Genetic parameters for predictors of body weight, production traits and somatic cell count in Swiss dairy cows

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Abstract

The main objective of this study was to estimate genetic parameters for body measurements and linear type traits that are indicators of body weight and investigate their genetic correlations with milk yield and udder health. Lactation records on 67,839 Holstein heifers, 173,372 Brown Swiss heifers and 106,725 Simmental heifers were used. Heart girth and stature were measured in cm, and linear type traits (body depth, rump width, udder depth and dairy character or muscularity) were scored on a scale from 1 to 9. Variance components for sires were estimated using AS-REML. Conformation traits were corrected for classifier, season of typing, age, lactation stage, and pregnancy stage at typing and an interaction of herd-year of typing. Production traits were corrected for season of calving, age at calving and an interaction of herd-year of calving. Heritabilities for stature were high (0.6 – 0.8), and heritabilities for linear type traits ranged from 0.3 to 0.55, for all breeds. Genetic correlations with milk yield and somatic cell score (SCS) differed depending on the conformation trait. For all breeds, udder depth is consistently negatively correlated with milk yield, indicating that cows with deeper udders produce more milk. However, they also have higher SCS, indirectly implying that high producing cows are more susceptible to intramammary infections.

Introduction

Body weight (BW) is an important functional trait regulating feed efficiency and energy balance traits in dairy cattle. As feed costs constitute a large proportion of the total costs, biological and economic efficiency of dairy production might be improved if genetic variation in feed intake and feed efficiency is considered (Koenen, 2001). Feed intake is mainly used to meet energy and protein requirements for growth, maintenance, pregnancy and milk production. The proportion of energy requirements for maintenance is substantial. As maintenance requirements directly depend on BW, information on BW provides information on the biological and economic efficiency of dairy production. Body weight depends on body frame, maturity rate, nutrition, stage of lactation, gut fill, degree of fatness, growth rate, etc., but studies have shown that BW is a heritable trait, and hence good for selection (Berry et al., 2002). Successful implementation of a selection strategy that optimally includes BW-information is hindered by lack of data and genetic parameter estimates.

To include BW in breeding schemes, a suitable method of recording has to be available. Weighing animals on a large scale is not a common practice. Therefore, traits that are already included in a regular recording scheme, such as conformation traits could be useful as predictors of BW (Koenen and Groen, 1998). The aim of this study was to study possibilities for genetic evaluation of BW in Switzerland using observations on body measurements and linear type traits, and to estimate genetic correlations with milk yield and udder health.

Materials and Methods

Records were available from the three herd books in Switzerland: (1) Holstein Association of Switzerland, (2) Swiss Brown Cattle Breeders' Federation, and (3) Swiss Simmental and Red & White Cattle Breeders' Federation.

Original data

Conformation traits on Holstein cows were recorded on 199,332 animals from January 1991 until May 2004. Information on milk recordings of all cows that were scored for conformation traits was provided, resulting in 2,652,164 test-day milk yields and somatic cell count (SCC).

Conformation traits of Brown Swiss cows were recorded on 423,846 animals from January 1994 until December 2003. Information on milk recordings of all cows that were scored for conformation traits was provided, resulting in 8,776,780 test-day milk yields and SCC.

Conformation traits of Simmental cows were recorded on 163,082 animals from June 1992 until July 2004. Information on milk recordings of all cows that were scored for conformation traits was provided, resulting in 3,095,096 test-day milk yields and SCC.

Data editing

A dataset with information on production and conformation traits was constructed from the phenotypic records. For the present study, only conformation traits recorded on heifers were included in the dataset. Heifers with extreme ages at calving and ages at typing were excluded from the dataset, as well as heifers with unknown pedigree. Final editing was done by excluding daughters of sires with less than 5 daughters, and by excluding the classes of herd-year of calving and herd-year of typing with less than 5 records. The final datasets per breed, consisted of 67,839 lactation records for Holstein heifers, 173,372 for Brown Swiss heifers and 106,725 for Simmental heifers.

For the analyses, pedigree files were constructed based on the sires of the heifers in the datasets. The pedigrees were traced back for four generations, and the identification of the bull's mother was only included when the cow had two or more sons in the pedigree file; otherwise she was included as a base parent. The pedigree files contained 1634, 4546 and 2286 AI bulls for Holstein, Brown Swiss and Simmental heifers, respectively.

Analysed traits

Analysed conformation traits were 1) body measurements of stature and heart girth (in cm), and 2) body depth, rump width, udder depth and dairy character (for Holstein) or muscularity (for Brown Swiss and Simmental) as linear type traits scored on a scale from 1 to 9. Production traits were averaged from test-day records, but SCC was first transformed to somatic cell score (SCS) ($SCS = \log_2(SCC/100{,}000)+3$). Each production trait was averaged over the test-day records up to 305 days in milk. An average over the first 305 days was calculated if a heifer had 5 or more recordings of SCS, and 7 or more of milk, otherwise a missing value was assigned.

Statistical analyses

AS-REML (Gilmour et al., 2003) was used to estimate variance components, and the same model was applied to all breeds. Heritabilities were estimated with univariate analyses, using a linear model. The model included random effects for sire and a herd-year interaction. Depending on the analysed trait, it was year of calving (HYC, for production traits) or year of typing (HYT, for conformation traits). The model was:

$$Y = \mu + \text{fixed effect} + \text{Sire} + \text{HY} + e$$

The sire effects were linked using the relationship matrix, and were assumed to be normally distributed with var(Sire) = σ^2_s. Herd-year effects contain environmental effects common to different years and different herds. This was assumed to be normally distributed as well, with var(HY) = σ^2_{HY}.

Fixed effects included for the production traits were season of calving (with 4 classes) and a polynomial of order two for age at calving (in days). Fixed effects included for the conformation traits were season of typing (with 5 classes), classifier, a polynomial of order two for age at type classification, for lactation stage at type classification and for pregnancy stage at type classification (all in days).

Bivariate analyses were carried out to estimate correlations between conformation and production traits, using linear models. Fixed effects were the same as mentioned for the univariate analyses. Genetic parameters were calculated from the estimated variance components.

Results

Lactating Holstein heifers were on average 143 cm high, and were the tallest heifers compared to Brown Swiss (139 cm) and Simmental (141 cm). However, the Simmental heifers had on average the widest heart girth (194 cm), in comparison with Holstein (193 cm) and Brown Swiss (192 cm). The linear conformation traits for Holstein heifers were scored between 5.2 and 5.9, on a scale from 1 to 9. For Brown Swiss heifers the scores were between 4.8 and 5.5, and for Simmental heifers between 4.7 and 5.9. So, in general, the scores were slightly above the mean for all breeds.

Lactating Holstein heifers produced on average most milk per day (22.12 kg), compared to Brown Swiss (18.99 kg) and Simmental (19.41 kg). However, these Holstein heifers also had the highest average SCC (125,000 cells/ml). Simmental had the lowest SCC (102,000 cells/ml), and Brown Swiss heifers had on average 112,000 cells per ml milk.

Heritabilities

The heritabilities for the conformation traits are shown in Table 1. For all breeds, stature was the most heritable trait. For Holstein heifers, the linear type traits showed heritabilities around 0.4-0.5. For Brown Swiss heifers, the heritabilities were estimated between 0.3 and 0.5. The heritabilities of the conformation traits for Simmental heifers ranged from 0.42 to 0.55.

Table 1. *Estimated heritabilities for body measurements and linear type traits of lactating Holstein (HO), Brown Swiss (BS) and Simmental (SI) heifers, with their respective standard errors as subscripts*

	HO	BS	SI
Stature	$0.69_{.03}$	$0.64_{.02}$	$0.78_{.03}$
Heart girth	$0.38_{.02}$	$0.35_{.02}$	$0.50_{.02}$
Body depth	$0.39_{.02}$	$0.34_{.02}$	$0.55_{.02}$
Rump width	$0.47_{.03}$	$0.47_{.02}$	$0.45_{.02}$
Udder depth	$0.37_{.02}$	$0.51_{.02}$	$0.42_{.02}$
Dairy Character	$0.40_{.02}$		
Muscularity		$0.42_{.02}$	$0.56_{.02}$

Genetic correlations

For all breeds holds that most genetic correlations had a similar direction of relationship to the phenotypic correlations, although the magnitudes differed. This implies that also for all breeds there is some genetic background to the trends we observe in the field.

Genetic correlations of milk production with conformation traits of lactating Holstein heifers were all positive, except for udder depth (Table 2). This negative correlation between udder depth and milk yield is consistent over breeds, with the strongest correlation for Brown Swiss heifers. This indicates that higher producing heifers have deeper udders.

Table 2. *Estimated genetic correlations between body measurements or linear type traits and milk yield of lactating Holstein (HO), Brown Swiss (BS) and Simmental (SI) heifers, with their respective standard errors as subscripts*

	HO	BS	SI
Stature	$0.47_{.03}$	$0.47_{.03}$	$0.58_{.03}$
Heart girth	$0.39_{.04}$	$0.16_{.03}$	$0.47_{.02}$
Body depth	$0.48_{.04}$	$0.28_{.03}$	$0.48_{.02}$
Rump width	$0.26_{.04}$	$-0.15_{.03}$	$0.08_{.03}$
Udder depth	$-0.23_{.04}$	$-0.63_{.02}$	$-0.03_{.03}$
Dairy Character	$0.67_{.04}$		
Muscularity		$-0.35_{.03}$	$-0.35_{.03}$

Table 3. *Estimated genetic correlations between body measurements or linear type traits and somatic cell score of lactating Holstein (HO), Brown Swiss (BS) and Simmental (SI) heifers, with their respective standard errors as subscripts*

	HO	BS	SI
Stature	$-0.16_{.05}$	$0.05_{.04}$	$0.17_{.04}$
Heart girth	$-0.18_{.05}$	$-0.10_{.04}$	$0.11_{.04}$
Body depth	$-0.08_{.06}$	$0.12_{.04}$	$0.37_{.03}$
Rump width	$-0.04_{.05}$	$-0.27_{.04}$	$-0.05_{.04}$
Udder depth	$-0.31_{.05}$	$-0.17_{.04}$	$-0.04_{.04}$
Dairy Character	$-0.03_{.06}$		
Muscularity		$-0.37_{.04}$	$-0.47_{.03}$

Somatic cell score is generally negatively, or only slightly positively, correlated with the conformation traits (Table 3). However, the correlations are relatively weak, and standard errors are reasonably large. The negative correlation between udder depth and SCS is consistent over breeds, with the strongest correlation for Holstein heifers. This indicates that heifers with deeper udders have higher SCS.

Discussion

Body weight measurements of replacement dairy heifers are important for monitoring the growth rate, optimising nutrient allowance and determining a suitable size for breeding. Since nutrient recommendations are based on BW and daily gain, it is necessary to know the live weight to optimise the nutrient intake of heifers. Most farmers do not have animal scales for measuring BW directly, and an alternative method of estimating BW is needed (Mäntysaari, 1996). Heart girth has been a trait highly correlated to BW, but wither height, body length and hip width have been used as well. (Mäntysaari, 1996; Koenen and Groen, 1998).

Heritability estimates of conformation traits of this study are generally in the same range as the estimated heritabilities reported by Koenen and Groen (1998). The estimated heritability for stature is much higher than those reported in literature (Kadarmideen and Wegmann, 2003; Wall et al., 2005). Even though stature has the tendency to show high heritabilities, they were not as high as estimated by us. Predictors of BW turn out to be heritable traits. Heritabilities are pretty consistent over breeds, although heart girth and body depth seem to be a bit more heritable for lactating Simmental heifers, than for Holstein and Brown Swiss heifers.

To evaluate the effect of inclusion predictors of BW in the breeding goal on genetic responses, genetic correlations with other traits such as milk production and udder health have to be considered simultaneously. Genetic correlations between BW predictors and milk production were moderately high for Holstein, with the highest genetic correlation estimated between dairy character and milk yield. This implies that more 'dairy' cows produce more milk than the 'coarse' cows. For lactating Brown Swiss heifers the genetic correlation between udder depth and milk yield is strongly negative, implying that cows with high yields have deep udders, which has been reported by other studies as well (e.g. Kadarmideen and Wegmann, 2003), but for Simmental heifers this correlation is hardly present. For both Brown Swiss and Simmental heifers, muscularity is negatively correlation with milk yield, implying that cows with more muscles produce less milk than cows with fewer muscles. In fact, this is the same result as found for lactating Holstein heifers, because the scales for dairy character and muscularity are opposite, and therefore, the signs of the correlations are opposite as well.

Genetic correlations between BW predictors and udder health were mostly negative, and only low to moderate. Therefore caution should be taken by drawing strong conclusions from these results. For lactating Holstein heifers, the highest genetic correlation was estimated between udder depth and SCS. This implies that cows with deeper udders have higher cell scores, which has also been reported by other studies (e.g. Kadarmideen and Wegmann, 2003). For Simmental heifers this correlation is hardly present. For both Brown Swiss and Simmental heifers, muscularity is negatively correlation with udder health, implying that udder health of cows with more muscles is worse than of cows with fewer muscles. One biological explanation for this might be that strongly muscled udders are hard to milk out completely. Therefore, milk will stay in the udder after milking and that's a perfect place for bacteria to multiply.

Conclusions

Body measurements and linear conformation traits that are indicators of BW are heritable traits, in all three Swiss breeds. Genetic correlations were quite strong and positive for body measurements and milk production traits (milk, fat and protein), indicating that taller heifers and heifers with wider heart girth produce more milk. Of the linear type traits, udder depth consistently showed negative correlations with all milk production traits, indicating that heifers with deeper udders have higher milk productions. However, they have higher SCS as well, indirectly implying that high producing heifers are more susceptible to have intramammary infections.

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