for females vs males. Further, greater anxiety and depression were associated with those working alone, feeding cows manually compared with using an automated system, and those whose cows produce milk with reduced protein content. Future studies with larger sample sizes should investigate the connections between human well-being, animal health, and environmental health.

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