Effects of Type traits on Functional Herd Life in Holstein Cows

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Abstract

The effect of descriptive linear type traits on Functional Herd Life in Holstein cows was studied by means of Survival Analysis. The data set contained 331,105 lifetime records from the Programme d'Analyse des Troupeaux Laitiers du Quebec, collected between January 1980 and March 1995. Only 191,167 records (or cows) had type information. A Mixed Weibull model was fitted to analyse the data; the probability of being culled (hazard) was defined as a product of a baseline Weibull hazard function and explanatory variables. The heritability estimates for Functional Herd Life were 0.07 in the log scale and 0.147 in the original scale. Sire Estimated Transmitting Ability for FHL, expressed as relative culling rate, ranged from 0.6 to 1.37. Among the linear type traits (all significant), the 5 traits with the highest impact on functional herd life, were Rear Attachment Height, Fore Attachment, Bone Quality, Stature and Fore Teat Placement.

1. Introduction

Longevity is one of the most important components of dairy cow profitability. The economic advantage of longevity lies primarily in retaining productive, healthy and trouble-free cows as long as possible. Functional herd life (FHL) is defined as the ability of a cow to remain sound and healthy in a herd, independently of her level of production (Ducrocq, 1987). Conformation is an important component of breeding and selection decisions in dairy cattle populations. For profitability or production efficiency, the main objective for genetic selection for conformation is improved herd life (Dekkers et al., 1994). Type traits have been used for many decades as indirect selection criteria for herd life, because they are recorded easily in first lactation, have higher heritability than direct measures of herd life (Schaeffer and Burnside, 1974; Van Doormaal and Burnside, 1987; Jamrozik et al., 1991; Boldman et al., 1992; Short and Lawlor, 1992; Van Raden and Klaaskate, 1993), and have moderate genetic correlations with herd life. The objectives of this study were to evaluate which are the linear descriptive type traits that may affect the length of productive life in Quebec Holstein and estimate genetic parameters for Functional herd life using survival analysis.

2. Material and Methods

2.1 Data

The data set consisted of 331,105 lifetime records of Holstein cows in Quebec herds from January 1980 to March 1995, obtained from the Quebec Herd Analysis Service (PATLQ) (109,610 non-supervised lifetime records and 221,495 supervised lifetime records). Only 191,167 cows (or records) had type information (57.74%) which consist of actual type scores of 15 linear type traits, evaluated in a 1-9 point scale. Type records are from first classifications. All lifetime records, both with or without type information were included in the model to avoid bias. The pedigree file includes information on male parents (sires) for a total of 1875 sires (1664 with data).

2.2 Model

The Survival analysis was performed using the Survival Kit V3.0 by Ducrocq and Sölkner (1998). The length of productive life was defined as the number of days between date of first calving and date at culling or censoring, which adjusted for milk production level becomes the Functional Herd Life. Cows, that were sold for dairy purpose, exported and rented to another herd, from herds with discontinuous data collection (stopping milk recording) and still alive in March 31st 1995, were

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treated as censored. Constraints were imposed upon the fixed effects to be estimated to obtain a set of meaningfully estimable effects to simplify the interpretation. The class effect constrained (its value is set to zero, and assumed to be average risk) is used as «reference». For the type traits two constraints were imposed. The first constraint was set to the first class (absence of information) and the second to an intermediary class of conformation trait to avoid extreme classes that usually have a few number of uncensored failures. The inclusion of the type indication variable and the imposition of two different constraints for each type trait included as covariate in the model made it possible to consider all lifetime records in the analysis, even from cows without type information. The analysis was carried out using the following mixed Weibull model,

$$\lambda(t) = \lambda_o(t) \exp\{y_i(t') + p_j(\tau) + z_k(t') + a_m + w_r(\zeta) + d_u + sta_{b1} + siz_{b2} + chs_{b3} + ln_{b4} + ps_{b5} + pw_{b6} + ft_{b7} + bq_{b8} + rls_{b9} + m_{b10} + ut_{b11} + fa_{b12} + ftp_{b13} + rah_{b14} + rtp_{b15} + h_n(t') + s_q\}$$

where,
$\lambda(t)$ = hazard function at time t (probability of being culled), $\lambda_o(t)$ = Weibull baseline hazard function, $y_i(t')$ = fixed time-dependent effect of year of calving i, $p_j(\tau)$ = fixed time-dependent effect of lactation number and stage of lactation j, $z_k(t')$ = fixed time-dependent effect of annual change in herd size k, a_m = fixed time-independent effect of age at first calving m, $w_r(\zeta)$ = fixed time-dependent effect of within herd-year-parity class of milk production at 305 days of lactation (first or later lactations) r. The 305-days yield for all cows were standardized to 4 % fat and 3.3 % protein (PATLQ), d_u = indicator variable for the presence or absence of type information, 2 classes were defined, for records without type information and for records with type information, the fixed time-independent effects of sta_{b1} = Stature; siz_{b2} = Size; chs_{b3}= Chest Width; ln_{b4} = Loin Strength; ps_{b}= Pin Setting; pw_{b6} = Pin Width; ft_{b7} = Foot Angle; bq_{b8} = Bone Quality; rls_{b} = Rear Leg Set; m_{b10} = Median Suspensory; ut_{b11} = Udder Texture; fa_{b12} = Fore Attachment; ftp_{b13} = Fore Teat Placement; rah_{b14} = Rear Attachment Height and rtp_{b15} = Rear Teat Placement. For all the linear type traits, 10 classes were defined, the first one corresponds to cows without type information and the others are the phenotypic scores assigned to that cow for each type trait. $h_n(t')$ = random time-dependent effect of the herd-year n. Herd-year effects were assumed to follow a log-gamma distribution, which was algebraically integrated out from the joint posterior density. A total of 28,629 effects were defined and s_q = random effect of sire q (1875 sires). Sire effects were assumed to follow a normal distribution. The sire variance σ^2_s, was estimated as the mode of its marginal posterior density, which was approximated by Laplacian integration. For more details about the estimation and theoretical aspects see Ducrocq et al. (1988a, 1988b). The following time scales were defined: t, with the origin on the date of first calving; t', with the origin on March 1st of each year; τ, changes occurring at 0, 120, 240 and 305 days of each lactation and ζ, with the beginning of a new lactation.

3. Results and Discussion

3.1 Likelihood Ratio Test

A total of 331,105 lifetime records were analysed, of which 42.93 % (141,142) were right censored (cows still alive when the data set was created). The mean length of productive life was 682 and 787 days for censored and uncensored records respectively.

Table 1 shows the likelihood ratio test used to check the importance of the factors that have an effect on a cow's hazard. All the effects included in the model were significant at $P < 0.001$, except the effect of annual change in herd size that was significant at $P < 0.01$ and Size and Loin Strength that were significant at $P < 0.05$. The most important changes in log likelihood were observed for the effect of 305-day milk yield deviation and the effect of stage of lactation by lactation number. Annual change in herd size, Size and Loin Strength had the smallest impact in the change of the log likelihood compared with other the effects, therefore, these effects have no influence on the length of productive life.

3.2 Solutions for fixed effects

To facilitate the interpretation, the hazard rate is expressed as relative culling rate (RCR), defined as the ratio between the estimated risk of being culled under the influence of a certain environmental or genetic effect and the mean risk, which is set to one. For example, a cow in a herd with a RCR of 2 has twice the probability of being culled as of an "identical" cow in an average herd (Ducrocq, 1994). Hence for improving productive life, lower culling rates are desirable. The solutions for type traits are presented in Table 2. The five traits with the biggest impact in the change of the log likelihood were Rear Attachment Height, Fore Attachment, Bone Quality, Stature and Fore Teat Placement respectively. The other traits showed moderate or small impact on FHL, suggesting that dairy producers do not consider in their culling policies these traits which may not affect the «functionality» of the cow. For Rear Attachment a sharply linear decrease in the relative culling rate is observed as cows are classified with a higher score. The difference in relative culling rate between class 2 and 8, which have a reasonable number of uncensored failures (not shown), is 64%. This shows that cows with strong attached udders have a higher chance of surviving than cows with weak rear attachments. It seems that this trait receives an important emphasis among Quebec producers. Fore Attachment also shows a clear trend: cows with a higher score (strong attached udder) are less likely to be culled than a cow with a low score (weak fore attachment). The decrease in the relative culling rate is almost linear and the difference in relative culling rate from class 2 to 7 is 46%. Fore Attachment is one of the type traits that have the highest positive correlation with different herd life traits (Boettcher et al., 1997; Dekkers et al., 1994; Short and Lawlor, 1992; Burke and Funk, 1993). Bone Quality shows a decrease in the relative culling rate as cows are classified with a higher score. In the interval from class 2 to 9 the difference in culling rate is 37%, but from classes 4 to 7 the relative culling rate is more or less stable (5% difference in culling rate). A flat, clean bone quality is associated with a refined angular open cow that has high production, but a an extreme class corresponds to a frail animal with extremely fine bone. In the other extreme a coarse, rounded boned cow lack of dairyness. Even if the optimal score is said to be 9 (Holstein Canada, 1997), the results show that the optimum could be between score 5 and 7. The estimates of stature show that there is a linear decrease in the relative culling rate. Taller cows have more chance of surviving than shorter cows. In the interval from class 2 to 9 the difference in culling rate is 36%. Fore Teat Placement shows a different pattern, being 5 the optimal score for this trait (Holstein Canada, 1997), it can be observed that the relative culling rate decreases from class 2 to 5 and then increases from class 5 to 8. This reveals that cows with centred fore teats have more chances of surviving than cows with extremely inside or outside teats. Chest Width showed an interesting result; the RCR decreases to an intermediate score and then increases; it seems that heavy and coarse cows (Score 9) are more likely to be culled. Holstein Canada (1997) suggests that the optimum score is 9, but from the result it seems that the optimum score would be an intermediate one. The solutions for Foot Angle show that cows with steeper hoofs (Score 9) have more chances of surviving, which agrees with Burke and Funk (1993). For Pin Setting, Rear Leg Set and Rear Teat Placement the optimal score is 5 (Holstein Canada, 1997). Cows with an intermediate phenotype or toward more straight legs have more chances of surviving; the same results were reported by Boettcher et al. (1997), Burke and Funk (1993) and Short and Lawlor (1992). Rear Teat Placement did not show a clear trend, but it seems that cows with centred and slightly inside teats are less likely to be culled. Size, Loin Strength, Udder Texture, Median Suspensory, Pin Width, Foot Angle and Chest Width did not show much variation in RCR.

3.3 Solutions for random effects

The estimated gamma parameter for the herd-year effect $h\gamma$ was 6.300 and the estimated sire variance, σ^2 was 0.032. The heritability in the logarithmic scale (h^2_{log}) was calculated according to Ducrocq and Casella (1996). The heritability for functional herd life in the logarithmic scale was $h^2_{log} = 0.071$ and the heritability in the original scale was $h^2 = 0.147$. Similar estimates were reported by Boettcher et al. (1998) and Dürr (1997) for Canadian Holstein. The Estimated Transmitting Abilities (ETA) for sires effects, expressed as relative culling rate range from 0.605 to 1.376 and have an average of 0.94. Daughters of a sire with an ETA of 0.7 have 25% more chance of surviving than daughters from an average sire (ETA=0.94).

4. Conclusion

Survival analysis was used to investigate the impact of conformation traits on Functional Herd Life. All the type traits included in the models had a significant effect on FHL. The descriptive linear type traits showed different and variable results, some of them had a very low impact in the FHL, such as Pin Width, Loin Strength and Size; it seems that producers do not consider them when they have to decide to keep a cow or not. On the other hand, traits such as Fore Attachment, Rear Attachment Height, Stature, Bone Quality and Fore Teat Placement had an important effect on the FHL. Culling based on conformation may be different for registered and grade cow, many studies in the literature reported different correlations between conformation trait and herd life for these subpopulations; in the present study the groups were not separated, but it would be interesting in future studies to consider the registration status. The Survival Kit V3.0 demonstrated that it is an useful and practical tool to work with large data set.

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Table 1: Results of the likelihood ratio test

Effect [1]	-2 Change in the log likelihood	df	prob
y	685.82	13	0.0000
p	2582	15	0.0000
a	699.26	18	0.0000
z	22.584	6	0.0009
w	44635	4	0.0000
d	1310.7	1	0.0000
sta	137.68	8	0.0000
siz	19.798	8	0.0111
chs	60.909	8	0.0000
ln	19.989	8	0.0104
ps	70.685	8	0.0000
pw	50.55	8	0.0000
ft	80.628	8	0.0000
bq	174.89	8	0.0000
rls	66.092	8	0.0000
m	92.503	8	0.0000
ut	42.081	8	0.0000
fa	362.2	8	0.0000
ftp	114.08	8	0.0000
rah	597.91	8	0.0000
rtp	41.666	8	0.0000

[1] y = year, p = lactation number by stage of lactation, a = age at first calving, z = annual change in herd size, w = 305-day milk yield deviation, d = indication of type information, sta = Stature, siz =Size, chs = Chest Width, ln = Loin Strength, ps = Pin Setting, pw = Pin Width, ft = Foot Angle, bq = Bone Quality, rls = Rear Leg Set, m = Median Suspensory, ut = Udder Texture, fa = Fore Attachment, ftp = Fore Teat Placement, rah = Rear Attachment Height, rtp = Rear Teat Placement

Table 2: Solutions for the linear type traits expressed as relative culling rate

Class	sta	siz	chs	ln	ps	pw	fa	bq	rls	ut	ms	fa	ftp	rah	rtp
1	1.12	0.99	1.29	1.18	1.25	1.27	1.28	1.55	1.03	1.69	1.10	1.76	1.26	1.19	1.12
2	1.12	0.97	1.11	1.15	1.12	0.98	1.11	1.16	1.03	1.20	1.00	1.32	1.07	1.14	1.14
3	1.11	0.98	1.01	1.07	1.05	1.04	1.05	1.10	1.00	1.07	0.98	1.14	1.05	1.10	1.12
4	1.07	0.97	0.99	1.02	1.02	1.01	1.01	1.03	1.01	1.02	1.01	1.07	1.04	1.04	1.06
5*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	0.97	1.02	1.04	1.00	1.02	0.97	0.99	0.99	1.01	0.97	1.00	0.96	1.10	0.92	0.99
7	0.93	1.03	1.08	0.99	1.06	0.96	1.04	0.98	1.05	0.95	0.96	0.91	1.07	0.82	1.01
8	0.88	1.02	1.10	1.00	1.10	0.94	0.98	0.93	1.15	0.95	0.92	0.81	1.13	0.70	1.02
9	0.82	0.94	1.18	1.01	1.26	0.94	1.02	0.84	1.27	0.89	0.94	0.87	1.08	0.59	1.02

sta = Stature, siz = Size, chs = Chest Width, ln = Loin Strength, ps = Pin Setting, pw = Pin Width, ft = Foot Angle, bq = Bone Quality, rls = Rear Leg Set, m = Median Suspensory, ut = Udder Texture, fa = Fore Attachment, ftp = Fore Teat Placement, rah = Rear Attachment Height, rtp = Rear Teat Placement
* = reference class (constraint, risk set to 1).