Use of Accelerometer Data for Genetic Evaluation in Dairy Cattle

***K. Schöpke*[1] *and K. A. Weigel*[2]**

[1] *Institute of Agricultural and Nutritional Sciences, Martin-Luther-University Halle-Wittenberg, Germany*

[2] *Department of Dairy Science, University of Wisconsin, Madison, WI, USA*

Abstract

Detection of estrus plays an important role in modern reproductive management of dairy cattle. Activity monitoring systems incorporating accelerometer devices are common on-farm tools for the detection of cows in heat and thus for timing AI. The use of these accelerometer data for genetic improvement of the ability of a cow to show estrus requires the definition of meaningful traits with sufficient genetic variance. In the present study, three different activity traits were defined and analysed based on activity data of 1.171 cows. Trait A1 is the general level of the activity of a cow calculated by the simple mean of a cows daily activity value over a time period of at least 100 days. A1 has a low heritability (0.03 – 0.12) and activity levels during the estrus period and the non-estrus period are highly correlated. Trait S1 describes the intradaily deviation from the baseline and is in close correlation to A1 (r_g=0.67). However, the estimated heritability for S1 is remarkably higher compared to A1, and S1 during the estrus period and S1 during the non-estrus period seem to be different traits. Thus, the difference between these two periods was analyzed separately and resulted in heritability estimates between 0.10 and 0.15. These first results for the inclusion of activity data in genetic evaluations are promising but further research is necessary in terms of alternative trait descriptions, sophisticated statistical models, and genetic relationships between activity traits and traits of milk performance and behavior.

Key words: activity monitoring, activity traits, estrus detection, female fertility

Introduction

Female fertility is a sensitive topic in current dairy farming and in present dairy research. Reproductive performance has declined over the last decades (Berry *et al*., 2008; Royal *et al*., 2000) and cows with a delayed or abnormal postpartum cycle, with insufficient expression of estrus and poor conception rates are common problems today (Butler, 2000; Dobson *et al*., 2008). Referring to the ability to produce offspring, the specific challenges of a cow are I) cycling, II) showing estrus, III) getting pregnant, and IV) staying pregnant. The visible detection of estrus is economically important, especially in countries where estrus synchronization is not generally used. Nevertheless, the ability of a cow to show estrus is hardly considered in today's dairy cattle breeding programs. Only the Swedish evaluation system considers this issue by using the subjectively scored trait *heat strength* (Mark *et al*., 2001). Methods for estrus detection are visual farm observations, and mount detectors or progesterone measurements; the latter is often taken as the gold standard (ICAR, 2013). Another on-farm tool for the detection of cows in heat is the monitoring of physical activity with pedometer or accelerometer systems. Activity monitoring can be an important part of management strategies for submission of cows for first AI (Fricke *et al*., 2014). Løvendahl and Chagunda (2009) used activity measurements to describe estrus traits, and found them to be helpful in selection for improved fertility. The use of accelerometer data for genetic improvement of the ability of a cow to show estrus still requires the definition of meaningful traits with sufficient genetic variance. The aim of the present study is the general description of a cow's activity based on cow individual activity data from accelerometer systems. Therefore different trait definitions for physical activity were derived and tested.

Materials and Methods

Data on individual activity of Holstein-Friesian cows were available from six Israeli dairy farms from April 2012 to June 2013. Animals were equipped with electronic activity neck tags (SCR Heatime HR system) which measure and store the cow's physical activity in 12 two hours blocks per day. For all trait definitions described in this study the average daily activity value calculated from the 12 time blocks was used. Furthermore, the raw activity value measured by the accelerometer was considered instead of the weighted activity index that is calculated via a complex internal algorithm by the Heatime system and which is used as an on-farm heat alert tool.

For data set I, activity recorded between days 29 and 399 post-partum is incorporated. Cows had an average number of 215 consecutive observation days; only those with at least 100 days are included (N=1,171 cows). To describe the cow's general level of activity, the simple mean over all daily measurements within the required timespan was calculated, hereinafter referred to as Activity_1 (A1).

Apart from the activity variation due to the herd management, each animal is assumed to have an individual diurnal rhythm resulting in activity phases of different lengths and intensities. To capture these deviations from the baseline the daily standard deviation of each cow, based on the 12 two hours blocks, was used. Trait definition S1 describes the average of this daily standard deviation over at least 100 days.

Trait S2 is the standard deviation over the daily activity value, and thus describes the variation between days. Summary statistics for trait A1, S1, and S2 are given in Table 1.

Table 1. Raw means, standard deviation (s.d.), minima and maxima for activity traits A1, S1 and S2 (N=1,171) .

Trait	Mean	s.d.	Min	Max
A1	37.1	6.4	17.3	71.9
S1	8.8	2.3	4.0	22.5
S2	4.9	2.0	1.2	14.7

To answer the question whether the activity during the estrus period is the same trait as the activity during the non-estrus period requires a differentiated approach. For this purpose, the activity data were divided into different stages (data set II, N=1,070 cows). Using the information on the date of successful artificial insemination (AI), provided a relatively knowledge of the time of estrus. Accordingly, the cow is considered to be in estrus at the day of successful AI and the day before (Stage2). Two weeks before and two weeks after the successful AI the cow is considered to be in the non-estrus period. In the following, Stage1 includes the pre-estrus period from day 15 to day 2 before successful AI. Stage3 implies the post-estrus period from day 2 to day 15 after the successful AI. For data set II, the traits A1, S1, and S2 have been calculated for all three stages. At first, the three stages were treated as separate traits. Later on, Stage1 and Stage3 were both grouped together as the non-estrus period (Stage1_3). Accordingly, the difference of a cow's activity during estrus period and non-estrus period is the difference between Stage1_3 and Stage2. This difference can be expressed as the absolute value (Δ_{abs}) and the relative value ($\Delta_{\%}$). An overview of the traits resulting from data set II is given in Table 2.

Table 2. Raw means, standard deviation (s.d.), minima and maxima for activity traits A1 and S1 within different stages and for the difference between estrus and non-estrus period (Δ_{abs}, $\Delta_{\%}$).

Trait	N	Mean	s.d.	Min	Max
A1_Stage1	1,008	36.4	7.1	14.9	69.2
A1_Stage2	1,008	47.7	10.2	21.7	88.8
A1_Stage3	1,060	36.1	7.0	15.1	66.0
A1_Δ_{abs}	998	11.6	6.5	-23.4	49.0
A1_$\Delta_{\%}$	998	0.32	0.17	-0.45	1.16
S1_Stage1	1,008	9.1	2.9	3.6	24.9
S1_Stage2	1,008	17.4	6.4	4.9	44.2
S1_Stage3	1,060	9.2	3.0	3.4	29.7
A2_Δ_{abs}	998	8.3	5.5	-4.0	32.9
A2_$\Delta_{\%}$	998	0.96	0.66	-0.37	5.06

Data preparation, editing, and examination of alternative modeling of fixed effects were conducted using the statistical package SAS 9.4 (SAS Institute Inc.). For the estimation of genetic parameters using mixed linear models including relationships between animals, the VCE software Version 6.0 was applied (Groeneveld *et al*., 2010). Models were developed for each trait of activity separately by subsequently eliminating the non-significant (P>0.05) effects. In total, the effects of herd, year, season, month, daylight length, parity, lactation stage, pregnancy stage, milk yield, as well as interactions between these effects were evaluated in various models. For the estimation of variance components, the models were chosen according to best fit or simplicity when compared with more complicated models of equal fit. The final models for data set I include the effects of herd-year season (for all traits), parity (for all traits), milk yield (for A1), pregnancy stage (for S1 and S2), daylight length (for S1 and S2), and stage of lactation (for S2). For data set II, the analyses of variance resulted in models considering the effects of herd-year season (for all traits), parity (for all traits), and lactation stage (for S1_Stage2, A1_Δ_{abs}, A1_$\Delta_{\%}$, S1_Δ_{abs}, S1_$\Delta_{\%}$).

Results & Discussion

For trait A1 which represents the average daily activity value over at least 100 days per cow, the mean is 37.1 and the values range between 17.3 and 71.9 (Table 1). Trait definitions S1 and S2 lead to mean values of 8.8 and 4.9 respectively. The summary statistics of Stage1 and Stage3 show very similar values for A1 as well as for S1, as expected, since both traits characterize the non-estrus period (Table 2). In contrast, Stage2 delivers remarkably higher raw values compared to the other two stages.
Multivariate estimation of variance components for data set I resulted in estimated heritabilities of 0.09 (for A1) and 0.27 (for S1); both traits are highly correlated, on the genetic as well as phenotypic level (Table 3). Standard errors are generally high, due to the still small data set. Especially S2 shows very high standard errors, and it is therefore not pursued in the further analyses.

Even though the traits A1 and S1 show a high genetic and phenotypic correlation, they are not identical traits. For practical purpose a cow with high A1 and high S1 is not favorable, since this would mean that the cow is permanently on a high activity level. Since we are not breeding for nervous, twitchy or restless animals, a cow with a moderate activity and an appropriate relation between active periods (moving, feeding) and passive periods (lying, ruminating) would be advantageous.

Table 3. Estimates of heritability (on diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) for activity traits A1, S1, and S2 (N=1,171); standard errors in parentheses.

Trait	**A1**	**S1**	**S2**
A1	0.09 (0.05)	0.67 (0.13)	0.62 (0.38)
S1	0.74	0.27 (0.06)	0.06 (0.56)
S2	0.54	0.41	0.03 (0.03)

When comparing the different stages, the cow's activity during the pre-estrus period and the post-estrus period show very similar results. For A1, the genetic parameters of Stage1 and Stage3 resulting from multivariate estimations are nearly identical (Table 4) and both stages are highly correlated with estimated values of 0.99. For S1 the genetic correlation is 0.98 (Table 5). Also the heritabilities confirm that Stage1 and Stage3 can be considered as the same trait.

Stage2 shows a slightly higher estimated heritability for A1 compared to the other two stages, and it has very high estimates for the genetic correlations with Stage1 and Stage3. However, when regarding S1, the genetic correlation between Stage2 and the other two stages are considerably lower. Consequently, S1 during estrus and during the non-estrus period should be regarded as different traits. This fact might also explain why S2 is not a meaningful trait since it blends estrus and non-estrus period.

Table 4. Estimates of heritability (on diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) for different stages of A1 (N=1,070); standard errors in parentheses.

Trait	A1_Stage1	A1_Stage2	A1_Stage3
A1_Stage1	0.05 (0.04)	0.96 (0.21)	0.99 (0.05)
A1_Stage2	0.77	0.12 (0.05)	0.95 (0.23)
A1_Stage3	0.91	0.76	0.**03** (0.03)

Table 5. Estimates of heritability (on diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) for different stages of S1 (N=1,070); standard errors in parentheses.

Trait	S1_Stage1	S1_Stage2	S1_Stage3
S1_Stage1	0.15 (0.05)	0.72 (0.24)	0.98 (0.11)
S1_Stage2	0.43	0.11 (0.06)	0.78 (0.15)
S1_Stage3	0.65	0.41	0.14 (0.05)

Studies in human have shown that accelerometers can provide an objective measure to monitor and classify activity (Lyons *et al*., 2005, Mathie *et al*., 2004). In dairy cattle research, the utilization of accelerometer systems to classify cattle behavior patterns was tested in several studies (Martiskainena *et al*., 2009; Robert *et al*., 2009). The current study used accelerometer data to describe a cow's physical activity. Of the three traits tested, A1 and S1 are deemed appropriate for further analyses. Both traits are closely related, however they describe physical activity in a different way. Additionally, there are indications that activity during the estrus period and activity during the non-estrus period are different traits. Estimated heritabilities for different trait definitions are in a low to moderate range. Results from the few existing studies describing estrus detection traits were found to be low with estimates of 0.03 for heat strength (Mark *et al*., 2001) and 0.04-0.06 for strength (Løvendahl and Chagunda, 2009).

After these first simple definitions and basic modeling, continuing analyses are focusing on alternative trait descriptions and different models; e.g. the inspection of different lactation stages in which physical activity is known to vary and hence genetic variation is varying (Løvendahl and Chagunda, 2006).

To further investigate whether the defined traits are useful for the assessment of the cow's ability to show estrus, the next step is the combined analyses of activity and fertility traits. At the same time correlation with other traits (e.g. milkability, performance) need to be tested to avoid negative side effects.

Conclusions

A general description of a cow's physical activity level by using data from accelerometer systems is feasible. Different trait definitions describe different aspects of activity (e.g. basic level, variation) and show different estimates for genetic parameters. Therefore, they need to be considered as different traits, as well as activity during estrus and non-estrus period.

Further investigations on larger data sets should focus on the relationship between activity traits and traditional fertility traits as well as between activity traits and traits of performance or behavior to pursue the goal for a better estrus detection and hence to improve female fertility.

Acknowledgements

We gratefully acknowledge SCR Engineers, Ltd. for providing activity data for this study, especially Doron Bar for direct support.

References

Berry, D.P., Roche, J.R. & Coffey, M.P. 2008. Body condition score and fertility—More than just a feeling. in: Royal, M.D., Friggens, N. C., Smith, R.F., Fertility in Dairy Cows: *Bridging the Gaps.* Cambridge, UK: British Society of Animal Science/Cambridge University Press, p. 107–118.

Butler, W.R. 2000. Nutritional interactions with reproductive performance in dairy cattle. *Anim. Reprod. Sci. 60,* 449–457.

Dobson, H., Walker, S.L., Morris, M.J., Routly, J.E. & Smith, R.F. 2008. Why is it getting more difficult to successfully artificially inseminate dairy cows? *Animal 2,* 1104–1111.

Fricke, P.M., Giordano, J.O., Valenza, A., Lopes, G.Jr., Amundson, M.C. & Carvalho P.D. 2014. Reproduction performance of lactating dairy cows managed for first service using times artificial insemination with or without detection of estrus using an activity-monitoring system. *J. Dairy Sci. 97,* 2771-2781.

Groeneveld, E., Kovač, M. & Mielenz, N. 2008. *VCE User's Guide and Reference Manual Version 6.0.* Available online at: ftp://ftp.tzv.fal.de/pub/vce6/doc/vce6-manual-3.1-A4.pdf (assessed 10 June 2014).

ICAR (International Committtee for Animal Recording). 2013. *ICAR guidelines for Recording, Evaluation and Genetic Improvement of Female Fertility in Dairy Cattle, Version 1.6.* Available online at: http://www.icar.org/Documents/Rules%20and%20regulations/Guidelines/Guidelines_Female_Fertility_for_approval.pdf (assessed 10 June 2014).

Løvendahl, P. & Chagunda, M.G.G. 2006. *Proc. 8th World Congress on Genetics Applied to Livestock Production,* Belo Horizonte, Brasil.

Løvendahl, P. & Chagunda, M.G.G. 2009. Short communication: Genetic variation in estrus activity traits. *J. Dairy Sci. 92,* 4683-4688.

Lyons, G.M., Culhane, K.M., Hilton, D., Grace, P.A. & Lyons, D. 2005. A description of an accelerometer-based mobility monitoring technique. *Medical Engineering & Physics 27:6,* 497–504.

Mark, T., Nielsen, U.S., Pösö, J., Gundel, M. & Svendsen, M. 2001. Genetic Relationship Among Functional Traits in the Nordic Holstein Populations. *Interbull Bulletin 27,* 64-67.

Martiskainena, P., Järvinena, M., Skönb, J.-P., Tiirikainenb, J., Kolehmainenb, M. & Mononen. J. 2009. Cow behaviour pattern recognition using a three-dimensional accelerometer and support vector machines. *Applied Animal Behaviour Science 119,* 32–38.

Mathie, M.J., Celler, B.G., Lovell, N.H. & Coster, A.C.F. 2004. Classification of basic daily movements using a triaxial accelerometer. *Medical & Biological Engineering & Computing 42:5,* 679–687.

Robert, B., White, B.J., Renter, D.G. & Larson, R.L. 2009. Evaluation of three-dimensional accelerometers to monitor and classify behavior patterns in cattle. *Computers and Electronics in Agriculture 67,* 80–84.

Royal, M.D., Darwash, A.O., Flint, A.P.F., Webb, R., Woolliams, J.A. & Lamming, G.E. 2000. Declining fertility in dairy cattle: changes in traditional and endocrine parameters of fertility. *Anim. Sci. 70,* 487–501.