Analysis of the Relationships Between Type Traits and Longevity in Croatian Simmental Cattle Using Survival Analysis

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Summary

Survival analysis with a Weibull proportional hazards model was used to evaluate the effect of linear type traits on the longevity in Croatian Simmental cattle. The data set consisted of 8,212 registered Simmental cows that first calved from 1997 to 2008. Longevity was defined as the number of days between first calving to culling or censoring. Cows alive at the end of the study (13.6%) were treated as right censored. Type information consisted of 19 linear type traits (with a nine-point scoring range) scored in the first lactation. Linear type traits were classified into four groups: muscularity, size traits, form traits and udder traits. The Weibull model included the time-independent effects of age at first calving, classifier, region and each type trait. The results showed a significant effect of 12 type traits on longevity. Among the form traits, low angled pasterns and extremely straight rear leg side view showed almost 2.0 times higher culling risks than normal posture. Cows with higher scores for the muscularity were at higher culling risk levels compared to lower scores. In the group of size traits, only rump height and body depth had significant impact on longevity. Lower scores for fore udder length were associated with lower risk of culling. In contrary, cows with lower scores for udder depth, suspensory ligament, rear udder length and teats thickness had higher probability of culling than the animals with higher scores.

Key words

Simmental cow, longevity, linear type traits, survival analysis

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Introduction

According to the actual strategy in animal breeding and animal welfare, numerous studies worldwide are focused on longevity and other functional traits from various aspects but with the common aim to improve its genetic evaluation. Longevity is an important and very complex trait which has a great impact on profitability in dairy herds (Essl, 1998). Direct selection for longevity in dairy cattle is limited because of low heritability and time required for the accumulation of sufficient data for breeding value estimation (Short and Lawlor, 1992; Harris et al., 1992; Philpot et al., 1997). Type traits are recorded early in cow's life, usually in the first lactation. Many studies reported moderate to high values for heritability of type traits as well as genetic correlations among longevity and type traits (VanRaden and Wigans, 1995; Weigel et al., 1998; Vollema and Groen, 1997). Studies indicate that linear type traits can be used as good predictors for longevity. Longevity is expressed as true and functional longevity. True longevity is real length of productive life, without correction for the effect of production. Functional longevity is corrected for the effect of production on culling decision and refers to the ability of a cow to avoid involuntary culling (Ducrocq, 1987). An appropriate method for analysis of productive life data is survival analysis because it allows using censored and uncensored data (Ducrocq, 1987; Vukasinovic, 1999). Moreover, it offers some crucial benefits compared with the traditional linear models in better fitting the survival data and using time-dependent variables properly (Ducrocq, 1987).

The aim of the present study was to evaluate the effects of type traits on true longevity of Croatian Simmental cows using a Weibull proportional hazards model.

Material and methods

The analysis of relationships between longevity and type traits was conducted using data provided by Croatian Agricultural Agency. The dataset with records on production traits consisted of 66,556 Simmental cows collected from October 1, 1992 until December 11, 2009. The dataset comprising scores on type traits consisted of 17,644 animals calving for the first time between 1997 and 2008. Records from animals without information, such as birth date, parity dates, linear scores and classifier code were not used. Cows first calving before 20 and after 40 months of age were excluded from the analysis. The final dataset included in the analysis consisted of 8,212 cows. True longevity was measured as length of productive life calculated as the number of days between the date of first calving and the date of culling or censoring. If a culling date was not available, the last known lactation end date was used. Cows with a final calving date greater than 365 days prior to the end of the study were considered as culled and culling date was declared to be 270 days from the initiation of the last parity. Otherwise, the record was considered as right censored. If the cow reached more than seven lactations, it was considered as censored at the end of 7^{th} lactation. In total, censoring procedure resulted with 1,115 (13.6%) right censored cows.

Table 1 shows the 19 linear type traits included in the analysis and defines the scale upon which each trait is scored.

Some of the traits, such as hock joint thickness, suspensory ligament, rear udder height as well as teats placement are scored more subjectively, where classifiers consider several aspects of appearance when assigning a score to a cow. Other traits are scored more objectively because those are defined as measurements.

According to the age at first calving, cows were divided in seven classes where each class comprised nearly equal number of animals (≤ 709 days, > 709 and ≤ 747 days, > 747 and ≤ 798 days, > 798 and ≤ 868 days, > 868 and ≤ 949 days, > 949 and ≤ 1005 days and > 1005 days). The classifiers with less than 30 animals scored were not taken into account during the analysis. These classifiers differed considerably in their estimated culling risks to other classifiers that scored more than 30 animals, probably due to the lack of experience. Including these classifiers in the analysis could lead to biased results.

Table 1. Description of linear type traits using nine-point scoring range

Group of traits	Trait	Score	
		1	9
Size traits	Rump height	<130 cm	>144 cm
	Rump width	narrow, <45 cm	wide, >58 cm
	Back length	<79 cm	>85 cm
	Body depth	shallow body, <63 cm	deep body, >84 cm
Form traits	Rump angle	high pinbones	sloped
	Rump length	<45 cm	>58 cm
	Rear leg side view	extremely straight	extremely curved
	Hock joint thickness	thick	thin
	Pasterns	low angle	steep angle
	Height of hoofs	flat	high
Udder traits	Fore udder length	very short	very long
	Rear udder length	very short	very long
	Suspensory ligament	extremely weak	extremely strong
	Udder depth	udder floor below hock	udder well above hock
	Teats thickness	≤ 1.5 cm	≥ 4.5 cm
	Teats placement	extremely outside	extremely inside
	Rear udder height	<41 cm	>28 cm
	Teats length	short	long
Muscularity	Muscularity	all profiles extremely concave	all profiles extremely rounded

Length of productive life was the dependent variable. The following proportional hazard model following Weibull distribution was used:

$$\lambda(t) = \lambda_0(t) \exp(afc_i + cls_k + reg_l + tt_m)$$

where:

$\lambda(t)$ = the hazard function of an individual depending on time t (days from first calving to culling or censoring)

$\lambda_0(t)$ = the baseline hazard function (related to the aging process) that is assumed to follow a Weibull distribution with scale parameter λ and shape parameter ρ

afc_i = the fixed time-independent effect of age at first calving

cls_k = the fixed time-independent effect of classifier

reg_l = the fixed time-independent effect of region

tt_m = the fixed time-independent effect of 19 type traits

All type traits and other effects were analyzed simultaneously removing the non-significant effects in a stepwise manner. It resulted with 12 significant type traits. Afterwards, 12 separate analyses were done including one type trait at a time in combination with other significant effects. Hence, the estimated risk ratios refer to the effect of particular type trait corrected for the effects of other traits.

The primary preparation of the data making the initial text file was performed by SAS 9.1. (2002-2003). Afterwards, the risk ratios for given effects were computed using Survival Kit 6.0 program (Ducrocq et al., 2010).

Results and discussion

The basic statistics overview of the analysed data is shown in Table 2. The average length of productive life in analyzed Simmental cows was 3.96 years, which corresponds to an average total lifetime of six years (table 2). The mean age at first calving was 26.25 months of age with SD ± 3.02 months. Among the preliminary 19 type traits included in the analysis (table 1), 12 had significant effects on longevity ($P < 0.05$). Other time-independent effects included in the model (age at first calving, the classifier and the region) were also significant ($P < 0.05$) but had a small effect on the risk of culling.

Table 2. Basic statistics of the analysed data involving censored records

Variable	Mean	SD	CV (%)	Min	Max
Length of productive life (years)	3.96	1.95	49.11	0.28	9.15
Age at first calving (months)	26.25	3.02	11.51	20	40
Rump height	5.72	1.90	33.27	1	9
Rump width	4.41	1.56	35.36	1	9
Back length	6.32	2.15	34.01	1	9
Body depth	5.26	1.51	28.64	1	9
Rump length	4.91	1.36	27.76	1	9
Rump angle	5.27	0.96	18.28	2	9
Muscularity	5.16	1.09	21.18	1	9
Rear leg side view	5.37	0.97	18.03	2	9
Hock joint thickness	5.95	1.14	19.18	2	9
Pasterns	5.51	1.10	20.00	1	9
Height of hoofs	5.22	1.14	21.95	1	9
Fore udder length	4.58	1.31	28.57	1	9
Rear udder length	4,60	1.17	25.56	1	9
Rear udder height	6.26	1.67	26.76	1	9
Suspensory ligament	6.53	1.39	21.37	1	9
Udder depth	6.44	1.26	19.57	2	9
Teats thickness	5.37	0.96	17.82	2	9
Teats placement	4.95	0.81	16.38	1	9
Teats length	5.55	1.03	18.58	1	9

The estimated Weibull parameter ρ, when all effects in the model are considered simultaneously, was equal to 2.14 and the intercept $\rho\log(\lambda)$, was equal to -16.05. The baseline hazard function is fully described by these two parameters (ρ and intercept), where a positive ρ indicates a baseline hazard function for which risk of culling increases over time. Similar values of the two parameters were obtained by Forabosco et al. (2004).

Linear type traits were classified into four groups: muscularity, size traits, form traits and udder traits. Muscularity had a negative effect on longevity that is even more expressed for extremely muscular animals (Figure 1). Thus, cows with the highest score had an approximately 1.8 times higher culling risk level than the animals scored with 5. Sölkner and Petschina (1999) found a similar trend in the correlation between muscularity and length of productive life of Simmental cows, where the muscularity of the front part of the body had a negative effect on longevity, especially pronounced in very muscular animals. In the study with Chianina beef cattle, Forabosco et al. (2004) found lower risk ratios for animals with more muscles due to specialization of the breed. Vukasinovic et al. (1997) found negative relationship between longevity and muscularity in Brown Swiss cattle that consequently showed shorter staying in the herd for more muscular types. Low muscular types were obviously preferable for breeders suggesting that highly muscular types produced less milk and therefore were culled for low production.

Only two size traits were significant ($P < 0.05$) in the model. Shorter animals had 1.55 times higher risks to be culled than taller animals or the animals of average rump height (Figure 2). Schneider et al. (2003) found 2.0 times higher risk levels for short animals, while tall animals had the lowest probability to be culled. Similar results were found by other authors (Boettcher et al., 1997, Forabosco et al., 2004; Larroque and Ducrocq, 2001).

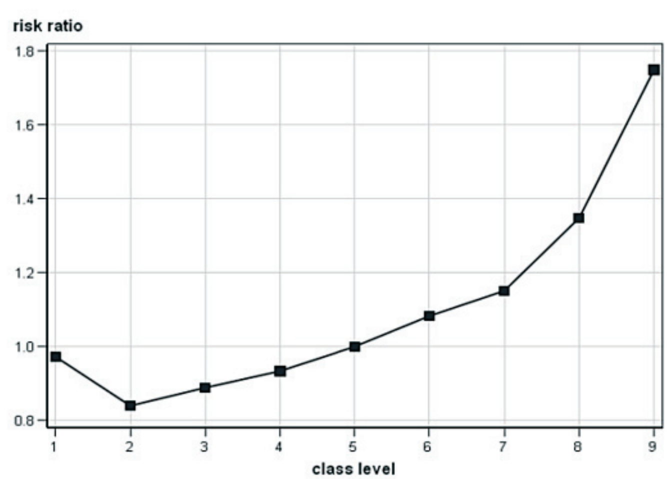

Figure 1. Estimates of risk ratios for classes of muscularity

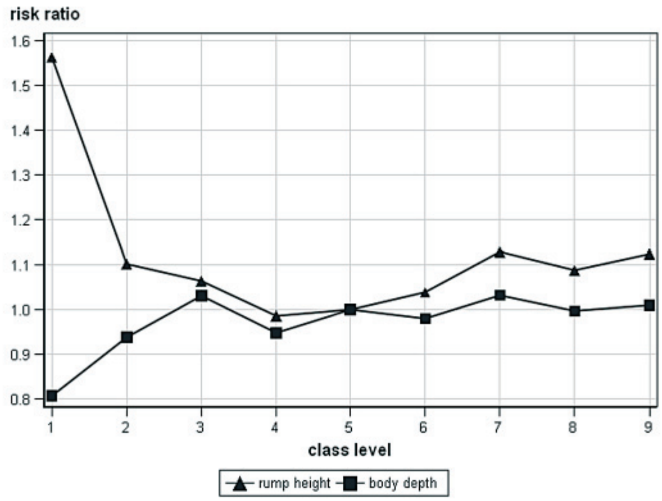

Figure 2. Estimates of risk ratios for classes of the size traits

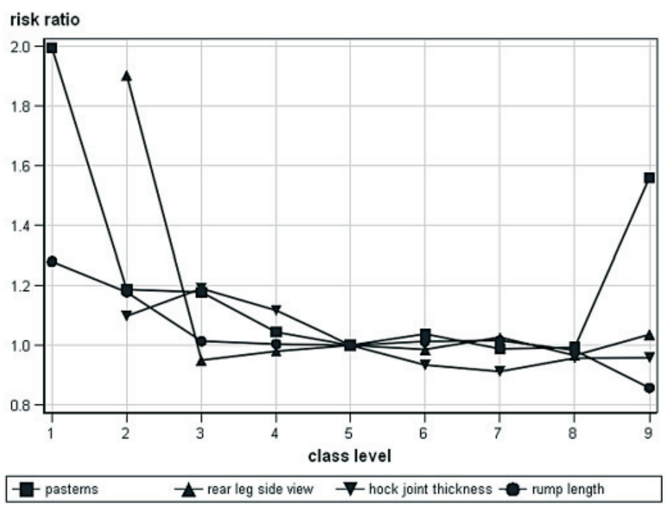

Figure 3. Estimates of risk ratios for clases of the form traits

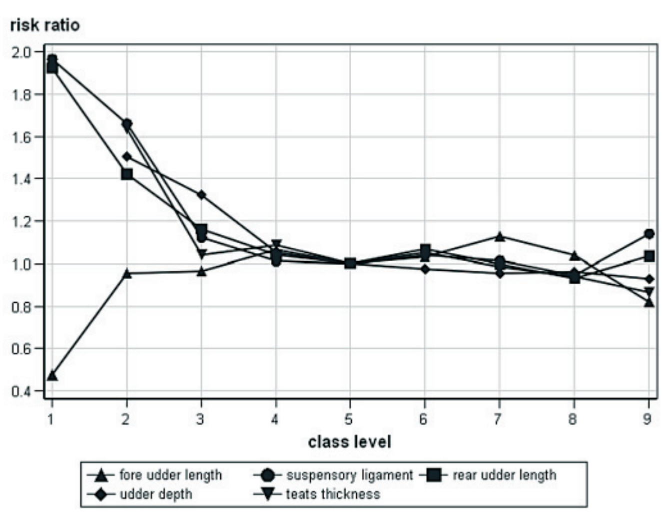

Figure 4. Estimates of risk ratios for classes of the udder traits

The opposite result was found by Caraviello et al. (2004) where effect of rump height on culling risk was minimal.

Body depth was less important for longevity (Figure 2). Only cows with very shallow body had a slightly lower risk (0.8) to be culled than the animals with average body depth.

Setati et al. (2004) also found that low linear type scores for body depth (shallow) were associated with increased longevity. In other words, selection for shallow bodied animals will improve longevity. Sewalem et al. (2004) found slightly higher culling risks (1.34) for both shallow and deep body animals.

Results in figure 3 show that form traits were more informative for longevity than size traits in terms of number of significant ($P < 0.05$) effects. Pasterns and rear legs side view had the highest influence on the culling risks. Animals with very low angled pasterns had 2.0 times higher probability to be culled than the animals with average pasterns. Moreover, cows with very steep angled pasterns showed to be under 1.6 times higher culling risk than the animals from class 5. A similar trend was found for rear legs side view where extremely straight types (class 2) had a 1.6 times higher probability to be culled than normal types. Other types were less exposed to culling. Hock joint thickness and rump length were less important for longevity than other two form traits where risk ratios ranged from 0.9 to 1.3. Same trends with slightly lower values in risk ratios for pasterns, hock joint thickness and rear legs side view were obtained by Schneider et al. (2003), Caraviello et al. (2004) and Sewalem et al. (2004). Berry et al. (2005) observed an intermediate optimum for legs where cows with an extremely high or low score for legs had a higher risk of being culled.

Five udder traits were the most influential group of traits on longevity showing positive or negative relationship with culling risks (Figure 4). Cows scored with lower scores for suspensory ligament, rear udder length, udder depth and teats thickness were at approximately 1.5 to 2.0 times higher risk to be culled than the cows scored with the score 4 and higher. One exception was observed for fore udder length where animals with shorter fore udder had smaller chance to be culled. Udder traits are the most important morphological trait for the dairy cattle breeders. Therefore, cows with good udder are more likely to avoid voluntary culling by the breeder than cows with poor udder. Many authors observed high impact of udder traits on longevity (Vukasinovic et al., 1997; Sölkner and Petschina, 1999; Larroque and Ducrocq, 2001; Schneider et al., 2003; Berry et al., 2005; Bouška et al., 2006; Zavadilova et al., 2009). In accordance to our results, Schneider et al. (2003) and Sewalem et al. (2004) found suspensory ligament of Holstein cows to be one of the most important udder traits, where animals with lower scores (extremely weak) had almost 2.0 times higher risk of culling than other types.

Conclusions

Results showed that udder traits, form traits as well as muscularity and size traits could be used as early predictors of longevity in Croatian Simmental cattle. Udder traits were of crucial importance for culling decisions. Longevity was mostly affected by suspensory ligament and rear udder length, where animals with lower scores were under 2.0 times higher risk of culling in comparison to average and high scored animals. Less expected results were obtained for fore udder length where animals with lower scores had lower chance to be culled. Muscularity had a negative effect on longevity. Size and form traits showed respectable influence on cows' productive life as well, particularly rump height, pasterns and rear legs side view.

References

Berry D.P., Harris B.L., Winkelman A.M., Montgomerie W. (2005). Phenotypic associations between traits other than production and longevity in New Zealand dairy cattle. J. Dairy Sci. 88: 2962-2974.

Boettcher P. J., Jairath L.K., Koots K.R., Dekkers J.C.M. (1997). Effects of interactions between type and milk production on survival traits of Canadian Holsteins. J. Dairy Sci. 80: 2984-2995.

Bouška J., Vacek M., Štipková, M., Nemec, A.(2006). The relationship between linear type traits and styability of Czech Fleckvieh cows. Czech J. Anim. Sci. 51(7): 299-304.

Caraviello D.Z., Weigel K.A., Gianola D. (2004). Analysis of the relationship between type traits and functional survival in US Holstein cattle using a Weibull proportional hazards model. J. Dairy Sci. 87: 2677-2686.

Ducrocq V. (1987). An analysis of length of productive life in dairy cattle. Ph.D. Diss., Cornell Univ., Ithaca, NY.

Ducrocq V., Sölkner J., Mészáros, G.: Survival Kit v6 - A software package for survival analysis. In 9th World Congress on Genetics Applied to Livestock Production, August 1-6 2010, Leipzig.

Essl A. (1998). Longevity in dairy cattle breeding: a review. Livest. Prod. Sci. 57: 79–89. Forabosco F., Groen A.F., Bozzi R., Van Arendonk J.A.M., Filippini F., Boettcher P., Bijma P. (2004). Phenotypic relationships between longevity, type traits, and production in Chianina beef cattle. J. Anim. Sci. 82: 1572-1580.

Harris B.L., Freeman A.E., Metzger E. (1992). Analysis of herd life in Guernsey dairy cattle. J. Dairy Sci. 75: 2008-2016.

Larroque H., Ducrocq V. (2001). Relationships between type and longevity in the Holstein breed. Genet. Sel. Evol. 33: 39-59.

Philpot (McWethy) J.C., Monardes H.G., Cue R.I. (1997). Correlations between herd life and type traits in Quebec Holsteins. Am. Dairy Sci. Assoc., 92nd Annual Meeting June 22-25, 1997 University of Guelph, Guelph, Ontario.

SAS Institute 2002-2003. The SAS System. Version 9.1., Cary, SAS Institute, CD-ROM.

Schneider M. del P., Dürr J.W., Cue R.I., Monardes H.G. (2003). Impact of type traits on functional herd life of Quebec holsteins assessed by survival analysis. J. Dairy Sci. 86: 4083-4089.

Setati M.M., Norris D., Banga C.B., Benyi K. (2004). Relationships between longevity and linear type in Holstein cattle population of Southern Africa. Tropical Animal Health and Production, 36: 807-814.

Sewalem A., Kistemaker G.J., Miglior F., Van Doormaal B.J. (2004). Analysis of the relationship between type traits and functional survival in Canadian Holsteins using a Weibull proportional hazards model. J. Dairy Sci. 87: 3938-3946.

Short T.H., Lawlor T.J. (1992). Genetic parameters of conformation traits, milk yield and herdlife in Holsteins. J. Dairy Sci. 75: 1987-1998.

Sölkner J., Petschina R. (1999). Relationship between type traits and longevity in Austrian Simmental cattle. INTERBULL Bull. 21, 91–95.

VanRaden P.M., Wiggans G.R. (1995). Productive life evaluations: Calculations, accuracy, and economic value. J. Dairy Sci. 78: 631-638..

Vollema A.R., Groen A.F. (1997). Genetic correlations between longevity and conformation traits in un upgrading dairy cattle population. J. Dairy Sci. 80: 3006-3014.

Vukasinovic N., Moll J., Künzi N. (1997). Analysis of productive life in Swiss Brown cattle. J. Dairy Sci. 80: 2572-2579.

Vukasinovic N. (1999). Application of survival analysis in breeding for longevity. Proceedings of the 4th International Workshop on Genetic Improvement on functional traits in cattle. Jouy-en-Josas. Interbull bulletin No. 21, Uppsala, p. 3-10.

Weigel K.A, Lawlor Jr. T.J., Van Raden P.M., Wigans G.R. (1998). Use of linear type and production data to supplement early predicted transmitting abilities for productive life. J. Dairy Sci. 81: 2040-2044.

Zavadilová L., Štípková M., Němcová E., Bouška J., Matějíčková J. (2009). Analysis of the phenotypic relationships between type traits and functional survival in Czech Fleckvieh cows. Czech J. Anim. Sci. 54: 521-531.

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