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Elisandra Lurdes Kern[1]*, Jaime Araujo Cobuci[1], Cláudio Napolis Costa[2], Vincent Ducrocq[3]

[1]Federal University of Rio Grande do Sul – Dept. of Animal Science, Av. Bento Gonçalves, 7712 – 91540-000 – Porto Alegre, RS – Brazil.
[2]Embrapa Dairy Cattle, R. Eugênio do Nascimento, 610 – 36038-330 – Juiz de Fora, MG – Brazil.
[3]French National Institute for Agricultural Research – UMR1313 Animal Genetics and Integrative Biology unit, Domaine de Vilvert – 78352 – Jouy-en-Josas – France.
*Corresponding author <elikern@hotmail.com>

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ABSTRACT: Longevity is an important trait due to its relationship with profitability. Type traits have been used as indirect predictors for productive life. The objective of this study was to evaluate the relationship of 20 type traits on length of productive life in Brazilian Holsteins, using a piecewise Weibull proportional hazard model. Three analyses were performed i) productive life was corrected for within herd level of production as a proxy for functional longevity, which included the time-dependent effects of region within year, class of milk production within herd-year, milk production class within lactation number, fat class and protein contents within herd and (variation in) herd size as well as the time-independent fixed effect of age at first calving and the type trait score; ii) the effects related to production were omitted from the first model (true longevity) and iii) with the first model, the effect of type was also studied considering five classes of percentage of type-scored cows within the herd. All analyses were performed using the Survival Kit program. The final score, angularity, top line, udder texture and suspensory ligament showed the strongest relationship with productive life. When type traits were available only for a small fraction of the herd, the cows had a better chance of remaining longer in the herd. The absence of type trait phenotypes was associated with a strong increase of culling risk for the cows. Type traits were not found to be good indirect predictors of productive life in Brazil.
Keywords: conformation traits, dairy cattle, longevity, culling risk, survival analysis

Introduction

Productive efficiency of dairy cattle has a strong relationship with increased longevity. Longer productive life lead to lower replacement and treatment costs associated with fertility and health disorders or problems related to cow morphology (Ducrocq et al., 1988; Essl, 1998).

Direct selection for longevity has always been a challenge, ranging from the choice of a proper measure of productive life compatible with short generation intervals up to the choice of an appropriate analysis accounting for the fact that environmental factors influencing culling change with time. The survival analysis allows to combine information from live (censored) and culled (uncensored) animals to model the nonlinear, the time-dependent factors influencing productive life, and describe of the evolution of a hazard function throughout the cow productive life (Ducrocq, 2005).

However, according to Buenger et al. (2001), reliability of young sire evaluations for productive life remains limited, because a majority of their daughters are still alive at the end of their first lactation and the problem increases since there are genotyped young bulls nowadays. Indeed, a large proportion of censored records lead to a low accuracy of productive life evaluations (Vukasinovic et al., 1999). To increase this accuracy, it is desirable to combine information on traits correlated with longevity, which can be recorded early in life (Larroque and Ducrocq, 2001; Buenger et al., 2001).

Type traits play an essential role in breeding and selection decisions in dairy cattle. According to Short and Lawlor (1992), the main objective of type classification is to identify and select desirable type traits associated with improved herd life. Several studies using different approaches showed the beneficial impact of type traits on longevity, especially udder, feet and leg traits (Larroque and Ducrocq, 2001; Buenger et al., 2001; Caraviello et al., 2003; Dadpasand et al., 2008). Similarly, Lavrinovič et al. (2009) reported significant influence of body size composite and udder traits on the productive life of Lithuanian dairy cattle. Type trait scores are often collected during first lactation and have higher heritability than productive life does.

The genetic evaluation of Holstein bulls for productive life of their daughters in Brazil has been investigated (Kern et al., 2016), but it is not routinely carried out. To promote future evaluations, an important step is to understand the relationship between productive life and potential early predictors, such as type traits. This study evaluated the effect of type traits on productive life in Brazilian Holstein cows, using a piecewise Weibull proportional hazard model.

Materials and Methods

Length of productive life and type traits records were obtained from the Brazilian Association of Holstein Cattle Breeders (ABCBRH) and its affiliated state agencies. Two longevity traits were defined as in Ducrocq et al. (1988): true longevity, measured as the number of days from first calving to culling, and functional longevity, approximated by correcting true longevity for within-herd-year level of production.

The type traits database was merged with production data. As a result, 54,633 cows had both type and production traits (milk yield adjusted to 305 days, fat and protein contents) while 78,289 cows had only production data. Production and type traits of Holstein cows with first calving occurring between 1989 and 2013 were included in the analysis. Cows younger than 20 or older than 40 months at first calving and cows without date of first calving were excluded from the analysis, as well as daughters of sires with fewer than five daughters.

Focusing on the effect of type traits on culling early in life (which most strongly impacts profitability), a cow with more than five lactations was assumed as censored on the day of her sixth calving. When the exact culling date was missing, the last known milk recording date was used as culling date. Cows that were still alive on 31 Dec 2013 were also considered as censored. To avoid biases due to potential poor recording of calving dates, lactation lengths were bounded at 800 days. Cows sold to other herds were censored on the day of their last milk record in the first herd to account for a possible preferential treatment in their new herd. Overall, 33 % of the cows had a censored record.

The linear classification system used by the ABCBRH included 20 type traits expressed on a scale from one to nine points (Table 1) as well as final score expressed on a scale from 1 (poor) to 6 (excellent), where body traits received a weight of 22 %, feet and legs 26 %, the mammary system 42 %, and rump traits 10 %. The impact of each type trait on functional longevity was studied separately. Of 132,922 cows, daughters of 6,084 sires in 915 herds were included in the analysis.

The type traits are often presented as good longevity predictors. Therefore, it is important study the relationship between type traits and true and functional longevity in Holstein cows in Brazil. The relationship found by the survival analysis is based on risk of culling and it can be used to describe the productive life of cows, environmental factors that could affect their productive life, and recommend traits to select index for longevity of cows. Three analyses were performed to evaluate the relationship between length of productive life and each type trait using proportional hazard models. The hazard $\lambda(t)$ of a cow at time t (i.e., the risk of culling given it is alive just prior to t) was modelled using a piecewise Weibull hazard function. In the first analysis, an approximation of functional longevity was studied in which all environmental effects found significant in the analysis of Kern et al. (2016). The effects were described below and analyzed with each type trait

Table 1 – Description of linear type traits.

Trait	Description of evaluation	Score			
		1	5	9	Ideal
Mammary system traits					
Fore udder attachment	Attachment to abdominal wall	Extremely weak	Intermediate	Extremely strong	9
Fore teat placement	Teat placement from the center of the quarter	Extremely outside	center	Extremely inside	5
Rear teat placement	Teat placement from the center of the quarter	Extremely outside	center	Extremely inside	5-6
Fore teat length	Length of the front teat	Extremely short	Intermediate	Extremely long	5
Rear attachment height	Distance between milk secreting tissue and the base of vulva	Extremely low	Intermediate	Extremely high	9
Rear attachment width	Width at milk secreting tissue	Extremely narrow	Intermediate	Extremely wide	9
Udder depth	Distance from the udder floor to the hock	Extremely deep	Intermediate	Extremely shallow	5-6
Udder texture	Softness and expandability	Extremely fleshy	Intermediate	Extremely soft	9
Median suspensory ligament	Depth of cleft	Extremely weak	Intermediate	Extremely strong	9
Feet and legs traits					
Foot angle	Toe angle	Extremely low	Intermediate	Extremely steep	7
Bone quality	Flatness of bone	Extremely coarse	Intermediate	Extremely flat	9
Rear legs side view	Degree of curvature (side view)	Extremely straight	Intermediate	Extremely curved	5
Rump traits					
Rump angle	Height of pin bones relative to height of hook bones	Extremely high	Intermediate	Extremely low	5-6
Loin strength	Strength of vertebrae between back and rump	Extremely weak	Intermediate	Extremely strong	9
Rump width	Distance between the most posterior point of pin bones	Extremely narrow	Intermediate	Extremely wide	9
Body traits					
Stature	Measured from top of the spine in between hips to ground	Extremely short	Intermediate	Extremely tall	7
Chest width	Measured from the inside surface between the top of the front legs	Extremely narrow	Intermediate	Extremely wide	7
Body depth	Depth of body at the rear rib	Extremely shallow	Intermediate	Extremely deep	7
Angularity	Appearance of angularity	Extremely rounded	Intermediate	Extremely angular	9
Top line	Relation between the posterior and anterior stature of the animal in dorsal line	Extremely low	leveled	Extremely high	5-6-7
		1	3	6	Ideal
Final Score	Balance between the type traits according to its importance within each section	Extremely poor	Intermediate	Excellent	6

presented in Table 1. In the second analysis, the effects related to level of production were omitted to study the effect of each type trait on true longevity. In the third analysis, the functional longevity and all effects in the first analysis were considered, except for effect change of each type trait caused by the effect of five classes of herd percentage of type-scored cows (1 = 0 to 10 %, 2 = from 11 to 30 %, 3 = from 31 to 50 %, 4 = from 51 to 70 %, 5 = from 71 to 100 % of herd percentage of type-scored cows). The analysis of the effect of percentage of type-scored cows was performed, because not all cows in a herd were scored for type.

The full model used for the three analyses above describes evaluated the relationship between type traits and longevity in Holstein cows in Brazil can be write as:

$$\lambda(t) = \lambda_{0,1s}(t)\ \exp\{\Sigma_m\ f_m\ (t) + hys_k(t) + s_i + 0.5\ mgs_j\} \quad (1)$$

where $\lambda(t)$ is the baseline hazard function of the cow at time t, defined as a piecewise Weibull hazard function of the form $\lambda_{0,1s}(t) = \lambda\rho(\lambda\tau)^{\rho-1}$ with scale parameter λ and shape parameter ρ differing for each combination of the l*th* lactation (1 to 5) and the *sth* stage of lactation *s* (1 to 4) resulting in 20 different Weibull functions, one per interval. Lactation stages from 0 to 270 days, 271 to 380 days, 381 to dried date, and a separate dry period were defined according to τ, the number of days since the most recent calving.

In the three analysis describe above, the model included the following fixed environmental effects (Σ_m f_m (t)) is the sum of fixed environmental effects): age at first calving was assumed to influence the whole productive life, it was time independent and estimated for each one-month class of age at first calving between 20 and 42 months. All the other fixed effects were time-dependent. These included the interaction effects of region by year of calving (from 1989 to 2013); variation in herd size class (i - with only one class for herds size with less than 5 cows, three classes of variation in herd size (ii - decrease by more than 10 % in herd size, iii - stable size, iv - increase by more than 10 % for herds size with 5 to 19 cows) and five classes of variation in herd size (v - decrease by more than 15 % in herd size, vi - decrease by 5 to 15 %, vii - stable size, viii - increase by 5 to 15 %, iv - increase by more than 15 %, separately for herds size with 20 to 49 cows and also to herds size with 50 cows or more)) the type trait score of *p* (*p* generally from 1 to 9) (Table 1). The 20 type traits and the final score were considered separately, one at a time. A particular "missing" class was used for cows without type score. In the third analysis, this fixed effect was changed by herd percentage of type-scored cows, as described above.

For the second analysis, the following fixed effects time-dependent were omitted when studying the impact of type traits on true longevity: milk production class by year of calving within herd milk production class (from 1 - worst (1- 20 %), 2 - (21 - 40 %), 3 - (41 - 60 %), 4 - (61 - 80 %), 5 - best (81 - 100 %) for milk production, and 6 - unknown); within herd milk production class by lactation number (1 - first lactation, 2 - later lactations); within herd fat content (from 1 - worst (1 - 20 %) 2 - (21 - 40 %), 3 - (41 - 60 %), 4 - (61 - 80 %), 5 - best (81 - 100 %) and 6 - unknown); within herd protein content (from 1 - worst (1 - 20 %) 2 - (21 - 40 %), 3 - (41 - 60 %), 4 - (61 - 80 %), 5 - best (81 - 100 %) and 6 - unknown).

The following random effects were also considered in the three analyses:
$hys_q(t)$ is the q*th* random herd-year effect assumed to follow a log-gamma distribution (with shape and scale parameters both equal to γ in order to force its mean to be 1), represents the additive genetic contribution from the sire r and of the maternal grand sire *s* of the cow.

Estimates of all fixed effects were expressed as relative culling risks, defined as the ratio between the risk of culling under a particular environmental factor and a specific reference class. For example, the risk ratio associated with a score of $p = 8$ for one of the 20 type traits was defined as $\exp\{t_p - t_5\}$, score 5 was chosen as the reference class.

The overall influence of each type trait on functional or true longevity was assessed using likelihood ratio tests, comparing a full model including each particular type trait with a reduced model without any type trait. For true longevity, in the second analysis, corrections for production traits were omitted from the model. All analyses were performed using the Survival Kit version 6 software (Mészáros et al., 2013).

Results

All type traits included in the model had a highly significant effect ($p < 0.001$) on risk of the cow culling. This was due to the existence of a "missing" class independent of type trait: this missing class represents contemporary cows, which were not type-scored (Table 2) and had a much higher relative risk of being culled (1.48 to 1.62) than a cow in the reference class. This motivated the extension of our analysis to consider the percentage of typed cows in the herds as in Terawaki and Ducrocq (2009).

The relative contribution of each type trait to minus twice the log-likelihood (-2logL) of the model for functional longevity (corrected for production) or true longevity (not corrected for production) is illustrated in Figure 1, after removing the contribution of the missing type class. The relative contributions were ranked in decreasing order and expressed as a percentage of the contribution of final score, which is the trait that caused the largest change in -2logL. Whether a correction for production traits was applied or not, the contribution of type traits on productive life (PL) was in general small and with limited variability, with a few exceptions considered below. Final score, angularity and top line were the most important traits related to PL, followed by some udder traits, such as udder texture and median suspensory ligament.

Table 2 – Relative risk of culling for body, feet and legs, rump and mammary system traits (reference: score 5).

Score	STA	CW	BD	AN	TL	FA	BQ	RLS	RA	LS	RW	FUA	FTP	RTP	FTL	RUH	RUW	UD	UT	MS
1	-	-	-	-	-	-	-	-	-	-	-	-	0.97	-	-	-	-	1.10	-	0.88
2	-	0.97	-	-	1.41*	1.03	1.25	1.08	0.75	0.89	0.92	1.14*	1.14	-	1.19	1.09	1.16	1.13	0.99	0.95
3	0.89	1.01	1.03	0.93	1.14*	1.02	1.14	1.05	1.08*	1.10*	1.07	0.99	0.98	1.00	1.06*	1.04	1.03	1.07	0.99	1.08
4	0.97	0.99	0.95	0.98	1.08*	1.02	1.02	1.05	1.01	1.00	0.96	1.03	1.04*	1.07	1.03	1.08	1.05*	1.04	0.97	1.02
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	1.00	1.00	1.00	1.00	1.00
6	1.00	0.94*	0.97	0.94*	0.94*	1.02	1.00	0.98	1.02	1.01	0.98	0.98	0.97	1.01	1.02	1.00	1.02	0.96*	0.99	0.96
7	0.99	0.92*	0.91*	0.92*	0.84*	1.00	1.00	0.95*	1.06*	0.98	0.95*	0.96	0.94	0.98	0.97	0.99	0.99	0.94*	0.97	0.95*
8	1.00	0.85*	0.87*	0.80*	0.74	0.78	0.94*	0.88*	1.06	0.95	0.90*	0.92*	1.00	0.98	1.00	0.94*	0.96	0.90	0.88*	0.89*
9	1.01	0.60*	0.70*	0.77*	-	-	0.93	0.86	1.28	0.86*	0.91*	0.78*	-	0.95	1.09	0.99	0.87*	-	0.87*	0.86*
Missing	1.60*	1.52*	1.51*	1.48*	1.57*	1.61*	1.58*	1.58	1.62*	1.58*	1.54*	1.56*	1.61*	1.59*	1.61*	1.59*	1.61*	1.61*	1.54*	1.53*

Body traits - stature (STA); chest width (CW); body depth (BD); angularity (AN) and top line (TL); *Feet and legs* - foot angle (FA); bone quality (BQ) and rear legs side view (RLS); *Rump traits*- rump angle (RA); loin strength (LS) and rump width (RW); *Mammary system traits*- fore udder attachment (FUA); fore teat placement (FTP); rear teat placement (RTP); fore teat length (FTL); rear udder height (RUH); rear udder width (RUW); udder depth (UD); udder texture (UT); median suspensory (MS). Values with an asterisk are significantly different from the reference class at a level of 0.05. Only classes with a minimum of 50 uncensored failures are reported.

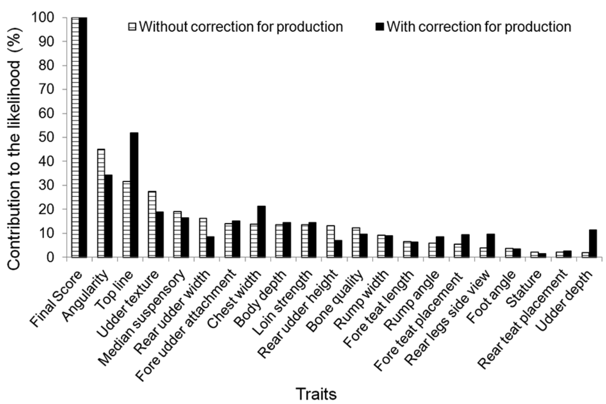

Figure 1 – Contribution to the likelihood of each linear type trait and final score of productive life (contribution percentage of the most important traits and excluding the contribution of "missing" score class).

Among body traits, angularity and top line had a relatively strong relationship with productive life corrected or not for production (Figure 1), but angularity had a larger contribution when production was not corrected, suggesting that it was also associated with better production. The opposite was observed for top line. Except for stature, high scores for body traits tended to be associated with a decrease in risk of culling (Table 2). There was no clear relationship between stature and productive life (Figure 1). When the fraction of type-scored cows was accounted for (Figure 2), there were few or no scores below 3 or 4 when less than 30 % of the herd was scored, probably because of a pre-selection of the animals to be scored based on these criteria.

Estimates of relative risk for feet and leg traits are in Table 2. Bone quality and rear leg set displayed a linear relationship with functional productive life, with slightly higher relative risk estimates for lower scores. The phenotypic trend for foot angle was so small that none of the scores showed a significant difference from the reference score. Cows with straight rear legs and coarse bone had an increased relative risk of culling. In herds with over 70 % of cows recorded for type traits, cows with highly sickled legs (score 9) showed a higher risk of culling (Figure 3), which is surprising because for other classes of percentage of type-scored cows in the herd, higher scores were associated with a lower relative risk. Low variation in the risk of culling for bone quality was observed when more than 70 % of cows were type-scored.

Except for rump angle, rump traits showed a low relationship with functional longevity (Table 2). For loin strength and rump width, higher scores are associated with a lower relative risk. For rump angle, there is an intermediate optimum score corresponding to the reference class (score 5). A linear trend in estimated relative risk of culling for rump width and loin strength was observed in herds with more than 70 % of type-scored cows. However, large fluctuations of effect of the same traits were found for cows in herds with less than 50 % percent of type-scored animals (Figure 3) illustrating the impossibility of drawing clear conclusions with partial performance recording.

Traits related to the mammary system presented low to moderate relationship with productive life (Figure 1). Among udder traits, udder texture, median suspensory ligament and rear udder width had the largest effect on longevity. Despite this relatively low impact of udder traits on productive life, fore udder attachment, rear udder width, udder depth and median suspensory ligament showed linear relationship with functional longevity with higher relative risk for cows with low scores, while the other udder traits showed no linear trend (Table 2).

Cows with close rear teats, extremely narrow rear udder, deep and fleshy udder were more likely to be culled compared to cows with opposite characteristics. High scores for median suspensory ligament were associated with lower culling rates. These observations are supported by some obvious problems caused by extreme scores. For example, when a cow has close rear teats, it

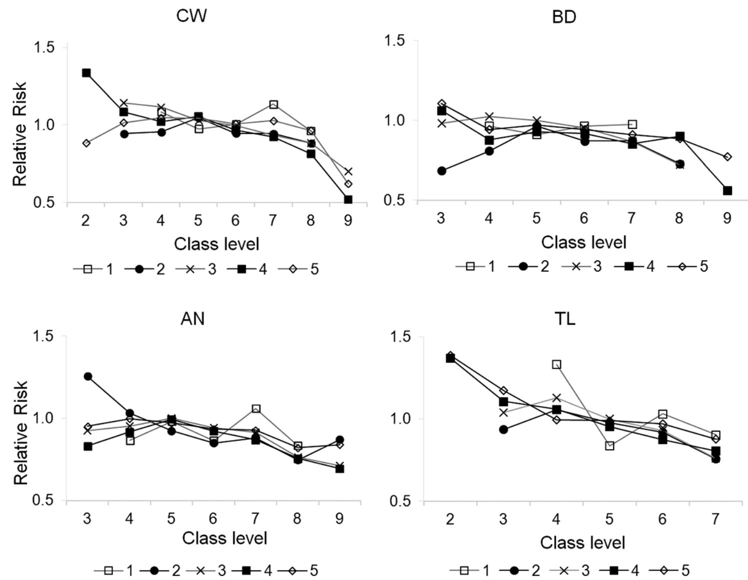

Figure 2 – Relative risk of culling for the body (chest width (CW), body depth (BD), angularity (AN) and top line (TL)) traits according to 5 classes of herd percentage of type-scored cows (1 = 0 to 10 %, 2 = from 11 to 30 %, 3 = from 31 to 50 %, 4 = from 51 to 70 %, 5 = from 71 to 100 % of herd percentage of type-scored cows) for Brazilian Holsteins (reference: score 5 in class 3 of herd percentage of type-scored cows). Only classes with a minimum of 40 uncensored failures are reported.

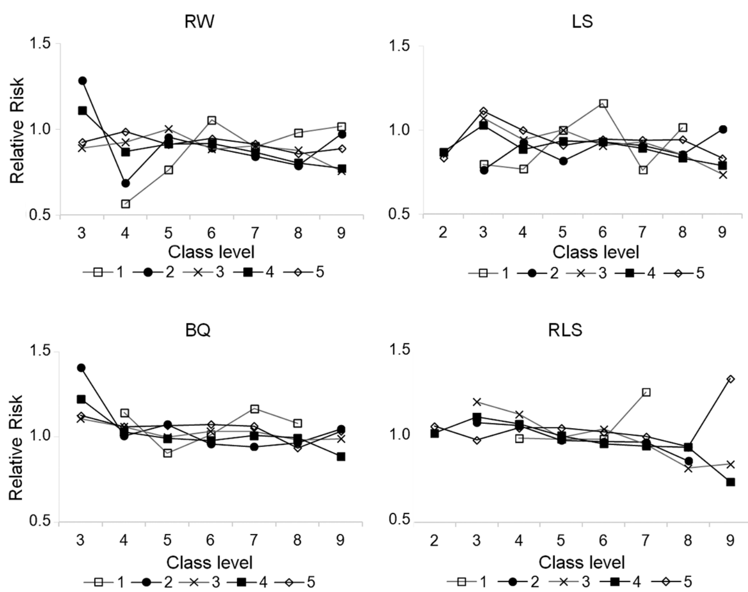

Figure 3 – Relative risk of culling for some rump (loin strength (LS) and rump width (RW)) and feet and legs (bone quality (BQ) and rear legs side view (RLS)) traits according to 5 classes of herd percentage of type-scored cows (1 = 0 to 10 %, 2 = from 11 to 30 %, 3 = from 31 to 50 %, 4 = from 51 to 70 %, 5 = from 71 to 100 % of herd percentage of type-scored) for Brazilian Holsteins (reference score 5 in class 3 of herd percentage of type-scored cows). Only classes with a minimum of 40 uncensored failures are reported.

is more difficult to put teat cups into place and they fall on the ground more easily. Another example is the incidence of mastitis that may be increased for cows with fleshy udder, needing more time to be milked.

Due to the large number of udder traits, only traits with the largest effects here or in previous published works (Larroque and Ducrocq, 2001; Caraviello et al., 2003) are displayed for the analysis showing the influ-

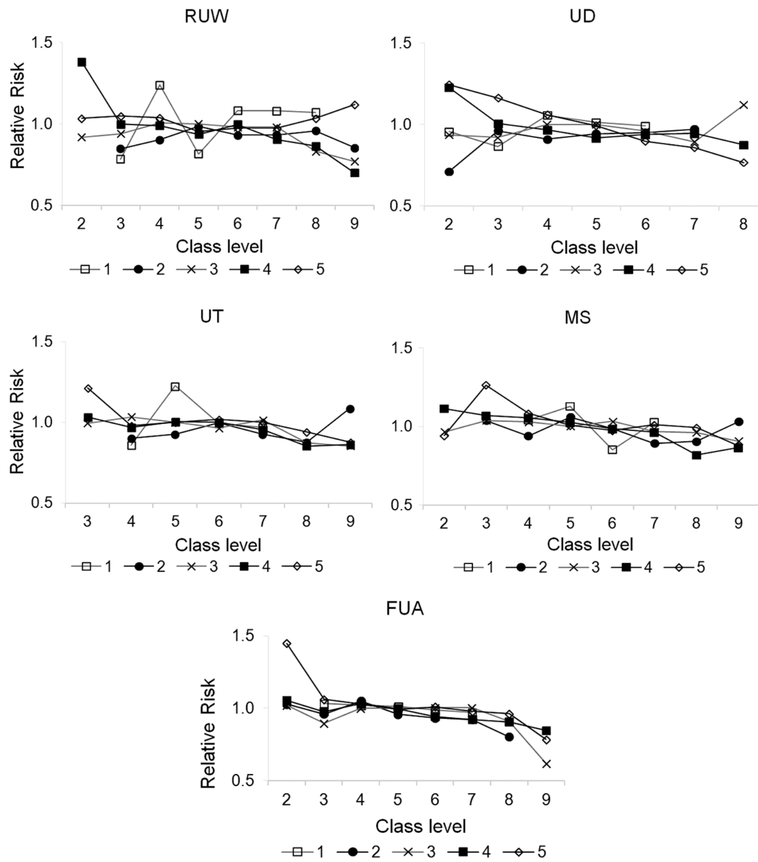

Figure 4 – Relative risk of culling for the mammary system (fore udder attachment (FUA), rear udder width (RUW), udder depth (UD), udder texture (UT), and median suspensory (MS)) traits according to 5 classes of herd percentage of type-scored cows (1 = 0 to 10 %, 2 = from 11 to 30 %, 3 = from 31 to 50 %, 4 = from 51 to 70 %, 5 = from 71 to 100 % of herd percentage of type-scored) (reference final score 5 with class of herd percentage of type-scored cows 3). Only classes with a minimum of 40 uncensored failures are reported.

ence of percentage of type-scored cows in the herd (Figure 4). In general, a higher variability in relative risk was observed for extreme scores (2 or 9) and for class 1, which has low percentage of type-scored cows. This can be explained by a lower number of observations of these cases. Low scores (scores 2 and 3) for fore udder attachment, rear udder width, udder texture and udder depth tended to be associated with a higher relative risk for herds with better data, i.e., with a higher percentage of type-scored cows (classes 4 and 5). Relative risks for fore udder attachment, rear udder width and udder depth decreased when the corresponding score increased.

Figure 5 shows a linear relationship between class 3 and 6 for final score and length of productive life. Cows with final score equal to 6 had a relative risk about 20 % lower than the reference class (class 5), whereas cows with a low score (1-3) were 1.5 times more likely to be culled. The final score was by far the trait with the largest impact on productive life, with or without correction for production (Figure 1). When percentage of type-scored cows in the herd was ac-

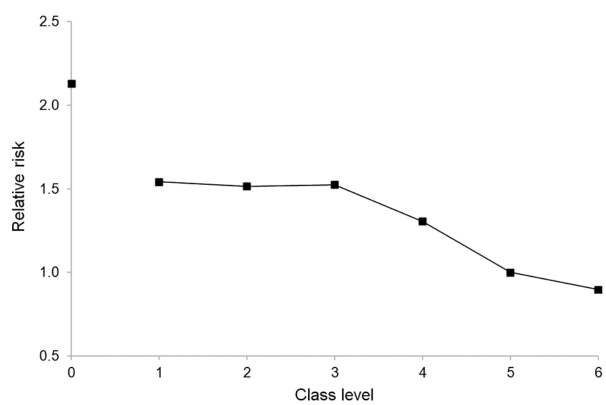

Figure 5 – Relative risk of culling for final score for Brazilian Holsteins (reference: score 5). Only classes with a minimum of 40 uncensored failures are reported.

counted for (Figure 6), a curious result was observed when less than 10 % of the herd was type-scored, the relative risk of culling appeared to be slightly better for cows with a low final score than cows with a better fi-

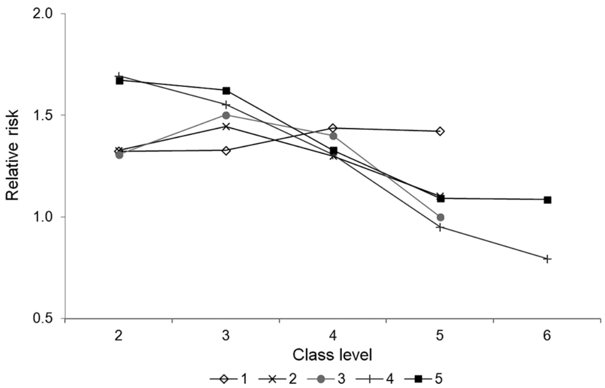

Figure 6 – Relative risk of culling for final score according 5 classes of herd percentage of type-scored cows (1 = 0 to 10 %, 2 = from 11 to 30 %, 3 = from 31 to 50 %, 4 = from 51 to 70 %, 5 = from 71 to 100 % of herd percentage of type-scored cows) for Brazilian Holsteins (reference: final score 5 in class 3 of herd percentage of type-scored cows). Only classes with a minimum of 50 uncensored failures are reported.

nal score. In contrast, when higher proportions of cows were scored, the impact of final score on productive life was large.

The effect of each type traits on the estimates of the γ parameter of the log-gamma distribution, the resulting variance of the herd-year random effect, the sire genetic variance and the effective heritability for functional length of productive life (i.e., assuming no censoring) were generally similar between all type traits studied (Table 3).

Discussion

To avoid biases in genetic evaluations of type traits, all first lactation cows in a herd must be recorded together for type traits. This is an ICAR (International Committee for Animal Recording) recommendation (ICAR guidelines, 2016, section 5.1.5.3, p. 199). However, in Brazil, breeders can choose which cows are scored – for example the ones that they consider as "best".

Frequently, not all animals in the herd may have been recorded for type traits and the worst animals may not have been included in our analysis. As a consequence, the absence of a type score had a very large influence on the cow survival for all type traits. This illustrates that selection of cows among breeders of the Holstein Association in Brazil is heavily based on type, probably because of its impact on sales of live animals rather than on production. Clearly, when information was available only for a small fraction of the herd, these cows were not chosen at random and had a better chance of remaining longer in the herd. A similar situation was reported by Terawaki et al. (2006; 2009) in Japanese Holsteins. The authors draw attention to the percentage of cows with a type score in a herd is

Table 3 – Estimates of parameters related to the herd-year and sire random effects genetic and non-genetic random effect parameters for functional longevity analyzed including the type traits effect.

Type Traits	STA	CW	BD	AN	TL	FA	BQ	RLS	RA	LS	RW	FUA	FTP	RTP	FTL	RUH	RUW	UD	UT	MS	FS
γ	1.901	1.900	1.901	1.908	1.905	1.901	1.902	1.902	1.901	1.906	1.902	1.901	1.900	1.902	1.901	1.902	1.900	1.900	1.903	1.901	1.905
$\psi^1(\gamma)$	0.687	0.688	0.688	0.684	0.686	0.688	0.687	0.687	0.688	0.685	0.687	0.688	0.688	0.687	0.688	0.687	0.688	0.688	0.687	0.687	0.686
σ_s^2	0.034	0.034	0.033	0.035	0.035	0.034	0.034	0.034	0.034	0.035	0.035	0.034	0.034	0.034	0.034	0.035	0.034	0.034	0.034	0.034	0.035
h²	0.080	0.080	0.077	0.081	0.081	0.079	0.080	0.080	0.080	0.080	0.080	0.079	0.079	0.079	0.079	0.080	0.080	0.079	0.080	0.080	0.082

γ = shape and scale parameters (assumed to be equal) of the log-gamma distribution (of the herd-year random effect); $\psi^1(\gamma)$ = variance of the herd-year random effect; σ_s^2 = sire genetic variance; h^2 = effective heritability. *Body traits* - stature (STA); chest width (CW); body depth (BD); angularity (AN) and top line (TL); *Feet and legs* - foot angle (FA); bone quality (BQ) and rear legs side view (RLS); *Rump traits*- rump angle (RA); loin strength (LS) and rump width (RW). *Mammary system* - Fore udder attachment (FUA); fore teat placement (FTP); rear teat placement (RTP); fore teat length (FTL); rear udder height (RUH); rear udder width (RUW); udder depth (UD); udder texture (UT); median suspensory (MS) and Final score (FS).

considered as a criterion that reflects the herd breeding goals and management. Consequently, the percentage of scored cows in each herd appears to be important to consider in the model for the genetic analysis of functional longevity.

Several studies compared the relative contribution of type traits on productive life variability. In contrast with the present study, other studies systematically found that udder traits had the largest impact on productive life, in particular udder depth and fore udder attachment (Larroque and Ducrocq, 2001; Buenger et al., 2001; Caraviello et al., 2003; Schneider et al., 2003; Sewalem et al., 2005; Dadpasand et al., 2008; Morek-Kopeć and Zarnecki, 2012). However, some also reported a significant contribution of final score and dairy character (or angularity) found by Zavadilová et al. (2011) in Czech Holstein cows. The high impact of angularity and top line on longevity found here can be explained by the breeder preferences and by the manner in which data collection is carried out, as described above.

With such a system of data collection, the available observations cannot properly describe the actual effect of type on productive life for the whole herd. For body traits, a slight negative trend in relative risk was observed, except for body depth for classes 4 and 5 (more than 50 % scored cows).

A linear relationship between angularity and productive life was also reported by Sewalem et al. (2004) and Dadpasand et al. (2008) in Canadian and Iranian Holstein, respectively. Conversely, Zavadilová et al. (2011) showed that angular cows tended to have poorer longevity, whereas less angular cows seemed to be favored with respect to survival. However, Caraviello et al. (2004) and Buenger et al. (2001) found an intermediate optimum for angularity and functional longevity.

A linear relationship for foot angle and bone quality was reported by Schneider et al. (2003) in Canadian Holstein and by Caraviello et al. (2004) for foot angle in US Holstein. However, Morek-Kopeć and Zarnecki (2012) in Poland and Berry et al. (2005), in New Zealand found an intermediate optimum for feet and legs traits in Holstein cows.

In relation to rump traits, other studies found a small to moderate impact of rump traits on longevity, in most cases with the lowest relative risks for intermediate scores and the highest for extreme scores (Buenger et al., 2001; Larroque and Ducrocq, 2001; Berry et al., 2005; Morek-Kopec and Zarnecki, 2012).

Among type traits, udder traits are generally considered the most influential for profitability on a farm. However, in this study, this logical relationship was not reflected by a longer herd life, probably because few animals with bad udders were type-scored. Then, they were included in the "missing" class that is characterized by higher relative culling risk. Several studies showed strong relationship between udder depth, fore udder attachment and median suspensory ligament and longevity (Larroque and Ducrocq, 2001; Buenger et al., 2001; Sewalem et al., 2004; 2005; Dadpasand et al., 2008; Zavadilová et al., 2011). The first two authors reported a difference in length of productive life of about a year between extreme categories for udder depth.

The final score was the trait with the largest impact on productive life. Similar results using the same methodology were reported by Schneider et al. (2003) in Quebec Holstein cows, Caraviello et al. (2003; 2004) in Jersey and Holstein in the United States and by Sewalem et al. (2004; 2005) in Canadian Holstein and Jersey cows. Sewalem et al. (2004) interpreted these results considering that final score represents a composite trait, combination of all individual type traits, with udder traits - which were the most closely related to survival in their case - receiving the largest weight.

The variance of the herd-year effect, sire genetic variance and effective heritability (h^2) were larger than published values with the same data set, statistical model in Holstein cows in Brazil (Kern et al., 2016), when the effect of each type traits was not included. It indicates that type traits are important factors related to the herd breeding goals and management policy in Holstein population in Brazil. Terawaki and Ducrocq (2009) and Terawaki et al. (2006) also reported that type traits might result in diverse management policy in herds in Japan, increasing the estimate of heritability when the percentage of type scored cows in herd also increased.

Conclusion

Both hierarchy of traits and magnitude of their effects were different from what previously reported in the literature. Udder traits were found to be relatively unimportant while final score, top line and angularity had a large effect. The most likely interpretation is that the current type recording system in Brazil allows farmers to choose the animals that should be scored, leading to a biased assessment of the relative importance of type traits. Cows with no type scores have higher risk of being culled than type-scored cows, showing a strong selection of the animals to be recorded. Within herd exhaustive type recording is required for a more precise evaluation of the relationship between type traits and longevity.

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