Analysis of the phenotypic relationships between type traits and functional survival in Czech Fleckvieh cows

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ABSTRACT: The phenotypic relationships between type traits and functional traits were analyzed in 47 786 Czech Fleckvieh cows first calved from 1994 to 2003. Functional survival was defined as the number of days from first calving to culling. All the cows were scored for conformation during the first lactation. Type information consisted of phenotypic type scores for 17 objectively scored linear type traits (with 9 classes each) and of the measurements for 6 body traits (measured in cm). The impact of the chosen conformation traits on functional longevity was estimated using the Cox proportional hazards model. The statistical model included the combined time-dependent effects of lactation and stage of lactation, age of the first calving, effects of the herd of culling, effects of year-season of culling, effects of the first lactation milk yield calculated within herd-year deviation. Analysis was performed separately for each of 23 type traits. The relative culling risk was calculated for animals in each class after taking into account the previously mentioned effects. All the traits analysed showed a relationship with the functional survival. Among linear type traits, rump angle, body depth, rear legs side view and pastern, fore udder length, rear udder attachment, and teats traits exhibited an intermediate optimum. Height at the sacrum, muscularity, rump length, and rump width, hock, and hoof angle, central ligament, and udder depth tended toward a linear relationship to functional survival. Body measurement traits showed an almost linear relationship concerning longevity except for chest girth, which exhibited an intermediate optimum. Body measurement traits and body conformation traits had an impact on functional survival especially in extreme classes, e.g. extremely ascending rump. Larger, broader, muscular cows had a higher risk of being culled compared with smaller and narrower cows and, hence, a shorter length of productive live. Foot and leg traits had an important influence on functional longevity, especially rear legs side view and pastern. Among udder traits, fore udder length, rear udder attachment, and front teat placement showed a higher impact on cows' longevity than the other analyzed udder traits.

Keywords: cattle; longevity; type traits; phenotypic relationship; survival analysis

In dairy production, longevity is a highly desirable trait which considerably affects overall profitability. Increased longevity is associated with reduced replacement costs and increased possibility for selection on the basis of other traits. It is possible to achieve genetic improvement of longevity but the herd life belongs to less heritable traits. Heritability estimates range from 0.03 to 0.12 (Van Doormaal et al., 1985; Jairath et al., 1998; Cruickshank et al., 2002) using a linear model. Estimates from survival analysis using the Weibull proportional hazards models range from 0.10 to 0.20 (Buenger et al., 2001; Vukasinovic et al., 2001; Ducrocq, 2002; Roxtrom 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 of longevity.

Type traits are recorded early in life, mostly during the first lactation, and are more heritable than

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longevity (Cruickshank et al., 2002; Kadarmideen and Wegmann, 2003). A low to moderate genetic relationship between various type traits and longevity was reported (Short and Lawlor, 1992; Jairath et al., 1998; Weigel et al., 1998; Larroque and Ducrocq, 1999; Cruickshank et al., 2002). Conformation traits represent logical predictors of survival (Vollema and Groen, 1997; Vukasinovic et al., 2002). The results from various studies confirm that they, especially udder traits, can be used as indicators of longevity (De Jong et al., 1999; Larroque and Ducrocq, 1999; Buenger et al., 2001; Schneider et al., 2003; Caraviello et al., 2004; Sewalem et al., 2004; Bouška et al., 2006). However, the results are highly dependent on the data and methodology used. Differences exist e.g. between breeds, countries, and status of registry.

Recently, the use of a method based on survival analysis has been proposed for the analysis of longevity (Smith and Quaas, 1984; Ducrocq, 1987, 1997). Ducrocq and Sölkner (1998) developed a computer package (the Survival Kit) for survival analysis which is suitable to animal breeding data. In dairy cattle, this package greatly facilitates the estimation of environmental effects (Mészáros et al., 2008) and variance components, and the genetic evaluation of animals (Vukasinovic et al., 2001). Survival analysis using a proportional hazards model is often more suitable for survival data because it properly takes into account censored records and skewed distribution of survival data. Time-dependent variables can be used for survival analysis to model the impact of environmental effects properly.

The objective of the present study was to explore the phenotypic relationship between conformation traits reflecting udder, feet and legs and body size, and functional survival in Czech Fleckvieh cows.

MATERIAL AND METHODS

Data

The data set consisted of 47 786 Czech Fleckvieh cows first calved from 1994 to 2003. All the cows used in the analysis were scored for conformation between the 60th and 180th day of the first lactation. Data were edited for a minimum of 4 records per herd. The following conformation traits were used: objectively scored linear type (*lt*) traits were height at the sacrum, muscularity, rump length, rump width, rump angle, body depth, rear legs side view, hock, pastern, hoof angle, fore udder length, rear udder attachment, central ligament, udder depth, front teat placement, teat length, and teat width. The traits were scored on a nine-point scale. Only 46 132 records were used for monitoring the following objectively scored linear type traits: height at the sacrum, rump length, body depth, hock, pastern, fore udder length, rear udder attachment, udder depth, front teat placement and teat width because of missing scoring records. The body measurements (*bm*) in cm were height at the withers, height at the sacrum, chest girth, body depth, rump length and rump width. Detailed descriptions of the traits analyzed are given in Table 1.

Longevity expressed as the number of days between the first calving and culling, i.e. the length of productive life, was 915 days on average with a minimum of 31 days and a maximum of 2 952 days. No censored records were included in the analysis. The cows were culled before the time of data collection (culled from 1998 to 2006). The average culling age was 1 788 days, with a minimum of 750 days and a maximum of 3 914 days. Because voluntary culling for low production is an important reason for disposal, our analysis was based on functional survival. Functional survival was defined as the ability to delay involuntary culling, and it was approximated by correcting true longevity for within-herd-year production ranking.

Model

Survival analysis was performed using the Survival Kit, version 3.0, by Ducrocq and Sölkner (1998). The Cox proportional hazards model was employed. Length of productive life was the dependent variable. The following model equation was used:

$$\lambda(t) = \lambda_0(t) \exp \{x_m'(t)\beta\}$$

where:

$\lambda(t)$ = hazard of a cow, i.e. her probability of being culled at time t given that she is alive just before t

$\lambda_0(t)$ = baseline hazard function which represents the aging process of the entire population and, loosely speaking, acts as a mean

t = time in days from the first calving to culling, i.e. the length of productive life

β = vector of regression coefficients

Table 1. Description of traits

Traits	Mean	SD	*CV* (%)	Description	
Body measurement traits					
Height at the withers (HW*bm*)	134.4	4.21	3.13	small	tall
Height at the sacrum (HS*bm*)	137.3	4.17	3.04	small	tall
Chest girth (CH*bm*)	195.1	7.63	3.91	small	capacious
Body depth (BD*bm*)	77.2	4.78	6.19	shallow	deep
Rump length (RL*bm*)	52.7	2.08	3.94	short	long
Rump width (RW*bm*)	51.8	2.66	5.14	narrow	wide
Objectively scored traits				class 1	class 9
Height at the sacrum (HS*lt*)	5.1	1.42	27.67	small	tall
Muscularity (M*lt*)	5.2	1.07	20.48	poor	excellent
Rump length (RL*lt*)	5.1	1.05	20.57	short	long
Rump width (RW*lt*)	5.2	1.35	26.27	narrow	wide
Rump angle (RA*lt*)	5.7	0.92	16.28	ascending	sloped
Body depth (BD*lt*)	5.8	1.03	17.71	shallow	deep
Rear legs side view (RLSV*lt*)	5.6	0.93	16.61	straight	sickle-like
Hock (H*lt*)	6.3	0.87	13.76	swollen	dry
Pastern (P*lt*)	4.7	0.91	19.19	weak	steep
Hoof angle (HA*lt*)	4.9	1.28	25.89	very low	very steep
Fore udder length (FUL*lt*)	5.3	1.06	20.05	short	long
Rear udder attachment (RUA*lt*)	6.4	1.03	16.03	low	high
Central ligament (CL*lt*)	3.9	1.58	40.12	weak	strong
Udder depth (UD*lt*)	6.4	0.94	14.75	deep	shallow
Front teat placement (FTP*lt*)	4.9	0.79	16.00	outside	inside
Teat length (TL*lt*)	5.1	1.05	20.60	short	long
Teat width (TW*lt*)	5.2	1.10	21.22	thin	thick

lt = objectively scored linear type trait; *bm* = body measurement traits
SD = standard deviation; *CV* = coefficient of variation

It involves the possibly time-dependent covariates affecting the hazard, with $x_m'(t)$ being the corresponding design vectors. The Cox model permits the estimation of regression coefficients in β without making any assumption about the form of the baseline hazard function $\lambda_0(t)$. It is possible to leave $\lambda_0(t)$ completely arbitrary.

The fixed covariates included in the model were as follows: combined time-dependent effects of lactation (1, 2, 3, 4, 5, 6+) and stage of lactation (days) (1 = 0–120, 2 = 121–240, 3 = > 240); age at the first calving (months) (1 = 20–27, 2 = 28–30, 3 = 31–40); the effects of herd; the combined effect of year (1998–2006) and season (months) (1 = 1–3, 2 = 4–6, 3 = 7–9, 4 = 10–12) of culling; the effects of first lactation milk yield calculated within herd-year deviations (1 = cows producing between the herd-year average and +1 SD above the herd-year average, 2 = cows producing between +1 SD and +2 SD above the herd-year average, 3 = cows producing over +2 SD above the herd-year average, 4 = cows producing between the herd-year average

Table 2. Relative risk of culling for objectively scored linear type traits[a,b] describing the body conformation

Class	HS*lt*	M*lt*	RL*lt*	RW*lt*	RA*lt*	BD*lt*
1	0.911	0.615	0.834	0.448	3.145	1.770
2	0.915	0.614	0.872	0.646	1.248	1.051
3	0.938	0.713	0.801	0.689	1.533	1.076
4	0.967	0.840	0.875	0.808	1.651	0.828
5	1.000	1.000	1.000	1.000	1.000	0.898
6	1.057	1.261	1.156	1.128	1.130	1.000
7	1.087	1.398	1.304	1.060	1.177	1.137
8	1.183	1.656	1.355	1.170	1.364	1.349
9	1.300	1.020	1.515	1.404	1.237	1.454

[a]see Table 1 for the class description

[b]HS = height at the sacrum; M = muscularity; RL = rump length; RW = rump width; RA = rump angle; BD = body depth; *lt* = objectively scored linear type trait

and –1 SD below the herd-year average, 5 = cows producing between –1 SD and –2 SD below the herd-year average, 6 = cows producing below –2 SD below the herd-year average). Analysis was performed separately for each of 15 type traits. Each type trait was evaluated by including it in the model as a covariate. The relative culling risk was calculated for animals in each class after taking into account the previously mentioned effects.

RESULTS AND DISCUSSION

The results were expressed as the relative risk of culling, 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 as 1. Values > 1 indicate a higher culling risk associated with a given environmental factor. Relative culling risk < 1 indicates a lower culling risk. For example, if the relative culling risk for a given class is 2, a cow in that class has a twofold chance 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 a 50% lower chance of being culled than a cow in the reference class.

For each trait, the class with the maximum number of records was designated as a reference

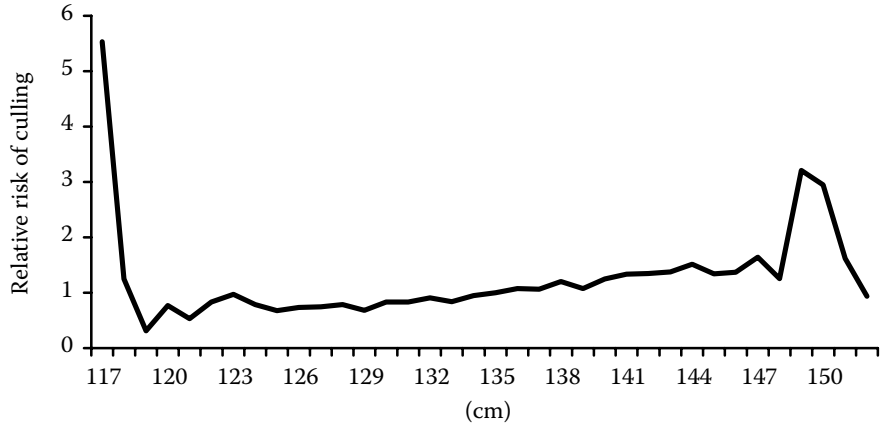

Figure 1. Relative risk of culling for body measurement traits: height at the withers

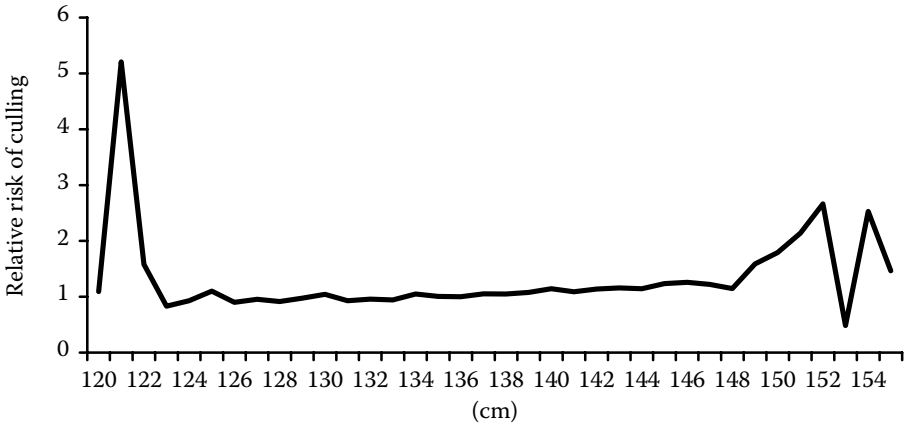

Figure 2. Relative risk of culling for body measurement traits: height at the sacrum

class. The number of records decreased approaching the extreme classes, in which the number of records was the lowest.

Body measurements

The relative risk of culling and the class description for body measurement traits are shown in Table 2 and Figures 1 to 6. The figures illustrate trends toward the relative risk of culling for a given trait, and described in detail in the middle part of the figure. The detailed figures include no extreme categories that generally have a low number of records. We assume that the low number of records in extreme categories caused a high variation of the relative risk of culling and the occurrence of extremely high values (negative as well as positive) of the relative risk of culling.

Figure 1 shows the relationship between longevity and height at the withers. Figure 2 shows the relationship between longevity and height at the sacrum. For both these traits, the risk of being culled increased with the size of the cow. A more expressive and constant trend toward increased risk of culling occurred for height at the withers, while a sudden impairment of longevity was found for height at the sacrum over 148 cm. Shorter lon-

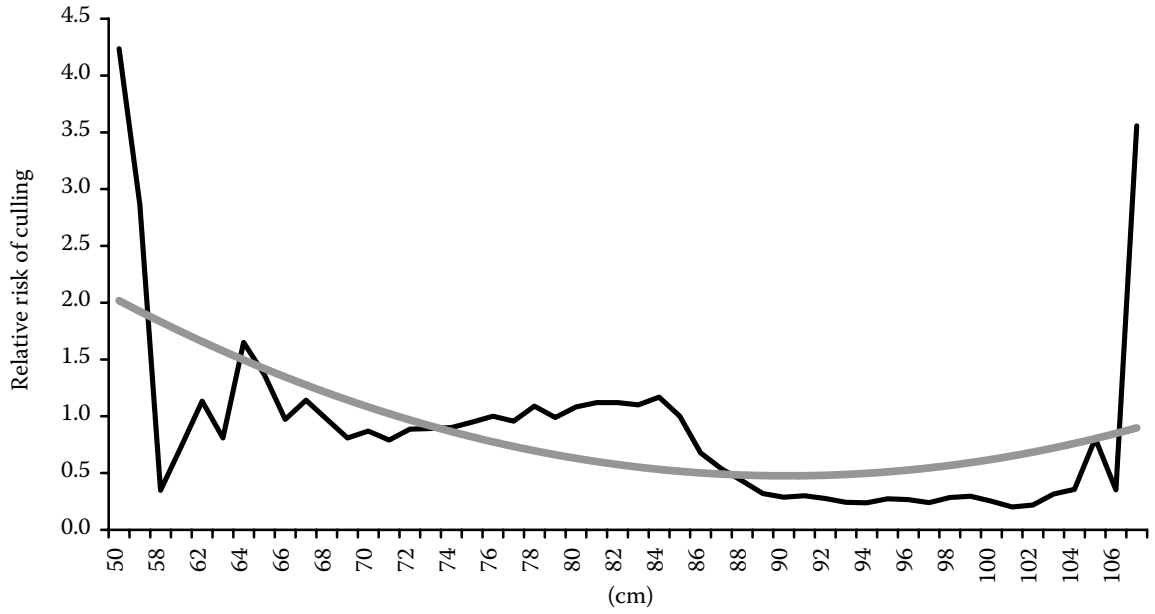

Figure 3. Relative risk of culling for body measurement traits: body depth

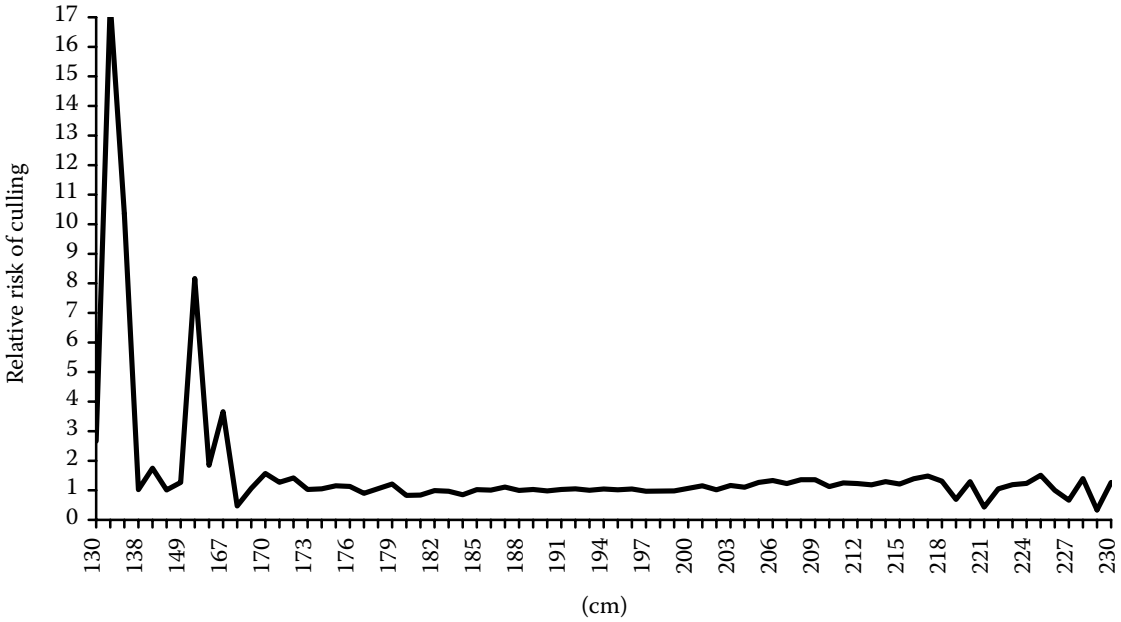

Figure 4. Relative risk of culling for body measurement traits: chest girth

gevity can be expected in cows that are extremely small or large.

Figure 3 displays the risk of relative culling for body depth. A threshold relationship was found between body depth and longevity. Even though deeper body depth was associated with lower risk compared to shallower ones, a borderline occurs at around 85 cm of body depth, which is connected with sudden improvement of longevity. Extremely deep or shallow cows showed again a high risk of being culled.

Figure 4 displays the relative risk of culling with regard to chest girth. Chest girth seems to exhibit an intermediate optimum as related to longevity. Especially cows with extremely small chest girth (under 167 cm) were associated with a higher risk of being culled. Otherwise, the relative risk of culling varied only a little.

Figure 5 shows the relationship between the relative risk of culling and rump length, and Figure 6 displays the relationship between the relative risk of culling and rump width. A moderate linear relationship between rump width, rump length and longevity was observed. Cows with a narrower and shorter rump proved less risky of being culled than cows with a broader and longer rump. At the same time it is necessary to say that both rump traits showed a wide intermediate optimum. Extreme values of both rump traits were connected with a high risk of being culled.

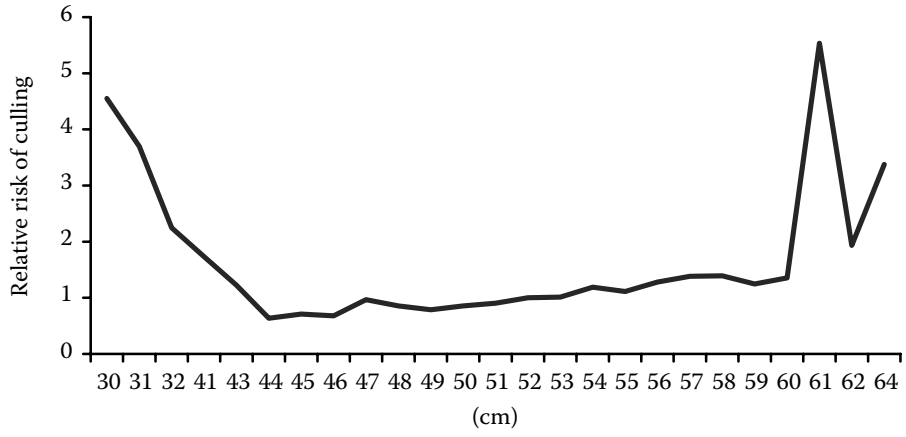

Figure 5. Relative risk of culling for body measurement traits: rump length

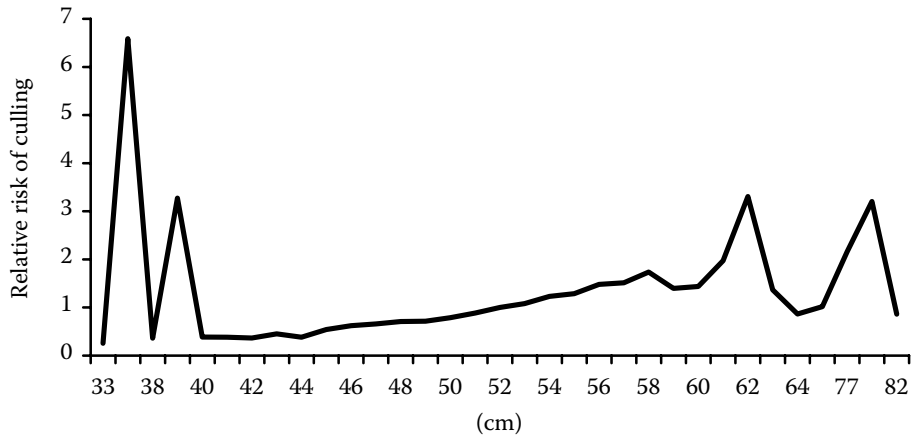

Figure 6. Relative risk of culling for body measurement traits: rump width

Linear type traits

Body conformation traits. The relative risk of culling for body conformation traits is shown in Table 2. Height at the sacrum, muscularity, rump length, and rump width show almost a linear relationship to functional survival. Cows that are larger, broader, more muscular, and with longer and wider rump had a higher risk of being culled compared with smaller and narrower cows and, hence, a shorter length of productive life. A moderate positive relationship between body type traits and longevity was reported by Boetcher et al. (1997). Schneider et al. (2003) found that taller and larger cows had better chances of survival than cows in other classes. On the other hand, Čanji et al. (2008) found that cows of intermediate size or smaller cows live longer. Sewalem et al. (2004) reported an intermediate optimum for body and dairy character traits. According to Buenger et al. (2001) and Caraviello et al. (2004), the size and stature did not have a strong relationship to functional survival. These different results might have been due to breed differences or definition of traits. Sölkner and Petschina (1999) reported a negative effect on functional longevity of the muscularity of the front part of the body. Since other muscularity scores show the same trend, they speculate about a biological contradiction between muscularity and longevity.

Rump angle and body depth exhibit an intermediate optimum concerning longevity. Cows with extremely ascending or extremely sloped rump were more likely to be culled than those with the optimum score of 5. In addition, cows with extremely ascending rump were 2.54 times more likely to be culled compared with cows with extremely sloped rump. The longevity of cows with score 1 was considerably impaired. Rump traits are associated with calving difficulty, and cows with intermediate rump are preferred. Similar findings were reported by Buenger et al. (2001), Schneider et al. (2003) and Čanji et al. (2008). However, Caraviello et al. (2003, 2004) did not find any close relationships between rump traits and longevity in US Holstein and Jersey cows. For body depth, extremely shallow or deep cows showed a higher risk of being culled compared with cows belonging to the broad range of scoring classes (from 2 to 7) with a risk of culling approaching 1. In contrast, Buenger et al. (2001) reported that shallow cows showed no deviation from functional longevity, and deep cows had reduced functional survival.

Foot and leg traits. The impact of foot and leg traits (rear legs side view, hock, pastern, hoof angle) on the functional longevity of cows is presented in Table 3. The relationship between the pastern and rear legs side view regarding longevity showed an intermediate optimum, indicating that cows with low or high scores were more likely to be culled compared with those having an intermediate score of 5. Similarly, Buenger et al. (2001) and Caraviello et al. (2004) reported an intermediate optimum for the rear legs side view. Contrary to our results, Caraviello et al. (2004) found a substantially higher risk of culling for cows with curved legs than for those with straight legs. Similarly, Vacek et al. (2006) reported the lowest longevity for cows with curved rear legs. There was a clear linear relationship of hock and hoof angle to relative culling risk. Cows with low scores for hock (representing swollen hock) were more likely to be culled compared to those with optimal, higher scores (representing dry hock). Cows with scores under and equal to

Table 3. Relative risk of culling for objectively scored linear type traits[a,b] describing feet and legs

Class	RLSV*lt*	H*lt*	P*lt*	HA*l*t
1	2.625	2.001	1.385	1.149
2	1.763	3.190	1.245	0.884
3	1.360	2.110	1.116	0.971
4	1.257	1.858	1.073	1.071
5	1.000	1.491	1.000	1.000
6	1.247	1.000	1.719	1.205
7	1.500	1.011	1.846	1.243
8	1.745	0.816	1.762	1.166
9	2.369	0.956	2.939	1.511

[a]see Table 1 for the class description

[b]RLSV = rear legs side view; H = hock; P = pastern; HA = hoof angle; *lt* = objectively scored linear type trait

5 for hoof angle (representing a lower hoof angle) showed a lower culling risk compared to cows with higher scores (representing a higher hoof angle). Cows with extremely low hoof (score 1) showed a slightly higher risk of being culled compared to cows that had scores between 2 and 5. Buenger et al. (2001) reported that a steep hoof increased functional longevity, whereas an extremely low hoof angle led to decreased survival. Vacek et al. (2006) found the lowest longevity in cows with a low hoof angle. Generally, the impact of foot and leg traits on longevity was greater than that of body size traits. In the literature, the relative importance of foot and leg traits varies from moderately important (Sölkner and Petschina, 1999; Buenger et al., 2001; Strapák et al., 2005; Čanji et al., 2008) to relatively unimportant (Larroque and Ducrocq, 1999), perhaps because of the difficulty in measuring these traits accurately under field conditions.

Udder traits. The relative risks of culling for udder traits are shown in Table 4. Fore udder length, rear udder attachment, teat width, teat length, and front teat placement exhibit an intermediate optimum as related to longevity. On the other hand, central ligament and udder depth show a slight linear relationship to functional longevity. The most important udder type traits were fore udder length and rear udder attachment.

High scores for the central ligament were associated with a lower risk of culling than were other scores. Cows with a stronger central ligament were less likely to be culled. The same findings were reported by Buenger et al. (2001) and Sewalem et al. (2004). Strapák et al. (2005) found a positive correlation between longevity and central ligament. Bouška et al. (2006) and Vacek et al. (2006) reported a linear relationship of functional longevity for the central ligament. In contrast to our results, Caraviello et al. (2004) found that high scores for the central ligament did not necessarily result in higher longevity than intermediate scores. Čanji et al. (2008) also found a lower effect of the central ligament on longevity of Simmental cows in comparison with udder depth and rear udder. Low scores for udder depth were associated with a higher risk of culling than were high scores. Cows with extremely deep udders might have exhibited higher susceptibility to mastitis and other infectious diseases. The same findings were reported by Buenger et al. (2001) and Bouška et al. (2006). Sewalem et al. (2004) reported an intermediate optimum for udder depth as related to longevity. In contrast to our results, Caraviello et al. (2004) found the highest risk of culling in cows with low udder depth.

Extremely low scores for fore udder length (short fore udder) were associated with a higher risk of culling than were high scores (long fore udder), but the lowest risk of culling was found in cows with an intermediate long fore udder. Short and Lawlor (1992), Larroque and Ducrocq (1999), Caraviello et al. (2003) and Schneider et al. (2003) reported low scores for fore udder length associated with a very high culling risk. Bouška et al. (2006) also found the lowest longevity in cows with short fore udder. Similarly, low scores for rear udder attachment (cows with low rear udder attachment) were associated with a higher risk of culling than were other scores. At the same time, a higher risk of culling was found for the highest score (cows with very high rear udder attachment) than for intermediate scores. An intermediate optimum for rear udder height was reported by Caraviello et al. (2003). However, Sewalem et al. (2004) found a clear linear relationship between fore udder length, rear udder height and functional longevity. Bouška et al. (2006) reported a negative influence of low rear udder attachment on longevity. Similarly, Vacek et al. (2006) found the lowest longevity for low rear udder attachment and longevity increasing with the scoring class for rear udder attachment.

Table 4. Relative risk of culling for objectively scored linear type traits[a,b] describing udder and teats

Class	FUL*lt*	RUA*lt*	CL*lt*	UD*lt*	FTP*lt*	TL*lt*	TW*lt*
1	2.066	2.469	0.987	1.435	2.114	1.982	1.198
2	1.399	1.690	1.013	1.484	1.427	1.743	1.031
3	1.227	1.044	1.047	1.164	0.928	1.298	1.118
4	1.121	1.013	1.166	1.127	0.919	1.264	1.035
5	1.000	0.944	1.000	0.942	1.000	1.000	1.000
6	1.090	0.944	0.933	0.894	1.187	1.181	1.424
7	1.240	1.000	0.992	1.000	1.435	1.086	1.504
8	1.380	1.040	0.770	0.898	2.189	1.149	1.608
9	1.157	1.192	0.749	1.090	3.149	1.178	1.410

[a]see Table 1 for the class description

[b]FUL = fore udder length; RUA = rear udder attachment; CL = central ligament; UD = udder depth; FTP = front teat placement; TL = teat length; TW = teat width; *lt* = objectively scored linear type trait

Cows with extremely thick teats were more likely to be culled than cows with extremely thin ones. However, the intermediate scores for teat width exhibited the lowest risk of culling. Similarly, cows with very short teats were more likely to be culled than cows with very long teats. However, intermediate scores for teat length were associated with the lowest risk of culling. The same findings were published by Buenger et al. (2001) and Caraviello et al. (2004). Bouška et al. (2006) found the lowest survival among cows with short teats. Čanji et al. (2008) reported a positive influence of shorter teats on the longevity of Simmental cows. Cows with nearly centred front teat placement are more likely to survive culling than cows with extremely inside or extremely outside front teat placement, which was also observed in other studies (Schneider et al., 2003; Sewalem et al., 2004). Caraviello et al. (2004) found that a high risk of culling with the wide placement of front teats indicates significant impairment of longevity. Buenger et al. (2001) reported that the close front teat placement increases cow's longevity, whereas the wide teat placement has an opposite effect. On the contrary, Vacek et al. (2006) found a linear relationship between longevity and the front teat placement.

CONCLUSIONS

The phenotypic effects of linear type traits and body measurements on functional survival in Czech Fleckvieh cows were investigated by survival analysis. The results of the effects of type traits are useful for identifying type traits which are important for the functional survival of the cow.

Among linear type traits, rump angle, body depth, pastern and rear legs side view, fore udder length, rear udder attachment, teat width, teat length, and front teat placement exhibited an intermediate optimum. Height at the sacrum, muscularity, rump length and rump width, hock and hoof angle, central ligament, and udder depth showed a linear relationship to longevity. Concerning body measurements: height at the withers and height at the sacrum, body depth, and rump width and length showed an almost linear relationship to longevity. Chest girth seemed to be exhibit the intermediate optimum.

Body measurement traits and body conformation traits were demonstrated to have a negative impact on functional survival, especially in extreme classes, e.g. extremely ascending rump. We can conclude from the results for these traits that larger, broader, muscular cows with wide and long rumps had a higher risk of being culled in comparison with smaller and narrower cows and, hence, a shorter length of productive live.

Foot and leg traits had an important influence on functional longevity, especially with regard to rear legs side view and pastern, traits which are connected with the optimal conformation of legs. Furthermore the hock determines the formation of

the leg joint. Therefore foot and leg traits seem to be very important with regard to functional survival in the Czech Fleckvieh population.

Among udder traits, fore udder length, rear udder attachment, front teat placement, teat width and teat length showed a high impact on cows' longevity. On the contrary, central ligament and udder depth did not demonstrate a high impact on survival, unlike that what was expected according to the majority of published findings.

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