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Welfare assessment in traditional mountain dairy farms: above and beyond resource-based measures

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Abstract

The Welfare Quality® project was one of the largest research undertakings into animal welfare. Despite animal-based measures (ABMs) being increasingly preferred over resource-based measures (non-ABMs), the Welfare Quality® protocol (WQ) for dairy cattle has a non-ABM, Ease of Movement that classifies housing systems using a threshold of 100 days of access to pasture or, inversely, of 265 days tethered. Since traditional transhumance to alpine pastures lasts for approximately 90 days most farms tend to be classified as having a year-round tie-stall system by the WQ. The aim of this study was two-fold: to discuss the appropriateness of using non-ABMs and related thresholds in welfare scoring and to classify mountain dairy farms using ABM records. Initially, a comparison was made with scores obtained using the WQ protocol in farms where cows were: i) tethered all year; and ii) tethered but having regular exercise or reared in loose-housing systems. No difference in terms of welfare was detected between groups of farms regarding their housing systems, thus we investigated welfare focusing on ABMs. Therefore, farms were grouped into four clusters, according to their ABMs. The results indicated that good ABM scores can be obtained in most traditional mountain farms where cows are tethered for around 275 days a year and have access to highland pasture for the remaining 90 days. In this study, ABMs were effective tools for classifying mountain farms according to their welfare status and for informing targeted action to improve dairy cow welfare.

Keywords: *alpine farming, animal-based measure, animal welfare, dairy cattle, small-scale farm, tie-stall system*

Introduction

Mountain farms are small-scale, family businesses that contribute greatly to high-value food chains in terms of the quality and diversity of their products (Kohler & Romeo 2013). In addition, due to their size and low/local inputs, mountain farms deliver ecosystem services, such as maintenance of cultural heritage, preservation of agro-biodiversity, disaster risk reduction and space for recreation and tourism that are vital for sustainable development far beyond mountain areas (Battaglini *et al* 2014).

In Italy, 78% of mountain dairy farms are micro-scale enterprises with less than 20 cows and most can be considered small-scale as they do not exceed 75 lactating animals (EFSA 2015). Despite a fairly pronounced farm abandonment rate of 64% in the Italian Alps between 1980 and 2010, mountain farms still account for 44% of national dairy farms in Italy (ISTAT 2012). In the Italian Alps, dairy cattle are traditionally kept indoors and tethered during winter in lowland farms and moved to highland pastures during summer (so-called transhumance). A study carried out by Sturaro *et al* (2013) in the autonomous province of Trento — a mountain area in the north-eastern Italian Alps — estimated that more than 70% of farms in the province were using tie-stall systems. At the same time, the majority of farms (55%) were practicing the traditional summer transhumance of lactating cows to highland pastures.

Animal welfare assessment is an ongoing challenge and several methods have been identified to assess it at herd level. The largest research project on animal welfare funded by the European Commission was the Welfare Quality® project (Blokhuis *et al* 2010) involving 44 research institutes and universities from all over the world. The Welfare Quality® Assessment Protocol (WQ; Welfare Quality® 2009) combined animal-, resource- and management-based measures in order to determine an overall level of welfare. The measures that affect animal welfare through the physical environment or available resources (eg housing system) are referred to as resource-based measures while the management practices (eg disbudding/dehorning) that could affect animal welfare are called management-based measures (EFSA 2012). The response of an animal to resources and management practices is assessed through animal-based measures (ABMs) which are increasingly preferred over resource- and management-based measures (non-ABM) among animal welfare experts since they reflect the actual response of animals to the environment and the management practices to which they are exposed to (Whay *et al* 2003; EFSA 2012; OIE 2015). Nevertheless, for most citizens and consumers, animal welfare is linked mainly to housing systems (Te Velde *et al* 2002; Vanhonacker *et al* 2008) and the WQ for dairy cattle, within the principle of good

housing, has a non-ABM, Ease of Movement, that considers cows tethered all year round if they do not have access to an outdoor or pasture area for at least 100 days. The length of summer transhumance to highland pastures in the Alps is defined by the length of the vegetative season, which may or may not exceed 100 days depending on pasture altitude, gradient and other climatic factors. Thus, according to the definition of Ease of Movement and to the scoring systems of the WQ, most farms, even if practicing summer transhumance, are classified as having a year-round, tie-stall system and score poorly on such criterion. Permanent tethering for lactating cows is considered critical or even unacceptable in terms of welfare according to several studies (eg Ostojić-Andrić *et al* 2011; Popescu *et al* 2013) and has already been banned in a number of Scandinavian countries (eg Norway). On the other hand, tie-stall systems where cows have access to pasture or are allowed to exercise are considered to promote enhanced welfare regarding such parameters as lameness, metabolic and reproductive disorders (Corazzin *et al* 2010; Popescu *et al* 2014).

In this study, we initially compared welfare scores obtained using WQ for dairy cows in alpine farms where cows are considered: i) tethered all year round (but some have access to pasture for less than 100 days); and ii) tethered but having access to pasture for more than 100 days or reared in loose-housing systems (with or without access to pasture) to seek differences between the two groups. Then, welfare was investigated on the basis of ABMs, neglecting information on management and resources. The aim of this work was to explore the appropriateness of using Ease of Movement, as an indicator of animal welfare, instead of ABMs, to identify critical farms in terms of welfare by presenting the case of small-scale mountain dairy farms in the eastern Italian Alps.

Materials and methods

Farm selection and visits

WQ was used to measure dairy cow welfare in 46 farms in the Eastern Italian Alps (834 dairy cows and heifers). The target population was selected according to the known ratios of tie-stalls/loose-housing systems and the spread of traditional transhumance in mountain areas (Veissier *et al* 2008; Sturaro *et al* 2013), resulting in 80% of tie-stalls and transhumant systems and 20% loose-housing (ie free-stalls) and permanently indoor systems in the sample. All farmers were recruited through breed associations and were rearing dual-purpose breeds (ie Italian Simmental and Rendena). Two groups (23 vs 23 farms) in which different breeds were evenly allocated, were identified according to the definition of Ease of Movement described in WQ. The first group was considered tethered all year (TAY) because cows were tethered for more than 265 days. In the TAY group, six farms had permanent tethering systems whereas the other 17 tie-stall farms provided cows with access to summer pasture for less than 100 days. In the second group, cows were either tethered only during winter and had access to summer pasture for more than 100 days or were reared in a loose-housing system (TWiL) with or without access to pasture. More specifically, nine farms had a loose-housing system whereas all the other 14 tie-stall farms provided cows with access to summer pasture for more than 100 days. Three out of nine farms with a loose-housing system did not provide cows with access to pasture. Three observers with previous experience in dairy production were trained to implement the WQ for dairy cattle and tested for inter-observer reliability reaching at least substantial agreement (Landis & Koch 1977) in all ABMs considered for the study (Cohen's kappa for categorical variables or Spearman's rho for continuous measures > 0.6). Each observer visited 15, 15 and 16 farms, respectively, and a balanced number of TAY and TWiL farms. All farm visits took place from February to March, before the traditional summer transhumance to alpine pastures.

Welfare measures

Fifty ABMs and non-ABMs (Table 1) collected at herd level in the two husbandry systems, TAY and TWiL, were collected under strict adherence to WQ definitions and methodologies (Welfare Quality® 2009). With the exception of information on time of access to pasture/outdoor run, rates of dystocia, downer cows, mortality, disbudding/dehorning and tail-docking practices that were retrieved using a questionnaire, all remaining measures were collected on animals or on farm facilities. Recorded measures were aggregated into 12 criteria, four principles and into an overall welfare score (Welfare Quality® 2009). Animal-level measurements were collected according to WQ guidelines for sample size calculation. All animals were assessed in herds of 30 or less. Computation of scores followed a bottom-up approach where all measures taken at herd level were weighted by experts and aggregated into criterion scores, then into principle scores using a Choquet integral and finally into a farm overall welfare score (Welfare Quality® 2009). Possible values for criteria and principles ranged between 0 and 100. The WQ distinguished four classes for the overall welfare score according to the results obtained in the welfare principles: excellent when welfare was at the highest level (ie the farm scored more than 55 in all principles and at least 80 in two of them); enhanced when animal welfare was good (ie the farm reached more than 20 in all principles and at least 55 in two of them); acceptable when animal welfare met minimum standards (ie the farm was scored at least 10 in all principles and more than 20 in three of them) and not classified when welfare was unacceptable (ie the farm did not reach at least 10 in all principles).

Statistical analysis

Welfare principles, criteria and measures obtained from the computation were compared between the two groups using logistic regression (TAY vs TWiL). A False Discovery Rate strategy was followed in order to control for multiplicity, as multiple testing in a single study results in an increased probability of detecting significant findings just by chance (Benjamini & Hochberg 1995). Differences in the overall welfare scores between TAY and TWIL were assessed for significance using the Fisher's Exact Test. The second part of the study aimed at investigating welfare using purely ABMs

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Table 1 Principles, criteria, measures and type of the Welfare Quality® assessment protocol for dairy cows.

Welfare principles	Welfare criteria	Welfare measures	Type of measure
Good Feeding	Absence of prolonged hunger	**Very leans cows**	ABM
	Absence of prolonged thirst	Is the number of functioning drinkers sufficient and clean? Are there at least two drinkers per cow?	Non-ABM
Good Housing	Comfort around resting	Time needed to lie down Frequency of animals lying partly or completely outside the supposed lying area Frequency of collision with housing equipment during lying down **Cleanliness: udder; legs; flank**	ABM
	Thermal comfort	No measure has been developed yet	–
	Ease of movement	Is the cow tethered all year round (> 265 days)? Does the cow have regular exercise (1 h per day)?	Non-ABM
Good Health	Absence of injuries	**Hairless patches** (carpus, **tarsus, hind leg, side/udder, neck/shoulder)**; **lesions** (carpus, **tarsus**, hind leg, side/udder, neck/shoulder); **swellings** (carpus, **tarsus**, hind leg, side/udder, neck/shoulder); **lameness**	ABM
	Absence of disease	**Nasal discharge**, ocular discharge, hampered respiration, **coughing**, diarrhoea, **mastitis (somatic cell count)**, **vulvar discharge, dystocia, downer cows, mortality**	ABM
	Absence of induced pain	Dehorning, disbudding; use of analgesics, anaesthetics Tail-docking with rubber ring or surgery; use of analgesics, anaesthetics	Non-ABM
Appropriate Behaviour	Expression of social behaviour	Frequency of **head butts** and **displacements**	ABM
	Expression of other behaviours	Percentage of days per year with at least 6 h on pasture	Non-ABM
	Good-human animal relationship (GHAR)	Cows that can be touched (**GHAR1**), that can be approached closer than 50 cm (**GHAR2**), between 100 and 50 **(GAHR3)**, and above 100 cm (**GAHR4**)	ABM
	Positive emotional state	**Qualitative behaviour assessment (QBA)**	ABM

Animal-based measures (ABMs) retained for cluster analysis are displayed in bold.

and no information on resources and management. ABMs that were not seen in more than 90% of the farms were excluded from data analysis in order to avoid the development of clusters on the basis of rare conditions (eg hampered respiration was an uncommon condition, recorded in 4% of farms and, thus, excluded from data analysis). Cluster analysis was performed using the R package ClustOfVar (Chavent *et al* 2012) in order to put together variables which were bringing the same information based on a measure of homogeneity. Boostrap samples (n = 100) of the observations and the corresponding 100 dendrograms were obtained to define a stable partition. The number of stable clusters of ABMs was defined as the number of clusters that produced the larger mean of adjusted Rand index (Hubert & Arabie 1985). A principal component analysis (PCA) was first performed on the ABMs previously selected to reduce dimensionality with the condition, to lose as little information as possible by maximising the variance between components. Once the principal components, explaining up to 80% of the total observed variability (Lê *et al* 2008) within ABMs were obtained, a hierarchical clustering analysis of farms was performed using those principal components as input. The number of clusters was defined looking at the minimum growth of within inertia which is a measure of variance within clusters. A Kruskal-Wallis test was used to test clusters' farm descriptors for statistical differences. Provided significance, *post hoc* tests with Bonferroni-type adjustment were applied to seek which of the pair-wise comparisons were responsible for the overall difference. All statistical analyses were performed using R version 3.2.2 (R Core Team 2015).

Results

Welfare Quality® approach

The first part of this study investigated potential differences in welfare in two husbandry systems, TAY and TWiL using ABMs and non-ABMs identified by the WQ project. Within the TAY group, the mean (± SEM) number of cows per farm was 17 (± 1.9), the number of days on pasture for all farms in the group was 60 (± 8.3) and milk production when all lactation stages were included was 5,726 (± 303.4) kg per cow per year. Within the TWiL group, the mean number of cows per farm was 31 (± 6.7), the average number of days on pasture for all farms in the group was 117 (± 9.7) and the average milk production when all lactation stages were included was 4,661 (± 274.4) kg per cow per year.

Table 2 displays farm descriptors collected in TAY and TWiL farms and sorts them according to the overall welfare

Table 2 Overall welfare score and farm descriptors of TAY (cows tethered all year) and TWiL (cows tethered and having regular exercise or in loose-housing systems) farms chosen according to the definition of Ease of Movement (Welfare Quality® 2009).

Overall Welfare Score	Number of farms		Mean (± SEM) of cows per farm		Mean (± SEM) milk yield (kg per year per cow)		Mean (± SEM) number of days tethered		Mean (± SEM) number of days on pasture	
	TAY	TWiL	TAY	TWiL	TAY	TWiL	TAY	TWiL	TAY	TWiL
Not classified	0	3	–	100 (± 13.7)	–	5,298 (± 451)	–	0 (± 0)	–	120 (± 11.5)
Acceptable	18	13	19 (± 2.3)	18 (± 4.8)	5,711 (± 369)	4,283 (± 409)	314 (± 9.8)	178 (± 29)	51 (± 9.8)	117 (± 16.5)
Enhanced	5	7	11 (± 2.3)	25 (± 5.8)	5,777 (± 493)	5,088 (± 391)	274 (± 4)	139 (± 49)	93 (± 4)	105 (± 19.6)
Excellent	0	0	–	–	–	–	–	–	–	–

Table 3 Principles, criteria, measures of TAY (cows tethered all year) and TWiL (cows tethered and having regular exercise or in loose-housing systems) farms chosen according to the definition of Ease of Movement (Welfare Quality® 2009).

Principles/Criteria	TAY			TWiL		
	Median	Min	Max	Median	Min	Max
Good Feeding	45.6	24.0	64.8	40.8	5.4	64.8
Absence of hunger	40.0	11.6	99.9	19.0	8.2	99.9
Absence of thirst	60.0	32.0	60.0	60.0	3.0	100.0
Good Housing	26.4	15.5	34.6	42.4	29.4	81.7
Comfort around resting	48.4	16.4	72.6	52.1	26.7	70.9
Ease of movement*	15.0	15.0	15.0	34.0	34.0	100.0
Good Health	66.9	36.1	99.9	49.0	34.0	99.9
Absence of injuries	91.6	58.9	99.9	93.0	77.7	99.9
Absence of diseases	64.6	36.6	99.9	56.6	33.3	99.9
Absence of pain	100.0	20.0	100.0	28.0	20.0	100.0
Appropriate Behaviour	41.7	24.0	62.5	53.0	14.2	68.7
Social behaviour	99.9	50.4	100.0	96.4	63.9	100.0
Other behaviours	41.6	0.0	43.7	53.6	0.0	99.9
Good human-animal relationship	80.4	35.5	100.0	77.0	31.7	100.0
Positive emotions	48.8	15.7	84.2	45.1	9.6	84.3

* Not included in the analysis.

score obtained by each farm. No difference in terms of frequency of overall welfare score classes was found between TAY and TWiL (Fisher Exact Test; $P = 0.183$).

Similarly, no significant differences were found between TAY and TWIL when comparing welfare principles, criteria (Table 3) and measures (not shown).

Animal-based approach

As no differences were highlighted between TAY and TWiL, it was decided to seek meaningful groups of farms on the basis of ABMs only. Twenty-five ABMs out of 41 were retained for cluster analysis. The number of clusters that maximised the mean adjusted Rand index was 24, implying no real need to exclude additional ABMs from PCA. Principal component analysis identified eleven components which were used as inputs to develop a hierarchical clustering of farms. Four clusters of farms were deemed appropriate to describe our sample of mountain farms on the basis of ABMs (Table 4). Cluster 1 and 2 represented the most traditional alpine farms in terms of herd size, milk yield and days on pasture. Cluster 2 and 3 had the smallest mean herd size, 14 and 16 cows per herd, respectively. Cluster 3 encom-

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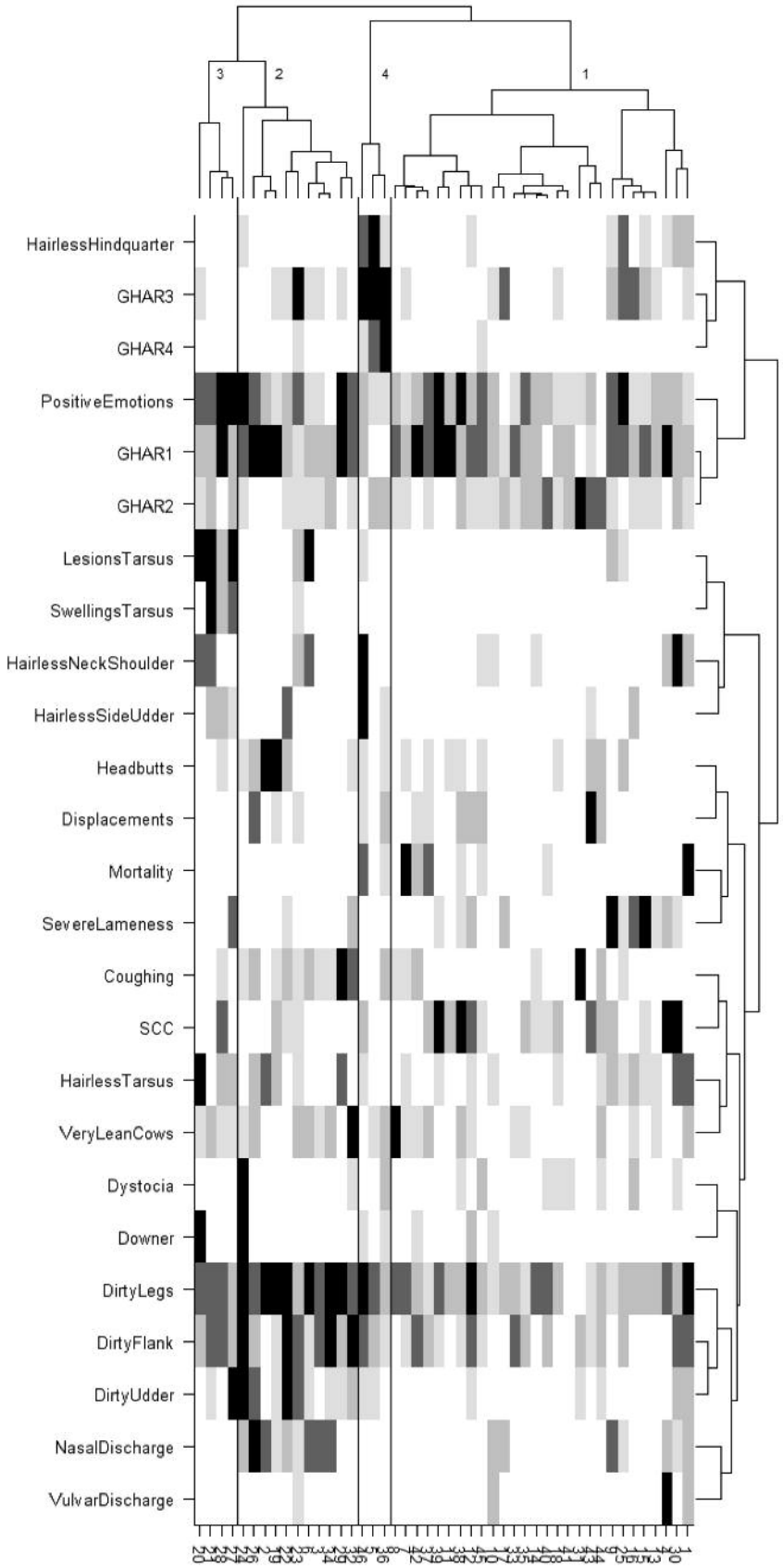
Table 4 Farm descriptors and animal-based measures mean values in four cluster of alpine dairy farms.

Farm descriptors	Cluster (mean) 1	Cluster (mean) 2	Cluster (mean) 3	Cluster (mean) 4
Number of farms	28	11	4	3
Mean number of cows per farm	26	14	16	54
Mean milk yield (kg per cow per year)	4,835[a]	4,932[a]	8,258[b]	5,402[ab]
Mean number of days tethered	207[a]	252[ab]	342[b]	115[ab]
Mean number of days on pasture	92	93	22	100
Animal-based measures				
Nasal discharge (%)	3.0	12.6	0.0	1.2
Vulvar discharge (%)	1.7	0.8	0.0	0.0
Dystocia (% last 12 months)	2.9	3.8	0.0	6.2
Downer cows (% last 12 months)	0.8	1.3	4.2	2.5
Mortality (% last 12 months)	1.7	0.0	0.0	4.3
Coughing (coughs per cow per 15 min)	2.3	3.9	1.0	7.3
Somatic cell count (% > 400,000 last three months)	10.8	2.4	3.8	4.0
Very lean cows (%)	14.1	20.1	19.8	19.0
Hairless patches tarsus (%)	10.5	13.1	24.0	4.0
Hairless patches hindquarter (%)	5.2	2.1	0.0	25.6
Hairless patches neck/shoulder (%)	2.7	2.4	8.3	8.0
Hairless patches side/udder (%)	1.5	3.0	10.3	13.6
Lesions tarsus (%)	0.5	2.4	13.7	1.3
Swellings tarsus (%)	0.5	1.8	26.2	0.0
Severe lameness (%)	4.0	1.5	3.4	0.0
Dirty legs (%)	52.6	85.7	64.3	74.8
Dirty flanks (%)	29.0	57.3	60.1	44.6
Dirty udder (%)	7.1	32.1	20.9	17.3
Frequency of headbutts	0.2	0.4	0.1	0.2
Frequency of displacements	0.1	0.1	0.0	0.1
Positive emotions score	46.0	49.3	68.0	37.4
Cows touched, GHAR1 (%)	65.6	75.9	72.6	31.5
Cows approached closer 50 cm, GHAR2 (%)	29.9	18.3	25.8	30.9
Cows approached between 50 and 100 cm, GHAR3 (%)	3.5	4.3	1.1	19.0
Cows approached over 100 cm, GHAR4 (%)	1.0	1.5	0.6	18.6

[a, b] Farm descriptors' differences in Kruskal-Wallis test followed by Bonferroni's *post hoc* comparison ($P < 0.05$)

Figure 1



Heatmap displaying results of cluster analysis performed on ABMs (rows) and farms (columns). Five levels of shading (white to black) based on a 20% increment of occurrence were used for each welfare condition (positive or negative) in the corresponding farm. Dendrogram branches were named according to the farm cluster number.

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passed cows with high milk yields (significantly different from cluster 1 and 2; $P = 0.006$ and $P = 0.018$, respectively) and mostly permanent tethering housing system (significantly different from cluster 1; $P = 0.039$). Cluster 4 was made of three farms with the greatest mean herd size and with the shortest mean time spent tethered. Results of cluster analysis are displayed in a heat map (Figure 1) which is a cross-tabulation of cluster of farms and ABMs. The main feature of cluster 1 in comparison to the others was a moderately high rate (10.8%) of cows with somatic cell count (SCC) above 400,000 cells ml^{-1}. The main feature of cluster 2 is a moderately high rate (12.6%) of cows displaying nasal discharge. Additionally, the frequency of headbutts expressing agonistic behaviours was the highest (0.4) among all clusters. Cluster 3 is characterised by moderately high mean prevalence of integument alterations on the tarsal region expressed as hairless patches (24%), lesions (13.7%) and swellings (26.2%). Highly positive patterns were observed on measures related to health status as no signs of nasal discharge, vulvar discharge, dystocia and mortality on-farm were reported. Positive emotional state and good human-animal relationship were also considered important features of cluster 3. Main features of cluster 4 were integument alterations related to hairless patches found on the side/udder and the hindquarter and poor behavioural and human-animal relationship. Positive emotions score (37.4) was reported to be the lowest throughout the clusters. Almost 40% of the cows could not be approached at all (over 100 cm; GHAR4) or approached between 50 cm and 1 m (GHAR3) when tested for a good human-animal relationship. Additionally, high rates of dystocia (6.2%) and episodes of coughing (7.3%) were observed on farms belonging to cluster 4.

All clusters showed poor conditions in terms of cleanliness. More than 50% of animals in all clusters had dirty lower legs, ranging from 52.6% in cluster 1 to 85.7% in cluster 2. Udder cleanliness conditions ranged from 7.1% of dirty udders in cluster 1 to 32.1% of dirty udders in cluster 2. High rates of very lean cows were also observed in all clusters (range: 14.1–20.1%).

Discussion

When the Welfare Quality® protocol was applied to a sample of mountain dairy farms it proved unable to highlight differences in terms of welfare between cows considered tethered all year round (TAY) and cows in a tie-stall system with regular exercise or in a loose-housing system (TWiL). Despite growing concerns regarding permanent tethering, all farms in the TAY group reached an 'acceptable' level of welfare, whereas three with loose-housing systems (TWiL group) resulted 'not classified' as a result of their unacceptable levels of welfare. However, it is worth considering that 'enhanced' levels of welfare were achieved only in those farming systems practicing the summer transhumance to highland pastures and belonging to both TAY and TWIL groups. In this regard, the threshold of 100 days on pasture seems inappropriate for discriminating housing systems (TAY vs TWiL) and inform welfare scores given that the length of access to summer pasture is dependent upon the length of the vegetative season (ie about 90 days in the Italian Alps). On the other hand, an ABMs approach, as suggested in the second part of this study, may help farmers and welfare specialists in identifying and addressing specific animal welfare issues irrespective of the housing system involved. As shown by clusters 1 and 2 (Figure 1, Table 4), good levels of welfare may be reached in most tie-stall farms which provide cows with an average of 90 days of access to highland pastures when comparing animal-based measures collected in this study with those found in the literature. In fact, several studies investigated welfare of dairy cows both in loose-housing and tie-stall systems (Burow *et al* 2013; Popescu *et al* 2013; de Vries *et al* 2015), some focused upon mountain regions or low-input systems (Regula *et al* 2004; Mattiello *et al* 2005; Corazzin *et al* 2010; Kirchner *et al* 2014) and one targeted small-scale farming systems (EFSA 2015). In our study, the main signs of disease associated with dairy production (Oltenacu & Broom 2010) displayed lower than usual mean prevalence. Severe lameness ranged between 0 and 4.2% while the mean prevalence of lameness is deemed to be around 20% (Burow *et al* 2013; de Vries *et al* 2013; Popescu *et al* 2013). Severe lameness is generally less prevalent in tie-stall systems (Sogstad *et al* 2005) and was also reported at lower rates (Corazzin *et al* 2010; Mattiello *et al* 2011) in other mountain farming systems rearing dual-purpose and low-yielding breeds. Swellings and lesions were reported at rates that ranged between 11 (Popescu *et al* 2013) and 43% (de Vries *et al* 2013) whereas we observed prevalences that ranged between 0.5 and 26.2%. This finding might be related to differing productivity levels associated with breed type and is supported by similar results presented by Mattiello *et al* (2011). In fact, higher swelling and lesion rates (26.2 and 13.7%, respectively) were observed in cluster 3 where the highest milk yields (significantly higher than milk yields in clusters 1 and 2) were reported. In our study, high SCC were recorded in 2.4 and 10.8% of cows while being reported to be between 6 and 14% of cows by Popescu *et al* (2013) and 8 and 13% by de Vries *et al* (2013). Moreover, SCC expressed as the mean bulk-milk value (198,092 cells ml^{-1}) was also lower than that reported by Bovolenta *et al* (2008, 2009) and Romanzin *et al* (2013) in dairy cows reared in mountain areas. Despite higher SCC being reported in farms with poor conditions of cleanliness (Dufour *et al* 2011) which were a concern in all clusters and in similar studies regardless of the housing system, cluster 1 had high SCC prevalence but good udder cleanliness levels (warning threshold for high SCC was set at 19% of cows per herd by de Vries *et al* 2014). Mean rates ranging between 14.1 and 20.1% of very lean cows were observed in our study. Our values were higher than those reported elsewhere which were spanning between 3 (de Vries *et al* 2013) and 17% (Burow *et al* 2013). This finding might be due to the fact that in transhumant systems calving is usually planned to happen during winter resulting in more cows at peak lactation during late-winter/early-springtime, when our study was performed.

Cluster 3, with its small farms (ie mean herd size), with higher milk yields and little access to pasture showed the best outcomes in all behavioural measures. Upper-end values in good human-animal relationship (GHAR1) and ranging between 65.6 and 75.9% for cows accepting contact with humans were seen in all smaller farms and mainly in tie-stall systems, such as those represented by clusters 1, 2 and 3. This finding is consistent with the fact that better human-animal relationship is more common when frequent interactions between cows and stockpeople are maintained (Uetake *et al* 2002). However, high values in both positive emotional state (ie qualitative behaviour assessment; QBA) and GHAR were also reported in organic and low-input Spanish farms (Kirchner *et al* 2014) and in herds with prolonged (120–300 days) access to pasture (EFSA 2015). Positive findings on behavioural measures in such a wide variety of husbandry systems could emphasise the role of management skills and knowledge, elevating it above the farm's physical resources in terms of determining good animal welfare outcomes (Fraser 2014). This could also explain why the frequency of agonistic behaviours, which are inversely related to good social outcomes (ie the lower the frequency, the better the score) was lower in cluster 3 than was reported by Popescu *et al* (2013) in other tie-stall systems with and without regular exercise. Mean frequency of headbutts per cow per hour in all-year tie-stall systems in Romania was reported to be 0.52 whereas mean frequency in cluster 3 (where cows were tethered for longer time) was 0.1. Similarly, frequency of displacements was more than ten times lower in cluster 3 compared to the findings of Popescu *et al* (2013). However, agonistic behaviours were recently removed from the protocol for small-scale farms for being too time-consuming in such a context (EFSA 2015). In addition to the time issue, measures taken from small-scale farms may be misleading in terms of the real occurrence and prevalence of targeted conditions in those herds, as they could represent the condition of a single animal more than the actual prevalence of the condition in the herd. To avoid the issue, several studies select herds with a minimum size of 30 (Ostojić-Andrić *et al* 2011; Popescu *et al* 2013) which would, however, exclude most farms located in mountain areas from the analysis. Repeated assessments would therefore be beneficial in order to identify recurrent issues in small-scale farms. Moreover, as already suggested by Weary *et al* (2016), a wider stakeholder involvement aimed at understanding and incorporating the general public's animal welfare concerns into science-based assessment methodologies would contribute to creating a more comprehensive and thereby effective approach to improving dairy cow welfare.

Animal welfare implications and conclusion

Welfare data collected in this study suggested that tie-stall systems do not necessarily produce negative welfare outcomes. The pressure for welfare improvement in the dairy sector should not focus simply on banning tethered systems but on identifying specific welfare issues through the collection of relevant ABMs. In fact, the case of small-scale mountain farms showed how resource-based measures, such as Ease of Movement and related thresholds for acceptability (ie at least 100 days of access to pasture) were not useful in discriminating critical farms in terms of welfare. Conversely, a selection of ABMs was helpful for clustering farms according to their major welfare characteristics. In a second step of the on-farm welfare assessment process, non-ABMs could play a role as potential risk factors to be investigated in order to correct those management practices negatively affecting dairy cow welfare.

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