

Impact of linear-type traits measured at first lactation on the productive life of Holstein cows

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ABSTRACT - The objective of this study was to identify how linear-type traits impact the culling risk and which traits are most associated to productive life of Holstein cows. Linear classification and test-day milk yield data of 34,653 primiparous cows obtained from the database of Associação Paranaense de Criadores de Bovinos da Raça Holandesa were used. Survival analysis was performed by PHREG procedure of SAS/STAT 9.4 using a Cox regression model. The model considered herd and year of the linear classification (2010 to 2019) as fixed effects and the linear effects of 305-day cumulative milk yield in first lactation (kg), age at first calving (months), the individual traits, and final score as covariables. Cows with intermediate rump angle (score 6) had the lowest culling risk. The culling risk for cows with inverted rumps (score 1) was four times greater than for cows with inclined rump (score 9). Females with moderately curved rear legs, side view, were more likely to remain for a longer period in the herd. Cows with extremely high and strongly attached udders had the lowest culling risk (1.0). Classification at first calving may be a strong indicator of long productive life of Holstein cows. Females rated as Good Plus or Very Good tend to remain in the herd longer. The traits of the mammary system have the most impact on the length of productive life.

Keywords: linear classification, longevity, survival analysis

1. Introduction

Currently, one of the objectives in dairy cattle breeding is to identify early and select animals capable of surviving and performing well in the face of the environmental challenges. The productive life of Holstein cows in many countries ranges from 2.5 to 7 years (Brazil, Paraná State: 5.3 years – Vernaschi et al., 2022; Canada: 6.8 years – Van Doormaal, 2009; Poland: 3.2 years – Adamczyk et al., 2017). According to Grandl et al. (2016), healthy cows reach their productive maturity in the fifth lactation. Therefore, it is important for the female to remain in the herd for at least seven years.

According to many studies (Veerkamp and van Pelt, 2019; Adamczyk et al., 2021; Grzesiak et al., 2022; Williams et al., 2022), involuntary culling is the major challenge of dairy farmers because it has a huge impact on breeding progress and generates costs correlated with replacement heifers, which represents a large portion of the investment made on the dairy farm. According to Grzesiak et al. (2022), the analysis of longevity of dairy cows has emerged as a prominent research focus in recent years.

The length of productive life (LPL), defined as the total number of days between first calving and last milk record, is an important economic factor in dairy production systems since it directly affects the profitability of dairy farms. For this reason, LPL has been included as a selection criterion in animal breeding programs (Miglior et al., 2017; Nascimento et al., 2023).

Heritability coefficients for longevity generally show a low magnitude, probably because multiple factors influence this complex trait. Thus, the genetic progress obtained by direct selection is small and slow, a fact that justifies the use of indirect selection for LPL. Some linear traits, such as rear udder height, teat length, udder depth, and udder support, showed a direct relationship with longevity (Cruikshank et al., 2002; Williams et al., 2022). When evaluated during first lactation, linear traits can be used as early predictors for the identification of long-lived cows (Caraviello et al., 2003; Nascimento et al., 2023), providing higher genetic gains in longevity by identification of best animals.

According to Ducrocq (2005), survival analysis is a statistical methodology used to study the timing and occurrence of an event, defined as a qualitative change (transition from one state to another) that can be situated in time. The Cox proportional hazards regression model (Cox, 1972) is the most widely used to study the influence of risk factors on survival time. This analysis enables the examination of the animal's lifespan, in which the response is the time until the occurrence of an event of interest, adjusted for covariates.

Therefore, the objective of this study is to determine whether linear-type traits in the first calving can be an indicator of a long productive life in Holsteins cows. Additionally, the goal of the study was to identify which linear trait is the most associated to longevity using the Cox regression model.

2. Material and methods

Linear classification and test-day milk yield records of 34,653 first-lactation cows that had calved between 2010 and 2019 were provided by the Associação Paranaense de Criadores de Bovinos da Raça Holandesa (Paraná Holstein Cattle Breeders Association; APCBRH), Paraná State, Brazil. Only herds greater than 50 cows, located in the center-eastern region of Paraná, in municipalities of Castro, Carambeí, Arapoti, and Witmarsum were considered in the analyses because of their similar production systems. Linear classifications of cows from 319 commercial herds were considered. Unfortunately, the database did not contain information on who performed the linear classification of the animals. However, this effect is nullified because the animals in the same herd were classified by the same evaluator, and this effect was included in the contemporary group definition.

As recommended by Pritchard et al. (2012), cows with lactations shorter than 200 days and longer than 700 days were excluded from the dataset. All traits of the four sections of the Canadian linear classification system (1 to 4) (Valloto and Ribas Neto, 2012), were included, in addition to the final score (5) (Table 1).

Table 1 - Four sections of the Canadian linear assessment and the final score classes

Section of linear classification				
Rump	Dairy strength	Feet and legs	Mammary system	Final score classes
Rump angle (RA)	Stature (STA)	Foot angle (FA)	Fore udder attachment (FUA)	Poor (50 to 64 points)
Rump width (RW)	Top line (TL)	Heel depth (HD)	Fore teat placement (FT)	Fair (65 to 74 points)
Loin strength (LS)	Chest width (CW)	Bone quality (BQ)	Teat length (TL)	Good (75 to 79 points)
	Body depth (BD)	Rear legs side view (RLSV)	Udder width (UW)	Good plus (80 to 84 points)
	Angularity (ANG)	Rear legs rear view (RLRV)	Rear teat placement (RT)	Very good (85 to 89 points)
			Udder depth (UD)	Excellent (90 to 97 points)
			Udder texture (UT)	
			Median ligament (ML)	

The scores were summed, and a weight was assigned to each trait. The final score was determined by considering the weights for each trait as the Canadian linear assessment. Additionally, the culling risk was determined for each final score.

Animals with a final score from 64 to 71 points were excluded from the dataset because of the small number of animals in each class. It should be noted that the data used refer to the first linear classification of first-lactation cows, and the dry period was disregarded. Because of the objective was to identify which linear-type trait in the first calving can be an indicator of a long productive life in Holsteins cows, only the classification performed at the first calving was used.

The LPL was defined as the total number of days of lactation and the last milk record of the female (the dry period was not considered). In addition, to verify if the cows classified in the first lactation remained in the herd for more than three lactations, LPL was calculated based on the animal's total lactations. Long-lived cows are those with a lactation history of three or more lactations. To proceed the survival analysis, the females that succeeded, meaning they were not culled and reached their third calving, were assigned a status of 0 (uncensored), while those culled during the first or second lactation were assigned a status of 1 (censored) (Hardie et al., 2021).

Survival analysis was performed with the PHREG procedure of the SAS/STAT software (Statistical Analysis System, version 9.4) using the following Cox regression model:

$$\lambda(t) = \lambda_0(t)g(x'\beta), \quad (1)$$

in which $\lambda(t)$ = failure rate, t = time (days), $\lambda_0(t)$ = nonparametric component, and $g(x'\beta)$ = non-negative function, calculated as:

$$g(x'\beta) = \exp\{x'\beta\} = \exp\{\beta_1 x_1 + \dots + \beta_p x_p\}, \quad (2)$$

in which β = vector of parameters associated with the covariates [individual linear trait (22 traits), sections of linear classification (rump, dairy strength, feet and legs, and mammary system), and final score].

The following effects were included as fixed effects: herd and year of classification (2010 to 2019); and the linear effect of 305-day cumulative milk yield in first lactation (kg), age at first calving (months), individual linear trait, and final score were included as covariables. In addition, to avoid the effect of multicollinearity among traits, survival analysis was performed individually for each linear trait (e.g., each score as one level, i.e., 1-9). For the final score of each section, a level was considered for each number. (i.e., 64-92).

Thus, according to the PHREG procedure, if a cow has a culling risk, $\lambda(t)$, of 2, this animal is two times more likely to be culled than the reference animal in the analysis with a culling risk, $\lambda(t)$, of 1.

For comparison, animals with $\lambda(t)$ of 1 were the ideal score for each trait (Table 2).

3. Results

The mean values for some linear traits (Table 2) were not close to the ideal scores (true type model) according to the Cox Model. Only the mean values of rump angle, foot angle, rear legs side view, stature, body depth, and body condition score obtained for Herd, Status 1 and Status 0 were close to the ideal score, indicating that priority has been given to these linear traits in dairy herds in the present study.

The mean values of all traits were similar for censored (Status 1) and uncensored (Status 0) animals. However, the mean values obtained for cows with more than three calvings, Status 0, were higher compared with the overall mean of the herd (Table 2).

In this study, cows with a long productive life remained in the herd, on average, for 1,374 days. On the other hand, females with a short productive life remained in the herd, on average, for only 784 days.

Table 2 - Mean and standard deviation of linear type traits in primiparous Holstein cows

Trait	Classified cows (database)	Status 1 (censored)	Status 0 (uncensored)	Ideal score ¹
Rump				
Rump angle	5.03 ± 1.07	5.04 ± 1.12	5.02 ± 1.01	5
Rump width	6.30 ± 1.36	6.33 ± 1.42	6.26 ± 1.29	9
Loin strength	6.20 ± 1.38	6.26 ± 1.44	6.14 ± 1.31	9
Final section score	81.20 ± 3.28	82.43 ± 2.79	82.28 ± 2.95	
Feet and legs				
Foot angle	6.17 ± 0.98	6.20 ± 0.96	6.13 ± 0.99	7
Heel depth	5.74 ± 1.43	5.82 ± 1.46	5.66 ± 1.40	9
Bone quality	6.82 ± 1.40	6.86 ± 1.46	6.77 ± 1.33	9
RLSV	5.12 ± 1.13	5.11 ± 1.15	5.13 ± 1.10	5
RLRV	6.13 ± 1.58	6.24 ± 1.63	6.02 ± 1.53	9
Final section score	81.76 ± 2.84	81.74 ± 2.75	82.08 ± 2.73	
Mammary system				
Fore udder attachment	4.98 ± 1.91	4.90 ± 1.22	5.07 ± 1.56	9
Fore teat placement	7.02 ± 1.28	6.99 ± 1.35	7.06 ± 1.20	5
Teat length	6.34 ± 1.49	6.39 ± 1.55	6.28 ± 1.43	5
Udder width	6.18 ± 1.67	6.18 ± 1.71	6.17 ± 1.63	9
Udder height	4.83 ± 0.99	4.84 ± 1.03	4.82 ± 0.95	9
Rear teat placement	6.16 ± 1.42	6.07 ± 1.48	6.24 ± 1.35	5
Udder depth	6.43 ± 1.50	6.51 ± 1.52	6.35 ± 1.47	5
Udder texture	5.96 ± 1.06	5.99 ± 1.08	5.92 ± 1.04	9
Median ligament	4.98 ± 1.03	4.94 ± 1.09	5.01 ± 0.96	9
Final section score	81.50 ± 2.87	82.56 ± 2.33	82.76 ± 2.33	
Dairy strength				
Stature	6.65 ± 1.19	6.63 ± 1.23	6.68 ± 1.15	7
Top line	4.90 ± 0.88	4.89 ± 0.91	4.91 ± 0.83	7
Chest width	5.77 ± 1.05	5.82 ± 1.07	5.72 ± 1.04	7
Body depth	6.34 ± 0.86	6.37 ± 0.87	6.30 ± 0.86	7
Angularity	6.72 ± 1.32	6.74 ± 1.40	6.71 ± 1.23	9
Body condition score	3.03 ± 0.41	3.07 ± 0.42	2.99 ± 0.39	2.5 - 3
Final section score	83.32 ± 2.17	84.09 ± 1.93	83.85 ± 2.02	
Final score	81.57 ± 2.30	81.58 ± 2.36	81.56 ± 2.25	

RLSV - rear legs side view; RLRV - rear legs rear view; Status 1 - cows that were culled in the first or second calving; Status 0 - cows with more than three calvings.

¹ Ideal score based on Canadian Linear Classification.

3.1. Final score section

Primiparous cows with a final linear score from 80 to 84 points had the lowest culling risk (0.5). These results indicate that low (< 77) or high (> 88) final scores in first lactation do not indicate a long productive life and that cows classified as fair (final score of 80 to 84 points) remain in the herd for a long period (Figure 1). On the other hand, females with low final scores (56 to 65 points) had a 1.35 times higher risk of being culled than those with intermediate scores.

3.2. Rump traits

Regarding the rump traits (rump angle, rump width, and loin strength), cows with score 5 were less likely to be culled (hazard ratio of 0.5, 0.6, and 0.5, respectively) (Table 3). Cows with sloping rump (RA = 9) and extremely narrow rump (RW = 1) had 2.0 and 1.3 times more risk of being culled, respectively (Table 3). In the present study, cows with extremely sloped rumps had 2.0 times higher risk of being culled than those with intermediate values (score 5).

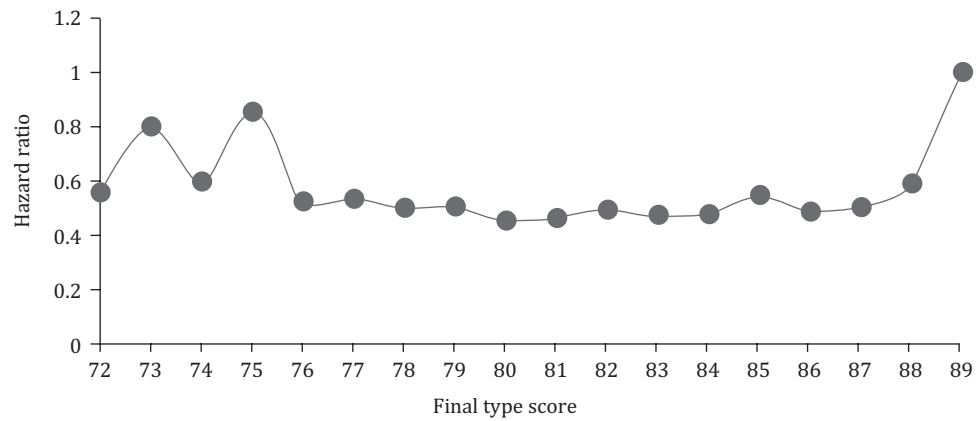


Figure 1 - Culling risk according to final linear classification score in primiparous Holstein cows.

Table 3 - Risk of culling according to scores for rump, dairy strength, and feet and legs traits in primiparous Holstein cows

Linear type	Score								
	1	2	3	4	5	6	7	8	9
Rump									
Rump angle	0.5	1.3	1.3	1.0	1.0*	0.9	1.4	1.3	2.0
Rump width	1.3	0.7	0.8	0.8	0.6	0.7	0.7	0.8	1.0*
Loin strength	0.9	0.6	0.7	0.6	0.6	0.6	0.6	0.7	1.0*
Dairy strength									
Stature		1.1	1.1	1.5	1.2	1.2	1.0*	0.9	1.3
Top line	0.9	1.0	1.0	0.9	0.9	0.9	1.0*	1.3	1.7
Chest width		0.8	0.9	0.9	0.8	0.9	1.0*	1.1	1.6
Body depth	15.5	5.5	0.8	1.0	0.8	0.8	1.0*	1.2	0.8
Angularity	7.5	1.0	1.5	1.2	0.8	0.7	0.8	0.8	1.0*
Feet and legs									
Foot angle	1.1	0.5	0.7	1.0	0.9	1.0	1.0*	1.0	2.0
Heel depth	0.3	0.4	0.7	0.7	0.6	0.7	0.8	0.8	1.0*
Bone quality	3.3	1.0	0.9	1.0	0.7	0.7	0.7	0.9	1.0*
RLSV	1.4	1.2	1.2	1.2	1.0*	0.9	1.2	1.0	1.1
RLRV	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.6	1.0*

RLSV - rear legs side view; RLRV - rear legs rear view.
The values with * represent the reference score.

Cows with a final section score of 82 for rump traits had a lower risk of being culled (0.7) than those receiving score 89 (Figure 2). On the other hand, cows with a score 67 were more likely to be culled early (3.0).

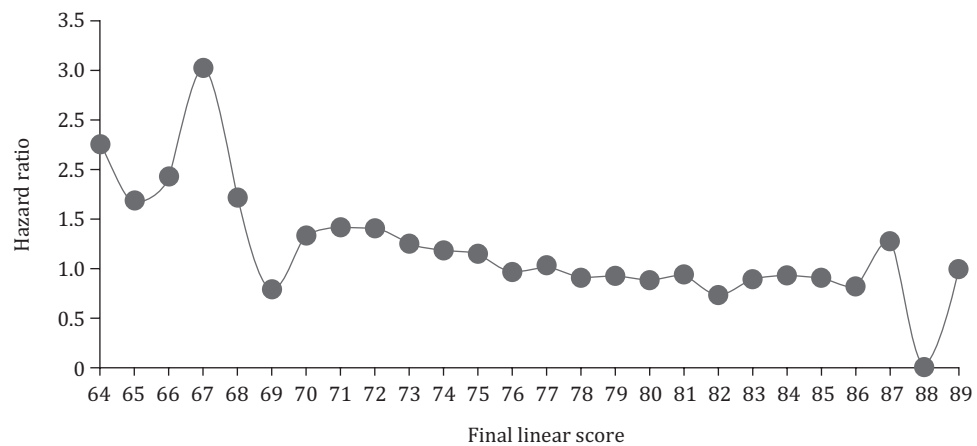


Figure 2 - Culling risk according to final section score for rump traits in primiparous Holstein cows.

3.3. Dairy strength traits

Individual analysis of dairy strength traits showed that body depth and angularity were associated with a higher culling risk (Table 3). Cows with high stature (score 9) were more likely to be culled (1.3).

Primiparous cows with an even and well aligned topline (score 5) and intermediate chest width (score 5), as well as angular cows (scores 5, 6, and 7), were more likely to remain in the herd. Moreover, cows with an extremely shallow body depth (score 1) had 15.5 times higher risk of being culled than deep cows (score 7) (Table 3).

Primiparous cows with a final section score of 70 for conformation traits had a three times higher risk of being culled than those with score 92. The lowest culling risk (0.8) was observed for Holstein cows with scores 81 and 82 (Figure 3).

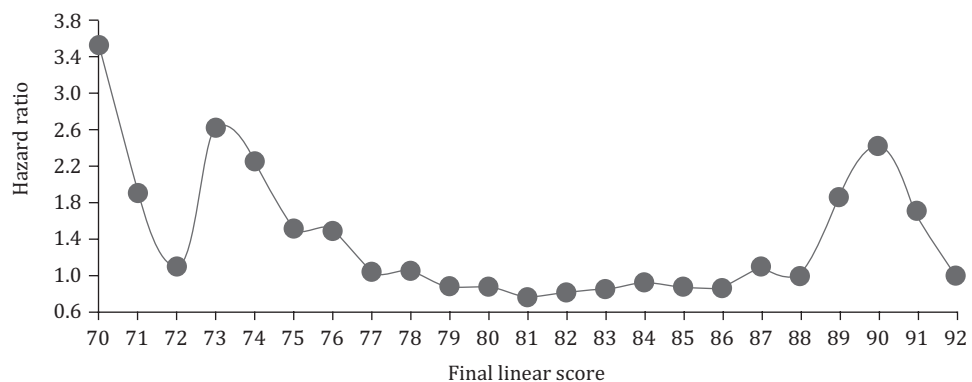


Figure 3 - Culling risk according to final section score for dairy strength traits in primiparous Holstein cows.

3.4. Feet and leg traits

First-lactation cows showed a hazard ratio from 0.3 to 3.3 (Table 3). The greatest amplitude was observed for bone quality, highlighting those animals with score 1 that had a 3.3 times higher risk of being culled than animals with reference score 9. Regarding foot angle (FA), females scored 2 to 5 had the lowest culling risk (0.3 and 0.4, respectively), indicating that cows with intermediate FA are more likely to remain in the herd for a longer period. Heel depth, the lowest culling risk (0.3) was observed for females with score 1 compared with the other cows. Primiparous cows not scored with 5, 6, or 7 for bone quality had the lowest culling risk (0.7), indicating that structured cows or cows thinner at the hocks had a longer productive life.

Holstein cows with moderately curved rear legs side view of the hocks (scores 5 and 6) had the lowest culling risk (1.0 and 0.9, respectively). Regarding rear legs rear view, scores 5 and 6 were associated with the lowest culling risks rather than score 9, classified as ideal. The primiparous females with these scores are probably being selected more frequently. So, the trait rear legs posterior view was not a primary reason for culling.

Holstein cows with a final section score for feet and leg traits from 77 to 84 points had the lowest culling risk (0.5), indicating that females with legs intermediately curved, a moderate foot angle, and plane and strong bones remain in the herd for a long time (Figure 4).

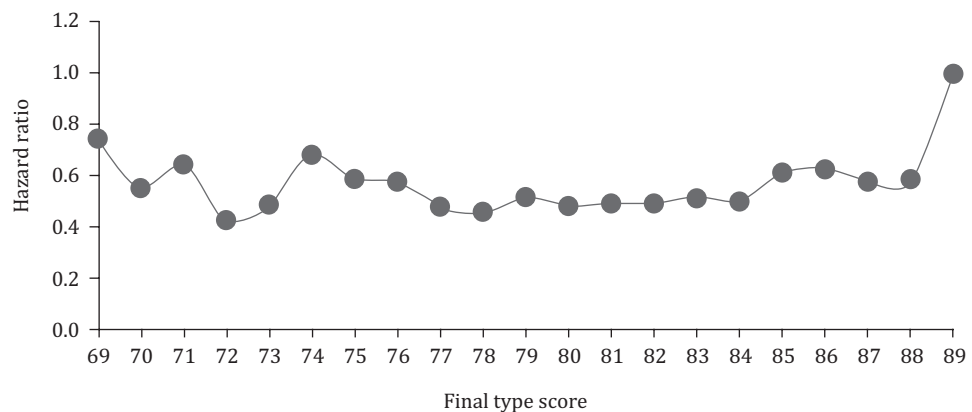


Figure 4 - Culling risk according to final section score for feet and leg traits in primiparous Holstein cows.

3.5. Mammary traits

The mammarian system traits evaluated in this study (Table 4) showed greater variations in culling risk, with a larger number of hazard ratios higher than 1.0. Females scored 7 for fore udder attachment had the lowest culling risk (0.8), indicating that cows with an udder that shows strong attachment to the abdomen remain in the herd for a long period of time. However, cows with weak fore udder attachment have high culling risk (1.7). Analysis of teat length showed the lowest culling risk (1.0) for cows with scores 5 and 6. Regarding fore teat placement, the highest culling risks were observed for cows with scores lower than 5 (Table 4). This trait showed the most visible oscillations in culling risk.

Females with extremely high udders (UH = 9) had the lowest culling risk (1.0) (Table 4) and probably have a high milk production capacity and a long productive life. Low hazard ratios (0.8 and 0.9) were also observed for primiparous females with intermediate udder width (scores 4 to 8). Cows with intermediate udder width showed the lowest culling risk (1.0). On the other hand, cows with extreme score (9) presented the highest culling risk (1.5), indicating that primiparous with shallow udders stay in the herd less.

Regarding median ligament, the hazard ratios for scores 4 to 8 were ≤ 1.0 (reference value for 9). However, cows with an extremely weak median ligament (scores 1 to 3) were more likely to be culled early. With respect to udder texture, females with a fleshy udder (score 2) were 1.3 times more likely to be culled than those with an extremely soft udder (score 9). Primiparous females scored 1 for median ligament had the highest culling risk (1.4). Cows that received score 6 to 8, close to the ideal (score 9), exhibited the lowest culling risk, suggesting that females with a good mammary system remain longer in the herd.

Cows with a final section score of 69 for mammary system traits had the highest culling hazard (1.3), while those with final section scores of 80, 81, 82, 83, and 84 had the lowest risks (Figure 5), i.e., the hazard ratio decreased with increasing final classification. Therefore, these cows are more likely to remain longer in the herd.

Table 4 - Culling risk according to scores for mammary system traits in primiparous Holstein cows

Linear type	Score								
	1	2	3	4	5	6	7	8	9
Fore udder attachment	1.6	1.5	1.3	1.0	0.9	0.9	0.8	1.0	1.0*
Fore teat placement	6.2	2.1	2.1	1.5	1.0*	0.9	0.8	0.8	1.0
Teat length	1.0	1.0	1.2	1.2	1.0*	1.0	1.1	1.1	1.7
Udder width	1.9	1.0	1.0	0.9	0.8	0.9	0.8	0.9	1.0*
Udder height	1.1	1.1	1.3	1.1	1.1	1.2	1.8	1.7	1.0*
Rear teat placement	1.5	1.5	1.4	1.2	1.0*	0.9	0.9	0.9	1.1
Udder depth	1.0	1.0	1.0	1.1	1.0*	1.0	1.1	1.3	1.5
Udder texture	-	1.3	0.8	0.8	0.8	0.8	1.0	1.0	1.0*
Median ligament	1.4	1.2	1.1	0.9	0.8	0.7	1.0	0.7	1.0*

The values with * represent the reference score.

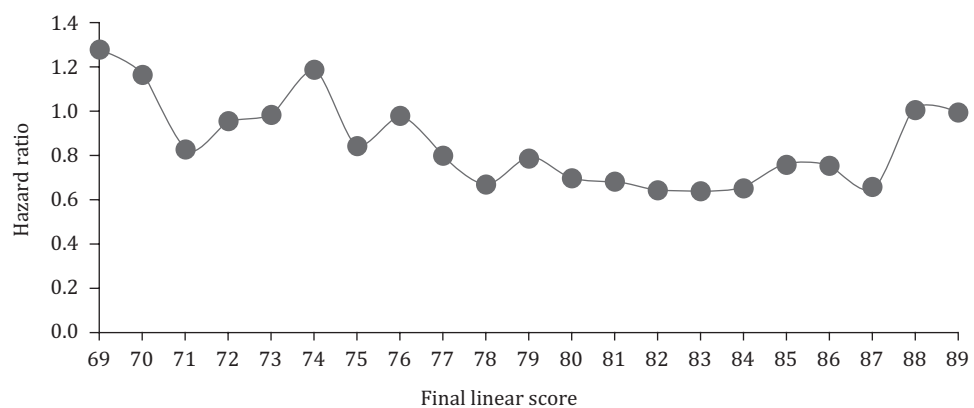


Figure 5 - Culling risk according to final section score for mammary system traits in primiparous Holstein cows.

4. Discussion

The importance of longevity in breeding programs has been increasing over the years (De Vries, 2017), and as a result, it has been included in selection indices worldwide (Van Doormaal, 2009). According to Lawlor (2017), the use of traits that reflect longevity in selection indices is essential, as it will provide greater economic return to the farm by reducing involuntary culling in the herd.

In the mid-1960s, breeders started to use linear-type traits as indicators of longevity and characteristics of economic interest in dairy cows because it is easily measured at the beginning of the animals' productive life, and heritability estimates are high. In the modern dairy industry, culling due to old age in Holstein cows is very rare. Longevity is linked to the economic performance of farms, the environmental footprint of the dairy industry, and animal welfare (Grandl et al., 2016). Thus, short longevity limits the potential of the dairy industry to become a more sustainable and functional activity (Dallago et al., 2021).

In the present study, Holstein cows with final score 80 to 84 remained in the herd for a long period as reported by Caraviello et al. (2003), in which primiparous Jersey cows with a high final score had a 0.8 times higher risk of being culled than cows with intermediate scores (71 to 75 points).

For the traits of the rump compound, cows with sloping or inverted rumps showed the highest culling risks, and this could be related to dystocia. A study with Jersey cattle in the United States indicated a relationship between involuntary culling and linear scores for rump angle (Caraviello et al., 2003), indicating that at the time of calving, the cow needs to express its maternal ability, and calving ease is essential for dairy cows.

In this study, the results indicated that cows with medium stature remained in the herds. This probably reflects the preference of producers for cows with score 7, since taller and heavier animals have greater nutritional requirements. Typically, taller cows are less efficient compared with smaller ones. Similar findings were reported by Sewalem et al. (2004), Atkins et al. (2008), and Zavadilová et al. (2011), despite the different production systems used in these studies. However, these authors noted that stature is not a reliable indicator of longevity, as it is directly associated with voluntary culling. Strapáková et al. (2021) found that the lowest culling risk occurred in cows measuring between 152 and 158 cm in height. Additionally, Kern et al. (2015) highlighted that very tall cows are being culled in Brazilian herds, reflecting a demand for more efficient animals. Based on the negative correlation between longevity and frame size, Novotny et al. (2017) proposed that cows with a smaller body frame may influence a genetic predisposition for a longer productive life.

Caraviello et al. (2003) and Sewalem et al. (2004) suggested that small cows with long legs and shallow body depth survive less in the herd. In a recent study, Török et al. (2021), in Hungary, found that cows with medium body depth (scores 5 and 6) had a lower risk of being culled than deep and extremely deep cows (scores 8 and 9), because it is related to the respiratory and digestive capacity of the animal.

Cows with tendency to accumulate body fat (non-angular females), generally have low milk yields and shorter lactations (Valloto and Ribas Neto, 2012), consequently remaining in the herds for a shorter period. According to Sewalem et al. (2004), angular cows (scores 5 to 8) are the most long-lived, in agreement with the present study. Zavadilová et al. (2011), in the Czech Republic, reported that more angular cows survived less in the herds due to the association between angularity and involuntary culling. Excess angularity may indicate a greater negative energy balance of the animals, a fact that would explain the lower culling risks for scores 5, 6, and 7 in the present study.

Mammary system and feet and leg traits have the greatest impact on the functional longevity of Holstein cows (Atkins et al., 2008), since the animals must have a good body structure to support the high milk production (Almeida et al., 2017), as well as the ability of constant locomotion, either to feed in grazing systems or to walk to the milking parlor.

For Fleckvieh cows, Strapáková et al. (2021) reported similar results because cows with score 9 for bone quality present the lowest culling risk (0.851). One explanation is the negative genetic correlation

between these two characteristics ($r_g = 0.14$, Novotny et al., 2017), indicating that cows with dry and fine hock may remain in the herd for a longer period.

Holstein cows should have rear legs side view with moderate curvature (score 5). The trait is essential since it is directly related to body support. However, for rear legs rear view, the score 9 (parallel legs) is necessary to accommodate the udder and for the cow to exhibit good locomotion (Valloto and Ribas Neto, 2012). Williams et al. (2022) reported that an effective locomotion (i.e., absence of compromised mobility) is important for the survival of dairy cows, especially in older ones, as demonstrated by the rise in culling attributed to feet and leg problems, such as impaired locomotion, observed in older dairy cows. Also, the authors highlighted that the importance placed on good locomotion is amplified in pasture-based systems, where cows must be able to walk to and from a milking parlor twice daily to avoid being culled—a highly important point for Brazil, as most farms produce milk in pasture-based systems with minimal supplementation.

Strapáková et al. (2021) highlighted that Simmental cows with 81-83 points for feet and legs presented a long productive life, and the animals that achieved the lowest linear points had a 2.3 times greater probability of being culled. In addition, Williams et al. (2022) estimated genetic correlations between linear-type traits related to feet and legs and survival, which were anticipated to strengthen as cows aged, which were found to be poor indicators of the genetic quality of survival in older dairy cows.

Females with wider udder and more centralized teats in the mammary quarters have more chances to remain longer in the herd. Similarly, in a study with Holstein cows from South Africa, Imbayarwo-Chikosi et al. (2017) found that fore udder attachment, rear teat placement, and udder width were the traits that most influenced the culling risk. In addition, a well-developed udder is a prerequisite for high milk production, and achieving a high score for it provides the opportunity to avoid voluntary culling (Strapáková et al., 2021).

In the present study cows with scores 5 or 6 for teat length live longer than those with very short or long teats. Cows with teats measuring 5 cm (score 5) in length presented a longer productive life (Valloto and Ribas Neto, 2012). On the other hand, Rostellato et al. (2021) found that teat length has no influence on longevity, indicating that this trait is not the primary in the selection of superior animals for longevity. However, this may change with the more frequent use of robotic milking. The conformation, position, and distance between teats are very important for this milking process.

The Canadian linear classification of Holstein cows defines score 9 as ideal since it indicates the capacity of milk production (Valloto and Ribas Neto, 2012). An extremely high udder is associated with a longer productive life, lower culling risk, and higher milk production due to the high concentration of mammary tissue. In addition to being an important trait of the mammary system, udder height represents the milk production capacity of mammary tissue, with deeper udders being more susceptible to trauma and infection (Valloto and Ribas Neto, 2012). Strapáková et al. (2021) found that Fleckvieh cows with a shallower udder had more chances to be discarded than females with a deeper udder.

Cows with a weak median ligament have pendulous udders, and that could increase the injuries and mastitis and, consequently, the risk of early culling (Zavadilová et al., 2011; Imbayarwo-Chikosi et al., 2017). Because of this, it is important for the udder to have a well-defined median ligament.

Cows classified as “Good Plus” and “Very Good” lived more time in the herd. Similar results were reported by Strapáková et al. (2021), who highlighted that those cows classified with udder scores ranging from 84 to 86 points at first calving had the greatest likelihood of reaching a longer productive lifespan compared with other cows.

Williams et al. (2022) and Samoré et al. (2010) highlighted that there is a genetic correlation between longevity and mammary traits (0.10 to 0.54). Because of this, some udder traits exhibit a higher heritability than longevity, and the assessment of these traits occurs earlier than the performed for longevity, indicating their use as an indirect selection criterion for evaluating longevity. Therefore, any genetic evaluation for survival using proxy measurements should include a variety of traits, with the

objective of improving genetic merit for survival across all age groups by reducing culling caused by both voluntary and involuntary reasons.

Despite exhibiting low heritability and slow genetic progress, selection for longevity is important for dairy farming. Enhanced dairy cow longevity is linked to increased profitability by reducing the need for replacement heifers to maintain herd size and achieving a higher average herd yield. Additionally, the ability to remain productive within the herd from the onset of productive life can be a criterion in selection indices, as it is directly related to the survival of mature cows (Hu et al., 2021; Nascimento et al., 2023).

Therefore, to improve the quality of the information and analyses, it is necessary to have access to the reasons of culling to build the herd profile. Checking the influence of linear traits at different ages is important to better understand their relationship with productive longevity.

5. Conclusions

Females classified as “Good Plus” and “Very Good” remain in the herd for a longer period. As expected, the mammary system is the section with the greatest influence on productive life. Therefore, linear classification during the first lactation is a key factor for determining and optimizing the longevity of Holstein cows.

Data availability

The data that support this study cannot be publicly shared due to ethical or privacy reasons, but may be shared upon reasonable request to the corresponding author.

Author contributions

Conceptualization: Vernaschi, L. C. G.; Zadra, L. E. F. and Dias, L. T. **Data curation:** Vernaschi, L. C. G.; Zadra, L. E. F.; Teixeira, R. A. and Dias, L. T. **Formal analysis:** Vernaschi, L. C. G.; Zadra, L. E. F.; Teixeira, R. A. and Dias, L. T. **Investigation:** Dias, L. T. **Methodology:** Vernaschi, L. C. G.; Zadra, L. E. F.; Teixeira, R. A. and Dias, L. T. **Project administration:** Vernaschi, L. C. G. and Dias, L. T. **Resources:** Valloto, A. A. **Supervision:** Dias, L. T. **Validation:** Teixeira, R. A. **Writing – original draft:** Vernaschi, L. C. G. **Writing – review & editing:** Zadra, L. E. F.; Teixeira, R. A. and Dias, L. T.

Conflict of interest

The authors declare no conflict of interest.

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References

- Adamczyk, K.; Jagusiak, W. and Weglarz, A. 2021. Associations between the breeding values of Holstein-Friesian bulls and longevity and culling reasons of their daughters. *Animal* 15:100204. <https://doi.org/10.1016/j.animal.2021.100204>
- Adamczyk, K.; Makulska, J.; Jagusiak, W. and Weglarz, A. 2017. Associations between strain, herd size, age at first calving, culling reason and lifetime performance characteristics in Holstein-Friesian cows. *Animal* 11:327-334. <https://doi.org/10.1017/S1751731116001348>
- Almeida, T. P.; Kern, E. L.; Daltro, D. S.; Braccini Neto, J.; McManus, C.; Thaler Neto, A. and Cobuci, J. A. 2017. Genetic associations between reproductive and linear-type traits of Holstein cows in Brazil. *Revista Brasileira de Zootecnia* 46:91-98. <https://doi.org/10.1590/S1806-92902017000200002>

- Atkins, G.; Shannon, J. and Muir, B. 2008. Using conformational anatomy to identify functionality & economics of dairy cows. p.279-295. In: WCDS Advances in Dairy Technology. Alberta, Canada.
- Caraviello, D. Z.; Weigel, K. A. and Gianola, D. 2003. Analysis of the relationship between type traits, inbreeding, and functional survival in Jersey cattle using a weibull proportional hazards model. *Journal of Dairy Science* 86:2984-2989. [https://doi.org/10.3168/jds.S0022-0302\(03\)73896-X](https://doi.org/10.3168/jds.S0022-0302(03)73896-X)
- Cox, D. R. 1972. Regression models and life tables (with discussion). *Journal of the Royal Statistical Society* 34:187-220. <https://doi.org/10.1111/j.2517-6161.1972.tb00899.x>
- Cruickshank, J.; Weigel, K. A.; Dentine, M. R. and Kirkpatrick, B. W. 2002. Indirect prediction of herd life in Guernsey dairy cattle. *Journal of Dairy Science* 85:1307-1313. [https://doi.org/10.3168/jds.S0022-0302\(02\)74195-7](https://doi.org/10.3168/jds.S0022-0302(02)74195-7)
- Dallago, G. M.; Wade, K. M.; Cue, R. I.; McClure, J. T.; Lacroix, R.; Pellerin, D. and Vasseur, E. 2021. Keeping dairy cows for longer: a critical literature review on dairy cow longevity in high milk-producing countries. *Animals* 11:808. <https://doi.org/10.3390/ani11030808>
- De Vries, A. 2017. Economic trade-offs between genetic improvement and longevity in dairy cattle. *Journal of Dairy Science* 100:4184-4192. <https://doi.org/10.3168/jds.2016-11847>
- Ducrocq, V. 2005. An improved model for the French genetic evaluation of dairy bulls on length of productive life of their daughters. *Animal* 3:249-256. <https://doi.org/10.1079/ASC41720249>
- Grandl, F.; Amelchanka, S. L.; Furger, M.; Clauss, M.; Zeitz, J. O.; Kreuzer, M. and Schwarm, A. 2016. Biological implications of longevity in dairy cows: 2. Changes in methane emissions and efficiency with age. *Journal of Dairy Science* 99:3472-3485. <https://doi.org/10.3168/jds.2015-10262>
- Grzesiak, W.; Adamczy, K. K.; Zaborski, D. and Wójcik, J. 2022. Estimation of dairy cow survival in the first three lactations for different culling reasons using the Kaplan-Meier Method. *Animals* 12:1942. <https://doi.org/10.3390/ani12151942>
- Hardie, L. C.; Heins, B. J. and Dechow, C. D. 2021. Genetic parameters for stayability of Holsteins in US organic herds. *Journal of Dairy Science* 104:4507-4515. <https://doi.org/10.3168/jds.2020-19399>
- Hu, H.; Mu, T.; Ma, Y.; Wang, X. P. and Ma, Y. 2021. Analysis of longevity traits in Holstein cattle: a review. *Frontiers in Genetics* 12:1-15. <https://doi.org/10.3389/fgene.2021.695543>
- Imbayarwo-Chikosi, V. E.; Ducrocq, V.; Banga, C. B.; Halimani, T. E.; van Wyk, J. B.; Maiwashe, A. and Dzama, K. 2017. Estimation of genetic parameters for functional longevity South African Holstein cattle using piecewise Weibull proportional hazards model. *Journal of Animal Breeding and Genetics* 134:364-372. <https://doi.org/10.1111/jbg.12264>
- Kern, E. L.; Cobuci, J. A.; Costa, C. N.; McManus, C. M. and Braccini Neto, J. 2015. Genetic association between longevity and linear type traits of Holstein cows. *Scientia Agricola* 72:203-209. <https://doi.org/10.1590/0103-9016-2014-0007>
- Lawlor, T. 2017. Total Performance Index (TPI): Keeping up with changing times. Focus on Genetic. Available at: <http://www.holsteinusa.com/pdf/genomic_ref_info/Total_Performance_Index_TPI_Keeping_Up_with_the_Changing_Times.pdf>. Accessed on: Dec. 01, 2022.
- Miglior, F.; Fleming, A.; Malchiodi, F.; Brito, L. F.; Martin, P. and Baes, C. F. 2017. A 100-Year Review: Identification and genetic selection of economically important traits in dairy cattle. *Journal of Dairy Science* 100:10251-10271. <https://doi.org/10.3168/jds.2017-12968>
- Nascimento, B. M.; Wolfe, C. W.; Weigel, K. A. and Peñagaricano, F. 2023. Effects of type traits, inbreeding, and production on survival in US Jersey cattle. *Journal of Dairy Science* 106:4825-4835. <https://doi.org/10.3168/jds.2022-23048>
- Novotny, L.; Frelich, J.; Beran, J. and Zavadilova, L. 2017. Genetic relationship between type traits, number of lactations initiated, and lifetime milk performance in Czech Fleckvieh cattle. *Czech Journal of Animal Science* 62:501-510. <https://doi.org/10.17221/60/2017-CJAS>
- Pritchard, T.; Coffey, M.; Mrode, R. and Wall, E. 2012. Genetic parameters for production, health, fertility and longevity traits in dairy cows. *Animal* 7:34-46. <https://doi.org/10.1017/S1751731112001401>
- Rostellato, R.; Promp, J.; Leclerc, H.; Mattalia, S.; Friggens, N. C.; Boichard, D. and Ducrocq, V. 2021. Influence of production, reproduction, morphology, and health traits on true and functional longevity in French Holstein cows. *Journal of Dairy Science* 104:12664-12678. <https://doi.org/10.3168/jds.2020-19974>
- Samoré, A. B.; Rizzi, R.; Rossoni, A. and Bagnato, A. 2010. Genetic parameters for functional longevity, type traits, somatic cell scores, milk flow and production in the Italian Brown Swiss. *Italian Journal Animal Science* 9:145-152.
- Sewalem, A.; Kistemaker, G. J.; Miglior, F. and Van Doormaal, B. J. 2004. Analysis of the relationship between type traits and functional survival in Canadian Holsteins using a Weibull proportional hazards model. *Journal of Dairy Science* 87:3938-3946. [https://doi.org/10.3168/jds.S0022-0302\(04\)73533-X](https://doi.org/10.3168/jds.S0022-0302(04)73533-X)
- Strapáková, E.; Strapák, P.; Candrák, J.; Pavlík, I. and Dockalová, K. 2021. Fleckscore system of exterior evaluation as a more accurate indirect predictor of longevity in Slovak Simmental dairy cows. *Czech Journal of Animal Science* 66:487-494. <https://doi.org/10.17221/102/2021-CJAS>
- Török, E.; Komlósi, I.; Szőnyi, V.; Béri, B.; Mészáros, G. and Posta, J. 2021. Combinations of linear type traits affecting the longevity in Hungarian Holstein-Friesian cows. *Animals* 11:3065-3077. <https://doi.org/10.3390/ani11113065>

- Valloto, A. A. and Ribas Neto, P. G. 2012. Avaliação e conformação da vaca leiteira. SENAR, Curitiba.
- Van Doormaal, B. 2009. A closer look at longevity. Available at: <<https://www.cdn.ca/document.php?id=162>>. Accessed on: Dec. 01, 2024.
- Veerkamp, R. and Van Pelt, M. 2019. Advances in dairy cattle breeding to improve longevity. p.337-354. In: van der Werf, J. and Pryce, J., eds. Advances in breeding of dairy cattle. Burleigh Dodds Science Publishing.
- Vernaschi, L. C. G.; Valotto, A. A.; Zadra, L. E. F.; Teixeira, R. A. and Dias, L. T. 2022. Factors affecting length of productive life of Brazilian Holstein cows assessed using survival analysis. *Animal Production Science* 62:482-489. <https://doi.org/10.1071/AN21407>
- Zavdilová, L; Nemcová, E. and Stípková, M. 2011. Effect of type traits on functional longevity of Czech Holstein cows estimated from Cox proportional hazards model. *Journal of Dairy Science* 94:4090-4099. <https://doi.org/10.3168/jds.2010-3684>
- Williams, M.; Sleator, R. D.; Murphy, C. P.; McCarthy, J. and Berry, D. P. 2022. Re-assessing the importance of linear type traits in predicting genetic merit for survival in an aging Holstein-Friesian dairy cow population. *Journal of Dairy Science* 105:7550-7563. <https://doi.org/10.3168/jds.2022-22026>