Estrus Traits Derived from Activity Measurements are Heritable and closely related to Conventional Estrus Traits

Ahmed Ismael [*,†], Morten Kargo [*‡], Anders Fogh[‡], Erling Strandberg[†], Peter Løvendahl[*]

*Department of Molecular Biology and Genetics, Aarhus University, PO Box 50, DK-8830 Tjele, Denmark
†Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, P.O. Box 7023, SE-750 07 Uppsala, Sweden
‡ Knowledge Center for Agriculture, Skejby, Denmark.

ABSTRACT: This study was aimed at assessing the genetic parameters for fertility-related traits, comparing the interval from calving to first insemination (ICF) to physical activity traits, especially days from calving to first high activity, DFHA. Data from commercial Holstein herds included insemination dates of 11,363 cows for ICF. The activity traits were derived from electronic activity tags for 3533 Holstein cows. Estimates of heritability were 0.05 for ICF and 0.15 for DFHA. The genetic correlation between ICF and DFHA was strong (0.92). The high heritability estimate and the strong genetic correlation between ICF and DFHA suggest that genetic gain in ICF can be improved by including DFHA as a supplementary trait in the genetic evaluation of female fertility.
Keywords: Activity tags, Genetic parameters, Fertility

Introduction

Fertility is considered one of the most important traits in the breeding goal because it has a significant impact on the overall profitability of dairy cattle production (Sun et al. (2009)). Selection indices have evolved worldwide, changing in focus from mainly yield to a more balanced breeding approach that includes longevity, udder health, and reproduction (e.g., Miglior et al. (2005)). The unfavorable genetic correlations between milk yield and fertility (Buch and Norberg (2008); König et al. (2008); Pryce et al. (1997)) makes the inclusion of fertility in the breeding program extremely important. Another important obstacle that faces the genetic improvement of dairy cattle fertility traits is that the traditional fertility traits have low heritability (0.01 to 0.10) (Buch and Norberg (2008); Roxström et al. (2001a,b); Sun et al. (2010)). The interval from calving to first insemination (ICF) describes the ability of a cow to return to cyclic estrus after calving, and considered an indirect measure for the interval from calving to first ovulation (Petersson et al. (2007)). However, ICF is likely to be influenced by the management strategies such as the voluntary waiting period (Lof et al. (2012)), or when the high-yielding cows are inseminated later than those producing less (Andersen-Ranberg et al. (2005)). Objective and automated methods of estrus detection provide alternative estimates of interval from calving to first estrus. The interval from calving to commencement of luteal activity (CLA) based on progesterone measurements has heritability estimates of 0.16-0.30 (Royal et al. (2002); Petersson et al. (2007)). The days from calving to first high activity (DFHA) is another alternative measure for fertility that can be determined from electronic pedometer or activity tags used to detect estrus in dairy cows. This trait has heritability estimates of 0.12 to 0.18 (Løvendahl and Chagunda (2009)). Although initial results look promising, a confirmation is needed on a larger data set and alignment with traditional data before being implemented in the breeding value estimation programs. The objectives of this study were to estimate the genetic parameters for the days from calving to first estrus based on activity measurements from cows in commercial herds, and compare that to the traditional measure based on AI services.

Materials and Methods

Activity data. The physical activity data and AI data were collected from the Danish Holstein population during the period of insemination from January 2010 to June 2012. Cows were equipped with electronic activity tags fitted on neckbands (Lely Qwes-H or -HR, Lely Industries BV, Maassluis, The Netherlands). Activity data were measured as physical impulses from changes in acceleration by head and neck movements as counts per 2 hours interval. Only cows of parities (1-3) were included in this study. Activity recorded between days 15 and 155 were used.

Heat detection algorithm. In order to detect changes in the cow's activity it is important to compare the cow against herd average. These data series are computed for 12 two-hour periods per day using an exponential smoothing algorithm. Thereafter, deviations from smoothed ratios and the observed ratio are used to detect the high activity episodes when the cow had at least 3 consecutive periods with deviations higher than a set threshold value.

Algorithm optimization. A training data set of 548 animals with successful AI was used to find the appropriate thresholds and setting for the episode detection. The activity data were selected to be 15 days before to 15 days after the insemination. This period was divided into 3 periods: early (-14 to -2 d), on time (-1 to insemination date), and late (1 to 14 d). A grid search was performed to find the optimum setting for the algorithm. The criteria of selecting best setting for the algorithm smoothing weights were:

1. Sensitivity of heat detection = (number of cows detected by the algorithm / total number of cow in

estrus)*100 (de Mol and Woldt (2001)), should be as large as possible.

2. Detection rate = (high activity episodes detected on time / total episodes for 548 possible cows)*100 (Løvendahl and Chagunda (2010)), should be as large as possible.
3. Daily error rate = [(number of early episodes+ number of late episodes) / (13 days early +14 days late) / 548]*1000 (Hogeveen et al. (2010)), should be as small as possible.
4. Heritability estimate of DFHA obtained from the full activity dataset should be as large as possible.

Traits studied and size of data. The most important estrus activity trait was "Days to first high activity" (DFHA), i.e., a trait similar to days to first estrus. Days from calving to first AI service, extracted from AI data, was used as a comparison. To compare the automated measurement to days from calving to first estrus based on the physical activity measurements and the traditional measurement based on AI services, the interval from calving to first insemination (ICF) was calculated and edited to be between 20 and 200 days.

The whole data set contained 11,363 records from 11,363 cows for the (ICF). Of these cows 3533 cows also had phenotypic records of DFHA in the same lactation. The total pedigree file included 87,916 animals.

Model. Genetic analysis was accomplished using average information REML in the DMU package (Madsen and Jensen (2010)). Univariate animal model was used to estimate heritability from variance components. Bivariate analysis was performed to estimate and genetic correlations between the traits. The following animal model in scalar notation was used to analyze the traits:

$$y_{ijkl} = ym_i + p_j + h_k + a_l + e_{ijkl}$$

where y_{ijkl} is the observation of the traits DFHA or ICF; ym_i is the fixed effect of the year month i of episode for DFHA and effect of year season of insemination for ICF; p_j is the fixed effect of the parity j; h_k is the random effect of herd k; a_l is the random genetic effect, and e_{ijkl} is the random residual. Standard errors of heritabilities and genetic correlations were obtained by Taylor series expansions (Madsen and Jensen (2010))

Increase in accuracy. Currently, ICF can be used for selection. Assuming that ICF is the breeding goal trait, the accuracy from selecting only on ICF and from also selecting on DFHA were compared based on the estimated parameters.

Results and Discussion

Efficiency of heat detection algorithm. The optimization step was implemented to choose the optimum setting for the algorithm which provides the highest detection rate and sensitivity with the lowest daily error rate. The optimum results gave 87% detection rate, 83.4% sensitivity, 9 cows per 1000 cows as daily error rate, and heritability of 0.15.

Descriptive statistics. The average of DFHA was 49.5 days while it was 75 days for ICF. The average of DFHA is slightly higher than the estimate obtained by (Løvendahl and Chagunda (2010)) of 44 days. However, it is difficult to compare the results across the studies because units are determined by the manufacturers and because activity devices can also be attached in different positions, either to a neckband or to the leg (Maatje et al. (1997)).

Heritability and variance components. The genetic parameters estimated for each trait are shown in Table 1. The heritability estimate for DFHA (0.15) was in agreement with the that obtained by (Løvendahl and Chagunda (2009)) (ranged from 0.12-0.18). The higher heritability estimate for DFHA compared with the traditional AI trait (ICF, 0.05) supports that the automated recording for fertility traits provides an inexpensive source of data, which may provide valuable information in the genetic evaluation for fertility.

Table 1. Additive genetic variances (σ_a^2), residual variances (σ_e^2) heritabilities (h^2) and standard error for the heritability (*SE*)

Traits	σ_a^2	σ_e^2	h^2	*SE*
ICF	44.7	806.7	0.05	0.01
DFHA	101.8	580.3	0.15	0.04

Phenotypic and genetic correlations. The phenotypic correlation between ICF and DFHA was moderate r_p = 0.36, but the genetic correlation was very strong (0.92 ± 0.07). This indicates that these traits measure the same aspect of reproductive performance in cows. This suggests the suitability of DFHA as supplement to ICF in the fertility selection index, because DFHA has a higher heritability estimate. Comparisons with other studies that used physical activity tags to develop activity traits were not possible, because no other published studies were found reporting the genetic correlation between ICF and the physical activity traits.

Increase in accuracy. Assuming 100 daughters per sire the accuracy in selection based only on ICF would be 0.75. If 25% of the daughters also had information on DFHA, the accuracy would increase to 0.81, a 9% increase, which would translate into this much larger genetic gain in ICF, all else equal. The maximum possible accuracy (assuming all daughters had information on DFHA) would be 0.87, a 16% increase.

The introduction of activity tags in a herd is done for other reasons than to use the data for breeding, so the cost of this equipment need not be paid back by the increased genetic progress only. It is more reasonable to consider that it is the added cost of collecting and storing the activity data in a common database, and the added costs for a new trait in genetic evaluations, that are necessary to recover. Whether the increase in genetic gain expected from addition of DFHA as a selection index trait would pay back that investment should be more thoroughly studied. However, one should also remember that the activity tags can also measure other traits, e.g., estrus strength and duration, that are not measured at all today in most breeding programs.

Conclusion

Heritability of DFHA was three times higher than that obtained for ICF. A strong genetic correlation exists between DFHA and ICF. Jointly this indicates that genetic gain in ICF can be increased by inclusion of DFHA in the selection criterion.

Acknowledgements

This work was supported by a scholarship from Nordic Research Network on Animal Genetic Resources in the Adaptation to Climate Change (NordGen) and further support was obtained from European Graduate School in Animal Breeding and Genetics (EGS-ABG). Data was kindly provided by a number of commercial dairy herds.

Literature Cited

Andersen-Ranberg, I. M., Klemetsdal, G., Heringstad, B. et al. (2005). J. Dairy Sci., 88:348-355.

Buch, L. H. and Norberg, E. (2008). Acta. Agr. Scand., A-An., 58:5-9.

de Mol, R. M. and Woldt, W. E. (2001). J. Dairy Sci., 84:400-410.

Hogeveen, H., Kamphuis, C., Steeneveld, W. et al. (2010). Sensors., 10:7991-8009.

König, S., Chang, Y. M., Borstel U. U. v. et al. (2008). J Dairy Sci., 91:4372-4382.

Lof, E., Gustafsson, H., Emanuelson, U. (2012). Acta.Vet. Scand.,54:5.

Løvendahl, P. and Chagunda, M. G. G. (2009). J.Dairy Sci., 92:4683-4688.

Løvendahl, P. and Chagunda, M. G. G. (2010). J. Dairy Sci., 93(1):249-259.

Madsen, P. and Jensen, J. (2010). DMU. Version 6, release 5.

Miglior, F., Muir, B. L., Van Doormaal B. J. (2005). J. Dairy Sci.,88:1255-1263.

Maatje, K., Loeffler, S. H., Engel, B. (1997). J. Dairy Sci., 80:1098-1105.

Petersson, K. J., Berglund, B., Strandberg, E. et al. (2007). J. Dairy Sci., 90:427-434.

Pryce, J. E., Veerkamp, R. F., Thompson, R. et al. (1997). Anim. Sci 65:353-360.

Roelofs, J. B., van Eerdenburg, F. J. C. M., Soede, N. M. et al. (2005). Theriogenology., 64:1690-1703.

Roxström, A., Strandberg, E., Berglund, B. et al. (2001a). Acta. Agr. Scand., A-An., 51:7-14.

Roxström, A., Strandberg, E., Berglund, B. et al. (2001b). Acta. Agr. Scand., A-An.,51:192-199.

Royal, M. D., Flint, A. P. F., Woolliams, J. A. (2002). J. Dairy Sci., 85:958-967.

Sun, C., Madsen, P. Nielsen, U. S. et al (2009). J. Dairy Sci.,92:4063-4071.

Sun, C., Madsen, P., Lund, M. S. et al. (2010). J. Anim. Sci., 88:871-878.