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GENETIC EVALUATION OF CALVING DIFFICULTY IN CATTLE: A REVIEW

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ABSTRACT

Advantages and drawbacks of different approaches of genetic evaluation of calving difficulty are described and discussed in the review. Calving difficulty is a complex trait, which affects the economics of cattle breeders. The main factors affecting calving difficulty include calf size, pelvic measures of the cow and, more importantly, their compatibility, breed, parity of the calving, sex of the calf, gestation length and the season of the calving. Scoring scales of calving difficulty differing in the number and description of the categories are applied across the countries. Among the various statistical approaches, preference is given to threshold and linear models for genetic evaluation of calving difficulty. It seems that linear models are more suitable for the use of field data. An improvement of predictions can be obviously achieved by the application of correlated traits.

Key words: prediction; genetic parameters; linear model; threshold model; calving difficulty; dystocia

INTRODUCTION

Dystocia or calving difficulty is a complex reproductive trait. Some sources also define it as delayed or difficult parturition. The impact of difficult calving can be identified directly through higher costs of labour and costs of veterinary assistance during the calving. The economic impact of the dystocia on production, fertility, cow and calf morbidity and mortality in dairy cattle was shown during a long time period across different countries (Dematawewa and Berger, 1997; López de Maturana *et al.*, 2007; Ghiasi *et al.*, 2011). Consequent problems, like retained placenta and longer calving period, also indirectly contribute to lower productivity of animals (Gaafar *et al.*, 2010; Bujko *et al.*, 2018)

The incidence of dystocia is different across breeds and countries. In beef cattle, Phocas and Laloë (2003) reported 8 % of the calvings in Charolais population to need mechanical assistance. Eriksson *et al.* (2004) reported 6.6 % and 6.2 % incidence of dystocia in Charolais and Hereford primiparous cows, respectively. De Amicis *et al.* (2018) reported 5.6 % incidence of dystocia in local beef breeds. Jamrozik and Miller (2014) reported 3.7 % incidence of difficult calving in Canadian Simmental.

Despite low frequency of dystocia in the beef herds, its large impact on the economics pushes farmers to avoid difficult calvings. In the past, birth weight was used as an indicator to avoid these problems (Eriksson *et al.*, 2004). Later, evaluation of calving difficulty was included into the recording scheme. This approach is based on subjective evaluation by the farmer or by the trained personnel from a breeding company. Calving difficulty became a part of the routine genetic evaluation programs. Consequently, an increasing number of countries that record calving ease were reported (Mark *et al.*, 2005) and international genetic evaluation started (Jacobsen and Fikse, 2005).

Calving difficulty is a part of the performance recording in dairy and beef cattle in the Slovak Republic. However, while these data are used in the genetic evaluation of the dairy cattle, they are not used in the genetic evaluation of the beef cattle

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so far. This review gives examples of systems of calving difficulty recording and genetic evaluation of this economically important trait.

Recording of calving difficulty

Due to its nature, calving ease is recorded as a discrete trait, with no strictly defined limits. In general, however, the categories have a linear ascent. Scoring systems are used to describe calving ease or calving difficulty depending on the country (Mee, 2008). In the Slovak Republic, a four-point scale is used with 1 referring to no assistance needed and 4 referring to caesarean section, and with additional category 0 referring to unknown calving. In Norway, a three-point scale with additional category of unobserved calving was used (Holmøy *et al.*, 2017). Four-point scales were used in France (Phocas and Laloë, 2003), Germany (Fuerst and Egger-Danner, 2003) and Ireland (Berry and Evans, 2004). Five-point scales were used in USA (Cole *et al.*, 2005), Austria (Fuerst and Egger-Danner, 2003), Canada (Jamrozik and Miller, 2014) and South Korea (Alam *et al.*, 2017). The scales have a slight differences and definitions of categories depending *e.g.* on the number of personnel needed or the level of assistance during the calving. In Sweden, Eriksson *et al.* (2004) described Swedish beef-recording scheme as having 7 categories of calving. In respect to the use of the data, Mee (2008) summarized that in some countries unknown calvings are excluded from analyses, while in some countries these are included in unassisted category (easy calvings). In some countries, more detailed information on reasons of difficult calving is recorded. These recordings can be further used for the analyses of foetal and maternal causes of dystocia. Other approaches to calving difficulty exist. In particular, De Amicis *et al.* (2018) studied incidence of dystocia in Italy and used the classification of maternal and foetal dystocia, and thus avoided the classification based on severity degree. In some countries, like Iran, the calving difficulty is recorded as a binary trait (Ghiasi *et al.*, 2014). This means that only easy calving (with no assistance needed) and difficult calving with assistance are distinguished and assigned as 0 or 1. This approach seems quite effective, especially in populations where animals are calving on the pasture, and the only concern of the farmer is the assistance needed but not its extent. Treating the calving ease as a binary trait can also help in avoiding common problems of categorical trait (occurrence of extreme categories) or continuous variable (deviation from normal distribution).

Factors affecting calving difficulty

Since dystocia is a complex trait, statistical modelling and estimation of breeding values require identification of the number of factors that affect its incidence. The most important factors can be divided into groups including factors of calf, factors of cow and environmental factors. Obviously, the model predicting the calving ease should, therefore, involve direct and maternal effects. The consequences of including solely the direct effect were shown by Ghiasi *et al.* (2014), who concluded that this approach was not sufficient and there has to be selection applied using both direct and maternal effect.

Calf weight and sex

Although one of the main factors leading to dystocia is incompatibility between the size of calf and the pelvic measurements of cow, De Amicis *et al.* (2018) reported that in the local Italian breeds most of dystocia occurred due to foetal causes, from which almost 93% were due to foetal malposition and foetal macrosomia. Similarly, Strapák *et al.* (2000) reported the influence of birth weight (and sex) of the calf on the calving ease. This can be supported by findings of Mujibi and Crews (2009) and Jamrozik and Miller (2014). However, the effect of calf weight may be confounded with the effect of calf sex (Nix *et al.*, 1998), since the male calves are born heavier than female calves. This suggestion can be supported by findings of Lombard *et al.* (2007), Atashi *et al.* (2012) and McHugh *et al.* (2014), who observed higher incidence of dystocia in cows giving birth to young males. On the other hand, Piwczyński *et al.* (2013) considered the body weight of the calf a more important factor of calving difficulty than the sex of the calf. In relation to the sex of the calf, it was shown that the incidence of dystocia may be decreased when sexed semen is used (Norman *et al.*, 2010). The increased risk of the dystocia, when twins are considered (Mee *et al.*, 2011), will not be discussed here, since these cases are often excluded from the genetic evaluations. In the prediction models, the sex of the calf can be treated as a single trait (Phocas and Laloë, 2004) or in combination with the age of the dam (Jamrozik and Miller, 2014). On the other hand, the weight of the calf is often used as a correlated trait in multivariate models (Varona *et al.*, 1999b; Matilainen *et al.*, 2009). The use of birth weight in prediction models can be questionable in situations where farmers estimate the weight and not truly measure it (as showed by Phocas and Laloë, 2004). The problem can be more visible in cases, when farmers only report constant birth weight, which lead to deviations from normal distribution or even getting the features of categorical one.

Gestation length, calving parity, body condition score

The gestation length can also affect the incidence of the difficult calvings (Eaglen *et al.*, 2013; Uematsu *et al.*, 2013). Higher incidence of the dystocia was recorded in cows with gestation length higher than 301 days and lower than 280 days. Very high incidence was recorded in the group of cows with gestation length lower than 270 days. Positive genetic correlations between calving ease and gestation length in multiparous cows can suggest that the calf that gestates longer before birth to a multiparous dam is genetically prone to a difficult birth (Eaglen *et al.*, 2012).

It is well known and proved that the incidence of dystocia differs according to the parity of the calving (Berglund, 2008; Atashi *et al.*, 2012; De Amicis *et al.*, 2018). Especially, the difference between the first and further calvings is emphasized in the literature sources. The problems with dystocia in primiparous cows can be explained by the fact, that young heifers have smaller pelvic size, which lead to calving difficulties (Fuerst and Egger-Danner, 2003). For older cows, malpresentation of the calf, weak labour and insufficient dilatation of the cervix are more likely to lead to calving difficulty (Meijering, 1984). According to older literature sources, the size of the cow expressed by her weight is not a good predictor of calving difficulty, since heavier cows tend to have heavier calves (Luo *et al.*, 2002). The area measurements solely used to predict the calving difficulty are not sufficient, because the compatibility of calf size with pelvic area size is important. Olson *et al.* (2009) added that the parity of calving can affect the dystocia occurrence through shorter gestation and lower calf weights in heifers. According to higher incidence of dystocia in primiparous cows, the herd management is an important factor (Holmøy *et al.*, 2017) and the emphasis should be put to adequate service weight of the heifers at the first mating. The trend of decreasing incidence of the dystocia with increasing parity of the calving was shown by several authors. Oppositely, Mõtus *et al.* (2017) reported higher incidence of dystocia in the third and later parities compared to the second one. This can be supported by Juozaitiene *et al.* (2017), who reported extremely difficult calvings in primiparous cows and also cows at the $6^{th} – 8^{th}$ lactation. According to their observations, most of the cows that experienced difficult calving had also consecutive calving scored as difficult.

The correlation between body condition score 10 days before calving and maternal calving ease was studied, emphasizing the relation between fat cows before calving and dystocia incidence (Bastin *et al.*, 2010). The positive genetic correlation between average daily gain and the calving performance can suggest, that animals that grow faster, tend to produce progeny with more problems at calving (Albera *et al.*, 2004).

The gestation length is mostly used as a correlated trait in the models (López de Maturana *et al.*, 2009), while the parity of the calving is always included as an explaining factor, or the single models are designated for the different parities. The use of the gestation length and parity in the genetic evaluation of calving difficulty puts higher demands to the data. While the parity of the calving can be assumed from the age of dam and previous calvings, lack of information on date of matings in the extensive farming systems leads to exclusion of the gestation length from the model.

Season of calving

The season of calving was identified as the factor affecting the incidence of the dystocia (Meyer *et al.*, 2000; Fuerst and Egger-Danner, 2003; Matilainen *et al.*, 2009). Although the seasons are not strictly defined across the countries, studies showed higher rates of dystocia in the winter and spring (Uematsu *et al.*, 2013; Mekonnen and Moges, 2016) and lower rates in the summer and autumn. The possible explanation of these differences is that cows calving in winter and spring experience the last part of gestation in the winter period with changed and maybe improved feeding regime, thus more intensive foetal growth leading to problematic calvings. Another explanation may be hostile environmental conditions during the parturition in the winter period. In fact, the increased temperature during the calving month (and 2 preceding months) reduced the need for the assistance during parturition (Colburn *et al.*, 1997).

Significant effect of the season is reflected in all statistical models for calving difficulty prediction. Mostly the joint year-season effect is used, but also single effect of season can be found (Eriksson *et al.*, 2004), or joint herd-year-season (Ramirez-Valverde *et al.*, 2001; Luo *et al.*, 2002). Including the season into joint effects is reasonable and helps saving computational costs. Treatment of this effect is important and needs more insight. Distribution of calvings in dairy herds is continuous and more or less regular over the year. However, beef cattle farmers try to manage all calvings during one or two seasons. Therefore, the definition of a season has to be adequate to reflect this fact. In case of joint effects (herd-year-season) in combination with field data, the attention should be also put on the number of records in the groups, in order to avoid too many groups with too few records. Including the herd effect can be considered as covering the effects of the management and nutrition, which are mentioned later.

Other factors

Differences in dystocia incidence between dairy and beef cattle (Mekonnen and Moges, 2016; De Amicis *et al.*, 2018) are generally known, and the difference can be also found among the breeds (Cole *et al.* 2005; Olson *et al.* 2009; El-Tarabany *et al.*, 2015). In some cases, differences among the breeds should be reflected in the matings and suitable combinations of the sire and dam breed should be chosen (Vallée *et al.*, 2013; Ahlberg *et al.*, 2016). This especially applies in beef cattle population, where many breeds with different exterior characteristics and measures are reared and their crossbreds are used for production. It is obvious that mating sires of large breeds to dams of small breeds can lead to the incompatibility between the size of calf and the pelvic measures of the dam. In this respect, not only the breed is relevant but also the effect of sire (Holm *et al.*, 2014; Mekonnen and Moges, 2016).

Beside obvious factors that are considered in various statistical models, other factors also directly or indirectly influence the incidence of dystocia. These can include nutrition, management, infection and exercise of animals (Zaborski *et al.*, 2009; Mato *et al.*, 2015; Mekonnen and Moges, 2016). It is commonly known, that overfeeding of the dam can lead to rapid intrauterine growth of the calf, while underfeeding can lead to poor condition of dam during the parturition. The type of husbandry system can also play a role in the incidence of calving difficulty (Mee *et al.*, 2011; Piwczyński *et al.*, 2013). The other effects are included in models through the effect of herd, which is mostly joined with the season or/and the year of the calving.

Models used for evaluation of calving difficulty

Since the calving ease in its nature is recorded as a discrete trait, it should be most suitable to use the threshold model to predict genetic parameters and breeding values. Although according to Gianola (1982), the threshold model should be superior over the linear model, due to different reasons linear models are widely applied in practice. The application of the linear model can be preceded with Snell transformation (Snell, 1964) of discrete variable into continuous (Mujibi and Crews, 2009; Alam *et al.*, 2017), which is based on the premise that there is exists an underlying continuous distribution of calving ease scores of which the Snell scores represent class interval midpoints.

Latest methods including multinomial regression models, decision trees, random forests and neural networks were studied by Fenlon *et al.* (2017) in order to provide decision support and simulation modelling for calving difficulty.

Genetic parameters

Generally, low heritability of calving performance is reported in the literature. Koots *et al.* (1994) reported that heritability for calving ease may be higher in beef breeds compared to dairy breeds. Low direct (up to 0.14) and maternal (up to 0.06) heritability of calving ease was reported in recent studies (Mujibi and Crews, 2009; Jamrozik and Miller, 2014; Alam *et al.*, 2017). Higher values of direct (0.40) and maternal (0.23) heritability were also reported (Lee, 2002b; Vostrý *et al.*, 2014). When studying and using heritability of the calving difficulty, it is important to consider what kind of model was used for their calculation. Although low estimates of heritability can be found in recent studies with threshold models (Ghiasi *et al.*, 2011; Vanderick *et al.*, 2014), it was shown that the estimates obtained from linear models are lower compared to the estimates obtained from threshold models (Alday and Urgabte, 1998; Varona *et al.*, 1999a). Lower heritabilities obtained by linear models were explained as underestimated (Abdel-Azim and Berger, 1999), when comparing with heritabilities obtained by threshold models. It was also shown that with increasing number of categories and frequency of records in the categories, the estimates from linear models were closer to estimates from threshold models. Estimates were similar for linear models using raw and transformed data, suggesting that the transformation of calving ease scores is not necessary. Differences among the breeds are also manifested in different direct and maternal heritabilities (Roughsedge *et al.*, 2005). When separate models for heifers and multiparous cows were applied, higher heritabilities were calculated for calving ease in heifers (Carnier *et al.*, 2000; Jamrozik *et al.*, 2014), showing the calving difficulty is more related to the primiparous cows.

Most of the authors reported negative correlations between direct and maternal heritability. This is explained by the fact that small calf born easily and becoming cow (with smaller pelvic dimensions) is prone to have difficult calvings (Eaglen *et al.*, 2012). It has to be pointed out, that negative correlations can be found mostly in the studies using linear models. These correlations are lower with increasing parity of calving. Positive correlations between these effects were reported when threshold model was used (Luo *et al.*, 2002). Based on older literature sources, it was shown that no or very weak correlation exists between cow birth weight and dystocia. Recent findings also showed that heifers, which experienced dystocia during their own birth, did not tend to experience dystocia during their first calving (Holm *et al.*, 2014). Differences between studies were attributed to different populations, genetic progress, treatment of the calving ease and type of statistical model used. Despite a linear model being used (Jamrozik *et al.*, 2014; Vanderick *et al.*, 2014), positive correlations between direct and maternal genetic effects were reported. Additionally, Vanderick *et al.* (2014, 2017), according to very low positive correlations, suggested application of the model with no correlation between maternal and direct additive genetic effects.

Threshold model

The choice of the threshold model is intuitive due to the nature of calving difficulty. Indeed, superiority of the threshold model over the linear model was reported many times. However, authors reported substantial requirements for computer hardware in order to use this type of the model in the past (Lee *et al.*, 2002a). Even nowadays, with more powerful computers, several authors (Matilainen *et al.* 2009; Vostrý *et al.*, 2014) reported practical problems (more time needed compared to linear model), when threshold model was applied.

Beside practical issues, some studies experienced other drawbacks of application of the threshold models. Problems with convergence may occur (Luo *et al.*, 2001). These problems may result from fitting the herd-year as fixed effect in the threshold model. On the other hand, treating the herd-year effect as random would result in incorrect ranking of animals based on their estimated breeding values. Eriksson *et al.* (2004) also reported failure to use threshold model in case of small contemporary groups and limited use of artificial insemination (only few offspring per sire). Many authors including Jamrozik *et al.* (1991) did not show advantages of threshold model over the linear model applied to calving ease as categorical trait.

Linear model

Many studies can be found which preferred the linear model over the threshold model based on the findings of Misztal *et al.* (1989) and Hoeschele (1988). The limiting factor of using the threshold model can be the number of progeny per sire. Ramirez-Valverde *et al.* (2001) showed that for bulls with at least 50 calving records, the threshold and linear models give similar results. Mujibi and Crews (2009) summarized that when the field data are used, the differences among linear and threshold models are decreasing and the rankings of animals by both types of model are almost similar. This trend was proven in the study on calving rate and calf survival (Guerra *et al.*, 2006). Linear models are more suitable than the threshold models in the situations where the populations with small sized herds (small size of herd-year groups) are considered (Phocas and Laloë, 2003). Similar findings were reported in the study where the linear model showed higher stability in predicting breeding values of animals whose records were randomly set to missing (Vanderick *et al.*, 2014). Vostrý *et al.* (2014) reported satisfying results with the linear model and Snell transformation, which were approximating to the results of the threshold model. When comparing the use of the original and normalized categories of calving, only slight differences between predictive ability of linear models were found (Matilainen *et al.*, 2009).

Although not ideal, the use of the linear model for the categorical trait has been shown to work for practical purposes in many studies. Especially, from the point of routine evaluation of animals, the preference of the linear model is obvious (Phocas and Laloë, 2004; Vanderick *et al.* 2013; Forutan *et al.*, 2015).

Multivariate models

Since most of calvings are scored as normal calving, i.e. recorded in one category, and other categories include only few records, there is a tendency of joining the records from extremely difficult calvings into joint category (Cole *et al.*, 2005; Alam *et al.*, 2017). This correction can lead to slight improvement of predictions (López de Maturana *et al.*, 2009). Some studies suggested that the first and later parities are genetically different but correlated traits (Carnier *et al.*, 2000; Steinbock *et al.*, 2003; Eriksson *et al.*, 2004) and, thus, they are sometimes treated as correlated traits in multivariate models.

From another point of view, the application of multivariate model is driven by the low heritability of the calving difficulty and efforts to use an information on other correlated traits in order to increase the accuracy of the prediction. Although, inclusion of birth weight and gestation length, as correlated traits, improved accuracy of prediction (Matilainen *et al.*, 2009; Jamrozik and Miller, 2014), addition of only the gestation length has no effect on the accuracy (López de Maturana *et al.*, 2009). The use of the gestation length in the multivariate model depends also on the importance of this trait, since its inclusion as an indicator trait for the calving ease has only limited effect (Hansen *et al.*, 2004). The advantage of bivariate linear-threshold model with inclusion of birth weight was shown by Varona *et al.* (1999b). The advantage of including the birth weight into analysis was explained by gaining the stabilizing effect of the continuous trait.

Anyhow, a higher improvement of the accuracy can be achieved when the multivariate model is preferred over the univariate in comparison to preference of the threshold model over the linear ones (Ramirez-Valverde *et al.*, 2001). They also showed that the preference of the animal model over the sire model should be made in cases where limited number of progeny per sire is expected.

The use of multi-breed models in genetic evaluation of the calving difficulty was shown by the Vanderick *et al.* (2017). Their study proved that this approach benefits from using the crossbreds and thus improving the accuracy of the estimates of purebred animals. They also showed increased values of heritability estimates and values of direct-maternal genetic correlations, when compared to single-breed approach.

In the last fifteen years, already known and newly identified SNPs were associated with calving ease and other calving traits (Fortes *et al.*, 2013; Purfield *et al.*, 2015; Abo-Ismail *et al.*, 2017). These can be used in the marker-assisted or genomic selection in order to improve the prediction accuracy, selection of animals and, thus, to decrease the incidence of calving difficulties.

CONCLUSION

Experiences show that, from the practical point of view, linear models are optimal choice for routine genetic evaluation. The main arguments for this choice may be the decreasing difference between models, when field data are used, and better suitability of the linear model for situations with small groups (herd-year-season). Higher impact on the predictive ability of the model can be achieved by the inclusion of correlated trait, *e.g.* birth weight. But there may be a risk of confusing results if the data on birth weight of the calves are only estimated by the farmers but not measured. The choice of other effects has to be done according to the availability of data. The sex of the calf, herd, season and year of the calving are routinely recorded, however the use of gestation length and parity can be limited in case of extensive farming systems. From the point of view of practical farmers it is worth to consider recording and treating the calving difficulty as a binary trait. Here, however, more research and discussion with farmers has to be done.

In case of actual data, primary analysis of the recorded data on calving difficulty in beef cattle in the Slovak Republic is required in order to decide on the next steps.

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