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Comparison between different statistical models for the prediction of direct genetic component on embryo establishment and survival in Italian Brown Swiss dairy cattle

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ABSTRACT

The aims of this study were to infer variance components and heritability for the direct component on embryo establishment and survival related traits and to compare different statistical models in terms of goodness-of-fit and predictive ability. Embryo establishment and survival (EES) was defined as the outcome of an AI event, its direct effect was represented as the effect of the service sire from which semen was taken. Indicators of EES were calving per service (CS) and non-return at 56 d after service (NR56). Insemination records from the Italian Brown Swiss population reared in the Alps were used. Data included 124,206 inseminations performed by 86 technicians on 28,873 cows in 1400 herds. Services were recorded from 1999 to 2008. Linear-sire, linear-animal, threshold-sire, and threshold-animal models were used to estimate (co)variance components for CS and NR56. Four levels of complexity within each model were tested, so that 16 different models were compared for each of the two fertility traits. Comparison was assessed on the basis of the goodness-of-fit and predictive ability. Paternal half-sibs groups were created as average outcome of the inseminations from a given service sire. Goodness-of-fit was evaluated by regressing the service sire estimated breeding value from each model to paternal half-sibs average CS or NR56. Predictive ability was assessed through sums of chi-squared and percentage of wrong predictions. Predictors were the respective service sire's estimated breeding values constructed on a reduced (independent) training dataset, including years from 1999 to 2005, and predictands were the paternal half-sibs means for every bull in the remaining years (2006–2008). Prediction of EES was considered differently according to whether service sires had observations in the training dataset (prediction of proven bulls) or they had not (prediction of young bulls). Estimates of heritability ranged from 0.011 to 0.119 for CS, and from 0.005 to 0.054 for NR56. In general, threshold models explained a larger proportion of additive genetic variance than linear models, and animal models yielded higher heritabilities than sire models. Calving per service was much more predictable than NR56, but no significant differences were found among models. Although heritabilities were low, the prediction of future EES of a paternal half-sib group is feasible.

1. Introduction

In investigating the loss of reproductive fitness in dairy cattle, female fertility has received considerable attention than its male counterpart. Low reproductive performances have been often ascribed to cow metabolism, as energy redirected to the mammary gland would hamper correct reproductive function (Veerkamp et al., 2003), and the antagonistic effect of pleiotropic genes affecting milk yield and fertility would play a relevant role (Royal et al., 2000; Lucy, 2001; Pryce et al., 2004). Nonetheless, there is evidence of the impact of male fertility on the efficiency of the dairy industry (Nadarajah et al., 1988; Clay and McDaniel, 2001; Blaschek et al., 2011).

The establishment and survivability of the embryo (otherwise called embryo establishment and survival, EES) has been recognized as a component of the whole reproductive performance (Bamber et al., 2009; VanRaden and Miller, 2006), but its impact has been seldom investigated. The EES meant as a trait of the potential calf (Azzam et al. 1988) and the phenotype is determined as the calf survival from spermatozoon to birth (or absence of rebreeding within 56 d from insemination).

The EES is composed of different features, from both male and

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female fertility (Ayalon, 1978). First, the fertilizing ability of the sperm cells plays a role together with the potentiality of the oocytes to be fertilized. Secondly, if conception successfully occurs, the uterine environment determines if the embryo will proceed to the cellular differentiation and the fetus will born giving a viable calf. It is intuitive that there will be a component of EES coming from the sire through the genes transmitted, i.e. a direct additive genetic effect. Also, the quality of the sperm cells affects conception success but is not transmitted to the embryo, therefore considered as an environmental effect of the service sire (Jansen, 1986). On the female counterpart, the dam is contributing to the viability of the embryo with the genes that are transmitted (maternal additive genetic effect) as well with providing a fertilizable oocyte and a uterine environment suitable for fetus growth (maternal environmental effect). Besides, other abiotic factors (climatic variation) together with management (herd level of fertility, insemination technician skills) are to be considered among the sources of variation for embryo establishment and survival.

Fertility success traits, such as non-return at 56 d after service (**NR56**) and calving per service (**CS**), can be used as measures of embryo survival, and can be easily derived from insemination records. While NR56 simply indicates the non-mating of the cow within 56 d after insemination, CS assigns success to inseminations followed by a registered calving. As the two traits are computed differently and none of them can give an incontrovertible measure of reproductive efficiency assessing embryo losses at different pregnancy timepoints, their simultaneous consideration in a study can improve fertility (and embryo survival) assessment (Sun and Su, 2010).

Estimates of heritability for EES as meant it in the present study are scarce and inconsistent. VanRaden and Miller (2006) found negligible direct and maternal heritabilities for embryo and fetal loss in US Holsteins defined as non-return rate at 70 d using field data analyzed with a linear model. On the other hand, Bamber et al. (2009) used data from previous reproductive management trials to estimate heritability for pregnancy loss. The higher quality of the data coupled with the used of the threshold model yielded substantially higher heritabilities (0.489 for the direct component and 0.166 for the maternal component). In similar studies, López-Gatius et al. (2002) and Starbuck et al. (2004) found that pregnancy retention was dependent on the service bull used, but no additive genetic effect was estimated. When EES was assumed as a trait of the calf it has been referred to as bull fertility (Azzam et al., 1988) but the direct additive genetic component were found to be extremely low. Andersen-Ranberg et al. (2003) used a linear model to analyze non-return rate after 50 d on Norwegian heifers and first-parity cows, but heritabilities were always below 2%. Hyppänen and Juga (1998) also used a linear model to analyze non-return after 60 d in Finnish dairy cattle, and found null estimates of heritability. Kuhn and Hutchinson (2008) used both linear and threshold models to estimate heritability of conception rate from filed data in US Holstein cattle, and both models gave almost null value of heritability. It could be inferred that some variance can be attributed to direct and maternal genetic components for embryo survival, however the possibility of estimating non-null values of heritability depends on the quality of the data. Field data can hamper the estimation of these small genetic effects.

Selection candidates' EBV for EES may also play an important role in prediction of future performance and selection of best candidates for next generation. The most used and reliable tool for the assessment of model predictive ability is cross-validation, which has already been exploited in dairy cattle (Caraviello et al., 2004; González-Recio et al., 2005; Vazquez et al., 2012) and other species (Matos et al., 1997a; Cecchinato et al., 2010).

Genes transmitted to the embryo from the service sire, and affecting its establishment, are recognizable as direct additive genetic effect on EES. Predicting performance of a service sire for offspring embryo establishment and survival might help in improving overall fertility in artificially inseminated dairy cattle. Therefore, the purpose of this study was to investigate the impact of the direct additive genetic effect on EES of dairy cattle comparing different traits (CS and NR56), pedigree structures (sire and animal models associated to 'sire-maternal grandsire' and 'sire-dam' pedigrees, respectively), distributional assumptions (linear and threshold models), and model specifications for random effects. Different statistical models were compared in terms of goodness-of-fit and predictive ability of service sire future records.

2. Materials and methods

2.1. Data

Insemination records on Brown Swiss cows were obtained from the Breeders Association of Bolzano-Bozen province (northeast Italy). The same original dataset was used for previous studies on male fertility by Tiezzi et al. (2013). More than 200,000 single inseminations performed on Brown Swiss cows and heifers between 1999 and 2008 were available. Inseminations were validated as successful for CS when giving an acceptable pregnancy length of 288 ± 15 d (mean value for Brown Swiss from Norman et al., 2009). If two inseminations fell within this range of pregnancy length, the latter was considered successful. If pregnancy length of a heifer or a cow was lower than 273 d, the animal was not validated as pregnant. Furthermore, cows having inseminations in a given lactation were required to have recorded inseminations on the previous parities, such that cows that showed gestation length shorter than 273 d were not validated as pregnant for that lactation and were eliminated for the subsequent lactations. Non-return at 56 d was also calculated for every service, validated as non-returned (NR56 = 1) if no inseminations were performed within 56 d, regardless of whether the non-return animal conceived or not. Approximately 30% of inseminations on Brown Swiss cows reared in the Alps are conducted using semen of beef bulls to produce crossbred calves for veal and beef production (Dal Zotto et al., 2009; Penasa et al., 2009). However, most of the heifers and the majority of the cows are mated to Brown Swiss bulls. Thus, from the whole set we retained inseminations from AI Brown Swiss bulls as service sire which represent approximately 70% of total inseminations. Fertility traits (CS and NR56) were computed before the extraction of Brown Swiss bulls, because completeness of data is needed. Service sires were required to have at least 100 inseminations, with herds and technicians requiring at least 20 inseminations. Furthermore cows with only 1 service, and sires of cows with less than 20 services on the respective daughters were not considered. Lenient editing criteria on cows and sires of cows were adopted, since female fertility was a nuisance variable in the present study. Service sires, herds, technicians, and sires of cow with an average CS and NR56 outside the 0.10–0.90 range were omitted from the analysis. Although interactions between effects were not fitted (e.g., technician by service sire), restrictions were imposed so that technicians were required to operate in more than one farm, and in each farm at least 2 technicians were required to be recorded. This was adopted for service sires, technicians, herds, and sires of cows (e.g., each sire of cow was imposed to have daughters in at least 2 farms). After editing, 124,206 single inseminations performed by 86 technicians on 28,873 cows in 1400 herds were available for analysis in the main dataset ($DATA_{TOT}$).