Analysis of the Relationship Between Type Traits and Functional Survival in Canadian Holsteins Using a Weibull Proportional Hazards Model

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ABSTRACT

The aim of this study was to explore the impact of type traits on the functional survival of Canadian Holstein cows using a Weibull proportional hazards model. The data set consisted of 1,130,616 registered cows from 13,606 herds calving from 1985 to 2003. Functional survival was defined as the number of days from first calving to culling, death, or censoring. Type information consisted of phenotypic type scores for 8 composite traits (with 18 classes of each) and 23 linear descriptive traits (with 9 classes of each). The statistical model included the effects of stage of lactation, season of production, the annual change in herd size, type of milk recording supervision, age at first calving, effects of milk, fat and protein yields calculated within herd-year-parity deviations, herd-year-season of calving, each type trait, and the sire. Analysis was done one at a time for each of 31 type traits. The relative culling risk was calculated for animals in each class after accounting for the previously mentioned effects. Among the composite type traits with the greatest contribution to the likelihood function were final score, mammary system, and feet and legs, all having a strong relationship with functional survival. Cows with low scores for these traits had higher risk of culling compared with higher scores. For instance, cows classified as poor plus 1 vs. excellent plus 1 have a relative risk of culling 3.66 and 0.28, respectively. The corresponding figures for mammary system are 4.19 and 0.46 and for feet and legs are 2.34 and 0.50. Linear type traits with the greatest contribution to the likelihood function were fore udder attachment, udder texture, udder depth, rear udder attachment height, and rear udder attachment width. Stature and size had no strong relationship with functional survival.

(Key words: functional survival, Holstein, type trait)

INTRODUCTION

In dairy production, longevity is a highly desirable trait that considerably affects overall profitability. With increased longevity, the mean production of the herd increases because a greater proportion of the culling decisions are based on production, and the proportion of mature cows, which produce more milk than young cows, is increased (Allaire and Gibson, 1992; VanRaden and Wiggans, 1995). However, genetic improvement of herd life is very hard to achieve because of its low heritability. Heritability estimates range from 0.03 to 0.05 (Van Doormaal et al., 1985; Jairath et al., 1998) using a linear model, and estimates from survival analysis using Weibull proportional hazards models range from 0.10 to 0.20 (Ducrocq, 2002; Roxstrom et al., 2003; Sewalem et al., 2003). Moreover, one must wait for the animal or its relatives to leave the herd before obtaining a direct measurement.

Type traits have been used as indirect selection criteria for herd life (Short and Lawlor, 1992; Dekkers et al., 1994; VanRaden and Wiggans, 1995; Weigel et al., 1998; Cruickshank et al., 2002). Type traits are recorded relatively early in life, most often in the first lactation, and are more heritable than longevity (Yazdi and Schaeffer, 2001; Kadarmideen and Wegmann, 2003), which makes selection relatively more efficient. To get reliable and direct information for sires regarding the longevity of their daughters, it is necessary to wait until a minimum number of daughters are culled or die. Moreover, these evaluations may be available too late to be useful in breeding programs. Hence, genetic evaluations for direct longevity information based on number of culled cows should be combined with indirect information based on early predictors such as type traits. Knowledge of genetic relationships between type and longevity are required, and, therefore, a proper identification of type traits to be used as early predictors is essential. In Canada, the breeding goal has emphasized high production combined with superior conformation to support such production levels, and considerable improvement on type traits has been made compared with other countries. Because type classification

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data are already recorded, their use as an indirect predictor for longevity would also be very cost effective.

Survival analysis using a Weibull proportional hazards model can offer a better fit to survival data because of its ability to account for censored records properly. This may increase precision by accounting for differences in days of productive life among cows that survive for the same number of lactations. Survival analysis also accounts for the skewed distribution of survival data. Time-dependent variables can be used for the survival analysis to model the effects of environmental factors accurately.

The objective of the present study was to evaluate the impact of linear descriptive type traits on functional longevity of Canadian Holstein cows.

MATERIALS AND METHODS

Data consisted of 1,130,616 cows from 13,609 herds sired by 18,457 sires. Data were obtained from lactation and type classification records extracted for the Canadian May 2003 genetic evaluation of the Holstein breed. All records were herd book registered and required to have a type record. Length of productive life was defined as time (days) from one calving to the next calving, death, or culling. Censored records represented cows being sold for dairy purposes, exported, or leased to another herd, or cows still in the herd. A lifetime record was considered to be completed (uncensored) if the cow received a termination code, indicating that the cow was removed for any reason. Records associated with missing sire identification, incorrect calving dates, and age at first calving outside an 18- to 40-mo range were excluded from the analysis. Type information consisted of phenotypic type scores of 23 linear descriptive traits evaluated on a 1 to 9 scale and 8 composite traits evaluated on a scale with 18 categories. Composite traits were directly calculated from the linear traits by weighing each linear score according to existing relative weights (Holstein Canada, 2004). A detailed description of each linear trait, the method of evaluation, and the optimum score for each linear type trait is shown in Table 1, and further information can be found at the Holstein Canada Web site (<http://www.holstein.ca>).

The following model was used:

$$\lambda(t) = \lambda_{0,s}(t) \exp(\mathbf{x}'_m(t)\beta + \mathbf{z}'_m\mathbf{u})$$

where $\lambda(t)$ is the hazard of a cow, i.e., her probability of being culled at time t given that she is alive just before t ; $\lambda_{0,s}(t) = \lambda\rho(\lambda t)^{\rho-1}$ is the Weibull baseline hazard function with scale parameter λ and shape parameter ρ ; and t is the time in days from one calving to the next calving for each stratum; β contains the possibly time-

dependent covariates affecting the hazard, with $\mathbf{x}'_m(t)$ being the corresponding design vectors, and $\mathbf{u}$ is a vector of random variables with associated incidence vector $\mathbf{z}'_m$.

The fixed covariates included in the model were as follows: time-dependent effect of stage of lactation in days (1 = 0 to 80; 2 = 81 to 235; 3 = >235); effect of year and season of calving (year of calvings from 1985 to 2003 and season of calvings were January to March, April to June, July to September, and October to December); effect of season of production with the same definition as seasons of calving; effect of the annual change in herd size with 3 classes (decreasing = a decrease in herd size of <-5%, nearly unchanged = no appreciable change ≥ -5 to $\leq 10\%$, and increasing = an increase in herd size of >10%); effect of the type of milk recording supervision with 3 classes (unsupervised, supervised, and unknown, i.e., records that do not fulfill the minimum criteria set by the milk recording agency); effect of age at first calving in months; and effects of milk, fat, and protein yields. The latter effects were calculated as within herd-year-parity deviations with 3 classes for each: low = cows producing >0.4 SD below the herd-year-parity average, average = cows producing between 0.4 below and 0.6 SD above the herd-year-parity average, and high = cows producing above 0.6 SD of the herd-year-parity average. Each type trait was evaluated separately by including it as a covariate on the model.

The random effects included were the effect of herd-year-season class, which was assumed to follow a log gamma distribution, and the genetic effect of the cow's sire, which was assumed to follow a multivariate normal distribution with mean zero and variance $A\sigma^2_s$, where σ^2_s is the variance among sires and A is the relationship matrix. A sire variance of 0.046 (Sewalem et al., 2003) was used in the analysis.

The following composite type traits were analyzed: final score, mammary system, feet and legs, dairy character, rump, frame/capacity, fore udder, and rear udder. The linear type traits analyzed are presented on Table 1. Analyses were performed for each type trait one at a time; hence, 31 analyses were performed on the same data according to the model previously described.

The analyses, using a Weibull proportional hazards model, were performed using the Survival Kit Version 3.12 (Ducrocq and Solkner, 1998). One baseline hazard function, $\lambda_{0,s}(t)$, was defined for each lactation (subscript 0 designates a baseline hazard, and subscript s relates to stratum). Detailed description of the model and survival analysis of longevity data in dairy cattle on a lactation basis were provided by Ducrocq (2002), Roxstrom et al. (2003), and Sewalem et al. (2003). The

Table 1. Description of linear type traits.

	Measurement of evaluation	Description of evaluation	Score		
			1	5	9
Udder traits					
Fore udder attachment	Linear code	Attachment to abdominal wall	Extremely weak	Intermediate	Extremely strong
Fore teat placement	Linear code	Teat placement from the center of quarter	Extremely outside	Center	Extremely inside
Fore teat length	Measurement	Average length of teats	Extremely short	Intermediate	Extremely long
Rear udder attachment width	Measurement	Width at milk secreting tissue	Extremely narrow	Intermediate	Extremely wide
Rear udder attachment height	Measurement	Milk secreting tissue to the base of vulva	Extremely low	Intermediate	Extremely high
Rear teat placement	Linear code	Teat placement from center of quarter	Extremely outside	Center	Extremely inside
Udder depth	Measurement	From hock to floor of the udder	Extremely deep	Intermediate	Extremely shallow
Udder texture	Linear code	Softness and expandability	Extremely fleshy	Intermediate	Extremely soft
Median suspensory ligament	Measurement	Depth of cleft (fore/rear)	Extremely weak	Intermediate	Extremely strong
Body traits					
Body depth	Measurement	Depth of body at the rear rib	Extremely shallow	Intermediate	Extremely deep
Chest width	Linear code	Width of chest floor	Extremely narrow	Intermediate	Extremely wide
Stature	Measurement	Height at rump	Extremely short	Intermediate	Extremely tall
Size	Measurement	Weight (mass) of animal	Extremely small	Intermediate	Extremely large
Angularity	Linear code	Appearance of angularity	Extremely non angular	Intermediate	Extremely angular
Front end	Linear code	Relative height at the front end	Extremely low	Level	Extremely high
Rump traits					
Loin strength	Linear code	Strength of vertebrae between back and rump	Extremely weak	Intermediate	Extremely strong
Pin width	Measurement	Point of pin to point of pin	Extremely narrow	Intermediate	Extremely wide
Rump angle	Measurement	Height of pin bones relative to height of hook bones	Extremely high	Intermediate	Extremely low
Feet and legs traits					
Foot angle	Linear code	Angle of toe	Extremely low	Intermediate	Extremely steep
Heel depth	Linear code	Depth of heel on outside claw	Extremely shallow	Intermediate	Extremely deep
Rear legs rear view	Linear code	Turn of hock when viewed from rear	Extremely hocked in	Intermediate	Extremely straight
Rear legs side view	Linear code	Degree of curvature (side view)	Extremely straight	Intermediate	Extremely curved
Bone quality	Linear code	Flatness of bone	Extremely coarse	Intermediate	Extremely flat

Figure 1. Contribution of each type trait and final score to the likelihood of functional survival (as a percentage of the contribution of the final score, which was the most important trait).

overall influence of each type trait on functional survival was assessed using the likelihood ratio test.

RESULTS AND DISCUSSION

Relative Contribution of Each Trait

All type traits included in this study had a highly statistically significant ($P < 0.001$) association with functional longevity. Figure 1 shows the relative contribution of each type trait (composite and linear traits) to the likelihood ($-2\log L$); this was determined by comparing the full model (with one particular type trait) to the reduced model (without any of the type traits). Final score was by far the most important single trait with respect to longevity, followed by mammary system, rear and fore udders, and feet and legs (Figure 1). Among the linear type traits, udder traits had the strongest effect on the survival of cows. Fore udder attachment, udder texture, udder depth, rear udder attachment height, rear udder attachment width, and median suspensory were the udder traits having the strongest relationship with longevity of cows. Among the feet and legs traits, bone quality and heel depth had the largest influence on functional survival. Stature and size had the least influence on the survival of cows. Only traits related to udder and feet and legs

contributed at least 20% of the relative contribution of final score to the likelihood. The average Weibull parameters (ρ) were 1.6, 1.5, 1.4, 1.4, 1.4, and 2.5 for lactations 1, 2, 3, 4, 5, and 6+, respectively. The $\log \gamma$ value ranged from 8 to 20.

The results were expressed in relative culling risk, defined as the ratio of the estimated risk of being culled under the influence of certain environmental factors relative to the average risk (or reference risk), which is usually set to 1. Values >1 indicate higher culling risk associated with that environmental factor. Relative culling risks <1 indicate lower culling risks, i.e., increasing effect of environmental factor on longevity. For example, if the relative culling risk for a given class is 2, a cow in that class has twice the risk of being culled compared with a cow in the reference class for that effect. Conversely, if the relative culling risk for a given class is 0.5, then a cow in that particular class has 50% less chance of being culled than a cow in the reference class.

Composite Traits

Figure 2 shows a clear linear relationship between final score and longevity. Cows with an extremely low final score of <65 (i.e., classified as poor) had a risk of

Figure 2. Relative risk of culling (RRC) by class of final score (relative culling rate for score 80 was set to 1).

Figure 3. Relative risk of culling (RRC) by category for mammary system (○), fore udder (*), and rear udder (△) (relative culling rate for category 10 was set to 1).

being culled that was 3.7 times more than that of cows scoring 80 points; whereas cows with final scores of >89 (i.e., classified as excellent) had a risk of being culled that was 0.28 times that of 80-point cows. Final score was the most important type trait. Similar results using the same methodology were also reported by Vollema and Groen (1998) for Dutch dairy cows, Schneider et al. (2003) for Quebec Holstein cows, and Caraviello et al. (2004) for US Holstein cows. Boettcher et al. (1997) used a linear regression approach and reported that overall conformation had the largest effect on survival through first lactation of Canadian Holsteins. Caraviello et al. (2003) reported, however, that final score was not the most important type trait that influences the functional longevity of US Jersey cows, perhaps because the Jersey breed is likely to have much less voluntary culling of cows with low final scores.

Figure 3 shows the relationship between risk of relative culling and mammary system, fore udder, and rear udder. Mammary system was the second most important trait next to final score for functional longevity in this analysis. Low scores (classified as poor) were 2 times more likely to be culled compared with the reference score of 10, which relates to a cow classified as good plus 1. On the other hand, cows with scores >15 (i.e., classified as excellent) had a risk of being culled that was 0.5 times less than cows with the reference score of 10. Figure 3 also shows that cows with low scores for rear and fore udder were >3 times more likely to be culled compared with cows with intermediate scores. The higher relative culling risk for category excellent 3 (i.e., score of 18) compared with excellent 2 (i.e., score of 17) as shown in Figure 3 is due to few

numbers of cows in the former category. Figure 4 shows the relationship between relative culling risk and feet and legs, rump, dairy character, and capacity. Relative culling risks for feet and legs also showed a clear relationship with a cow's survival. Low scores were associated with less risk compared with the higher scores. Capacity and rump angle also showed the same trends as feet and legs; however, the magnitude of risk of culling for these traits was much lower. Figure 4 also shows the influence of dairy character on functional survival. The relative culling risk for cows with low scores was

Figure 4. Relative risk of culling by (RRC) category for feet and legs (○), capacity (△), rump (×), and dairy character (*) (relative culling rate for category 10 was set to 1).

Table 2. Relative culling risk of cows for udder traits (relative culling risk for score 5 was set to 1).

Score	Fore udder attachment	Fore teat length	Fore teat placement	Rear udder attachment height	Rear udder attachment width	Rear teat placement	Udder depth	Udder texture	Median suspensory ligament
1	2.04	1.14	2.25	1.61	1.32	2.82	2.40	2.32	1.90
2	1.41	1.07	1.36	1.40	1.16	1.63	1.65	1.57	1.47
3	1.25	1.04	1.17	1.23	1.11	1.38	1.34	1.28	1.25
4	1.12	0.88	1.06	1.11	1.03	1.11	1.14	1.13	1.08
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	0.89	1.00	0.96	0.92	0.96	0.94	0.94	0.91	0.93
7	0.78	1.06	1.01	0.84	0.92	0.92	0.98	0.82	0.88
8	0.69	1.16	1.05	0.79	0.90	0.95	1.12	0.75	0.88
9	0.64	1.25	1.21	0.73	0.89	1.03	1.57	0.68	0.96

>2.6 times that of cows with an intermediate score for this trait. A positive strong relationship of mammary system and feet and legs with longevity was also reported by Boettcher et al. (1997), Larroque and Ducrocq (2001), and Schneider et al. (2003).

Linear Type Traits

Udder traits. Relative culling risk for udder traits are shown in Table 2. Fore teat length, fore teat placement, rear teat placement, and udder depth exhibit an intermediate optimum as they relate to longevity. On the other hand, fore udder attachment, median suspensory ligament, rear udder attachment height, rear udder attachment width, and udder texture show a clear linear relationship with functional longevity. Cows with high scores for these traits had higher chances of surviving than cows with low scores. Udder traits had an important influence on the culling decisions. This might have been due to their influence on the reduced susceptibility to mastitis and other infectious diseases. Cows with nearly center fore teat placement are more likely to survive culling than cows with extremely inside or extremely outside fore teat placement, which has also been observed in other studies (Caraviello et al., 2003; Schneider et al., 2003). Cows with extremely close rear teats were more likely to be culled compared with cows with extremely wide rear teats, which was also found by Buenger et al. (2001), Larroque and Ducrocq (2001), and Schneider et al. (2003). However, Caraviello et al. (2003) reported an intermediate optimum for rear udder height and rear udder width. This result might have been due to breed differences or trait definitions. Low scores for median suspensory ligament or depth of cleft for rear udder and fore udder were associated with higher risk of culling than the other scores. Cows with extremely fleshy udders were more likely to be culled compared with cows with soft, pliable, elastic udders that collapse well after milking. Cows with ex-

tremely deep or extremely shallow udder depth from hock to the floor of the udder were also associated with higher risk of being culled.

Body and dairy character traits. The impact of body and dairy character traits (body depth, chest width, stature, size, front end, and angularity) on the functional longevity of cows is presented in Table 3. Cows that are extremely short, small, and narrow-chested with a shallow body depth had a higher risk of being culled compared with cows in an intermediate class and, hence, a shorter length of productive life. As for size, Table 3 also shows that cows with a score of 9 were essentially equivalent to a score of 2, indicating that extremely large cows have a relative risk of culling similar to that of extremely small cows. A moderate positive relationship between longevity and body type traits was reported by Boettcher et al. (1997). Size and stature did not have a strong relationship with functional survival (Buenger et al., 2001; Caraviello et al., 2003). On the other hand, Schneider et al. (2003) found that taller and bigger cows had better chances of surviving than cows in other classes. However, Mahoney et al. (1986) reported that larger cows are more predisposed to displaced abomasums than small cows. Rogers et al. (1999) did not find a significant difference, indicating that genetically larger body size or more strength would be advantageous from a disease perspective.

The influence of angularity on functional survival is presented in Table 3. A clear linear relationship between angularity and longevity was observed, indicating that the rounded, nonangular cows were 2.47 times more likely to be culled compared with the intermediate score of 5; extremely sharp cows had a 1.28 times better chance of surviving than cows with intermediate scores. However, Buenger et al. (2001) and Caraviello et al. (2004) did not find a linear relationship between angularity and longevity. Moreover, Buenger et al. (2001), after correcting for milk production, found no strong relationship between angularity and longevity of cows.

Table 3. Relative culling risk of cows for body type traits (relative culling risk for score 5 was set to 1).

Score	Body depth	Chest width	Stature	Size	Angularity	Front end
1	1.37	1.37	1.24	1.15	2.47	1.20
2	1.18	1.16	1.07	1.07	1.50	1.22
3	1.11	1.09	1.02	1.03	1.26	1.13
4	1.04	1.03	1.00	1.01	1.08	1.05
5	1.00	1.00	1.00	1.00	1.00	1.00
6	0.97	0.98	0.99	1.01	0.93	0.95
7	0.95	0.97	0.97	1.02	0.90	0.87
8	1.09	0.96	0.97	1.04	0.85	0.94
9	1.34	0.94	0.95	1.06	0.78	1.05

The varying relationships between angularity and longevity in different countries may be partly due to differences in the trait definition across countries. In Canada, the appraisal of angularity is based on the degree of angular shape at the chine and the fore rib, also accounting for the spring of rib. The cow receiving high marks for angularity has angularity with substantial, wide well-sprung, and open ribs. The frail, flat-sided cow is coded down for angularity, as she lacks this spring of rib.

Rump traits. The relationships between risk of relative culling and linear score for loin strength, pin width, and rump angle are shown in Table 4. Cows with weak strength of vertebrae between back and rump showed a higher culling risk compared with cows with strong loins. Cows with low or high scores for rump angle (representing extremely high or low pin bones relative to the height of hook bones, respectively) were more likely to be culled compared with the optimum linear score of 5. No strong relationship was observed between pin width and relative culling risk except that cows with extremely narrow pins were 1.18 times more likely to be culled compared with cows that were scored 5 (Table 4). Rump traits are associated with calving difficulty, and cows with intermediate rump angle are pre-

ferred. Similar findings were reported by Buenger et al. (2001) and Schneider et al. (2003). Moreover, Rogers et al. (1999) found a favorable moderate positive genetic correlation of 0.39 between rump angle and foot and leg diseases. However, Caraviello et al. (2003 and 2004) did not find strong relationships between rump traits and longevity in US Holstein and Jersey cows.

Feet and legs. Table 4 shows the relationship between the risk of relative culling and linear score for feet and legs traits. There was a slight linear relationship for bone quality and rear legs rear view with relative culling risk. Cows with low scores were more likely to be culled compared with those having high scores for these traits. The relationship between foot angle and rear legs side view with longevity showed an intermediate optimum, indicating that cows with low and high scores were more likely to be culled compared with those having an intermediate score of 5. The importance of feet and legs traits to the functional survival of cows found in the present study corroborates the findings of Boettcher et al. (1997), Buenger et al. (2001), and Caraviello et al. (2004). Extremely coarse bone, extremely shallow heel depth, extremely low foot angle, and extremely straight or curved rear legs led to a decreased functional survival of cows.

Table 4. Relative culling risk of cows for rump traits and feet and legs traits (relative culling risk for score 5 was set to 1).

Score	Rump traits			Feet and legs traits				
	Loin strength	Pin width	Rump angle	Bone quality	Foot angle	Heel depth	Rear legs rear view	Rear legs side view
1	1.06	1.18	1.44	1.83	1.57	1.76	1.37	1.47
2	1.22	1.07	1.24	1.40	1.33	1.38	1.20	1.21
3	1.10	1.04	1.12	1.21	1.18	1.17	1.09	1.11
4	1.05	0.99	1.04	1.09	1.08	1.07	1.02	1.03
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	0.97	0.99	1.05	0.93	0.96	0.96	0.98	1.06
7	0.93	1.00	1.16	0.87	0.95	0.97	0.94	1.17
8	0.90	1.01	1.26	0.82	1.04	1.00	0.93	1.31
9	0.89	1.03	1.31	0.77	1.23	1.08	0.97	1.58

Results from this study are from a model that includes a sire genetic effect. Buenger et al. (2001) and Larroque and Ducrocq (2001) argued that inclusion of the genetic effect in the model would bias the effect of type trait's phenotype effect on culling risks. In this study, a phenotypic analysis of each trait (excluding the sire effect in the model) was also analyzed, and results were compared with the present study (not shown). Neither the estimates of breeding values nor significance tests changed. Schneider et al. (2003) also found no differences between phenotypic and genetic analysis of type traits and its impact on the functional survival of cows.

Previous studies by Dekkers et al. (1994), Boettcher et al. (1997) using different methodology, and Schneider et al. (2003) using the same approach as the present study but data only from Quebec Holstein cows reported the impact of type traits on survival of cows for Canadian Holsteins. The completeness and volume of data and the advantage of methodology in the present study reflect the relationship between type traits and functional herd life more precisely than previous studies. The present study also rendered an estimate of the contribution of each type trait to the hazard function, or instantaneous risk of relative culling, in Canadian Holstein cows. Both the previous and present studies assume that culling for type traits is involuntary. Breeders of Canadian Holsteins have always placed more emphasis on type traits than Holstein breeders in other countries. Therefore, voluntary culling for type traits was much more likely for cows in this data set than for cows in other studies of Holstein populations globally. The extent to which culling for type is voluntary, and the association between type traits and fertility and/or disease incidences such as reproductive problems, metabolic disorders, and foot and leg disease, would be of interest in the future.

CONCLUSIONS

Survival analysis was used to investigate the effect of type traits on the functional longevity in Canadian Holstein cows. Based on the results presented herein, using registered cows, final score had the greatest contribution to the hazard function, or instantaneous risk of culling. Mammary system and feet and legs also had strong relationships with functional longevity. All composite type traits showed a linear relationship with functional longevity, indicating that cows with higher scores for these traits were found to survive longer than cows with low scores. Among the linear type traits, udder traits, such as fore udder attachment, udder texture, and udder depth, were the most important, with a strong relationship with functional survival of cows.

Fore teat length, fore teat placement, rear udder attachment width, rear teat placement, udder depth, body depth, front end, rump angle, and rear legs side view showed an intermediate optimum relationship with functional longevity. Stature and size have negligible effects on functional longevity. Improvement of type traits either through genetics or management would have a positive influence on the functional longevity of cows. Therefore, by choosing the right type traits, the functional herd life of cows can be effectively predicted. The present study assumed that culling for low production is voluntary, but it would be interesting to determine to what extent culling for type is also voluntary. In the future, it would also be interesting to investigate the genetic correlation between functional survival and type traits with fertility and/or disease resistance.

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