Relationship between calf size at birth with its own and its dam's performance in Holstein cattle

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Summary

The effects of a calf's size (CS) on subsequent performance and on their dams performance were studied using data from Holstein cattle. Overall CS at birth was scored subjectively into 5 categories: tiny, small, average, big and huge and had significant effects on performance as adult. Tiny and small calves at birth produced significantly less milk than those scored big and huge. Also calves that were scored to be of average at birth had better fertility relative to those scored as huge. Variability in CS also had a significant effect on the subsequent performance of their dams. Cows that had tiny calves produced less 305- (806 Litre) and 150- (292 Litre) day milk yields and have poorer survival than cows that produced an average sized calf. Heifers that calved earlier than average (i.e. at younger age) were more likely to produce tiny and small calves. Survival from 1st to 2nd lactation was also reduced by 8 and 7% if the size of the calf produced was huge and tiny, respectively. Overall the effect of producing calves that are different from average affected the performance of the dam more than the performance of a calf as an adult. The relationship between size at birth and performance as an adult to some extent reflects the antagonistic relationship of fitness with size and production traits in dairy cattle.

Keywords: calf size, adult performance, genetic correlations

Introduction

In human studies, size at birth is related with increased risk of adulthood diseases (Gluckman and Hanson, 2004). In cattle, CS, in addition to its use as predictor of calving difficulty, may serve as an early indicator of lifetime performance and may aid selection of replacement heifers that are more likely to remain in the herd longer and produce optimal milk yields (Kamal et al. 2014). Understanding the relationships between CS at birth and performance as an adult could help the development of management and genetic strategies to optimize calf growth and enable the selection of replacement heifers based on early-life measurements that are relatively easy to record (Swali and Wathes, 2006). Most studies that looked at the relationship of CS with growth and adult performance have used birth weight and are generally from experiments conducted to explore these relationships (Swali and Wathes, 2006; Kamal et al. 2014; Van De Stroet et al. 2016). Also most studies were limited to phenotypic relationships rather than both genetic and environmental relationships. The use of widely available data on CS and other performance traits can help to explore the circumstances that lead to variability of CS and their link to performance as adults.

One of the objectives of this study was to quantify the effect of CS at birth on performance traits observed as adults, such as age at first calving (AFC), milk yield (MY), fertility and survival in Holstein cattle. Because traits observed at calving, including CS, can also be considered as the trait of the cow calving, we also assessed if the performance of dams is affected by the size of the calf born. To better understand the relationship between CS at birth and performance as adults we also estimated genetic and environment correlation between CS and other traits observed as adult.

Materials and methods

Data on CS and other performance traits including fitness and MY traits of cows that calved between 1995 and 2016 were extracted from the national database operated by DataGene Ltd. (Melbourne, Australia). The data on calving performance included information on CS at birth subjectively scored as tiny, small, average, big and huge by farmers. Female calves with CS data were then matched to their performance as adults. The AFC for the animals selected for this study varied from 18 to 40 months. The number of animals with their own CS score and performance as adults is shown in Table 1. The other objective of this study was to assess if variability in CS as a trait of the cow affects her own performance (AFC, MY, calving interval (CI) and survival (Surv)). CS categories and the number of observations for each trait is shown in Table 1.

First, the effect of size at birth on performance as adult was estimated. The effect of CS (5 levels) on AFC, CI, Surv and 305 MY was assessed by fitting a model including herd-year-season of calving as an adult, month and year of birth as a calf and AFC for all traits except AFC. For AFC, herd-year-season of birth instead of calving was fitted. The effect of CS on MY traits was also estimated using test-day MY in the first 150-day of lactation. For this analysis the fixed effects fitted were herd-test date and year-season of calving instead of herd-year-season. In the test-day model, days in milk was also fitted as a covariate in addition to cow and sire as random effects. The random effect of cow was fitted to account for repeated test-day records of cows and the random effect of sire was fitted to estimate the effect of CS on milk after accounting for genetic differences in sires.

Secondly, the effect of CS on performance of the calving cow was estimated. These analyses and the model used was similar to the model described, with the exception that CS was assumed to be the trait of the cow, so the performance traits considered were of the cow that calved. To explore the possible reasons for the effect of CS on fitness and production traits, covariance analyses were performed using multi-trait models. These analyses provided estimates of correlations between CS levels converted to weights as shown in Table 1 and MY, CI, Surv and AFC using a sire model with additive genetic relationships. The pedigree used included sires of animals with information on CS and performance and their parents going back to 1950s. All data analyses were performed using ASReml (Gilmour et al. 2009).

Results and discussion

Table 1 shows that there is more variability in CS in cows that calved because it includes male and female calves, while the CS for animals with adult performance is limited to female calves. There were also fewer tiny calves with adult performance records, reflecting the observation that stillbirths were higher in tiny (33%) than in average or small sized calves. Stillbirth rates were also 45% and 20% in huge and big calves, respectively, relative to only 7% in both average and small sized calves. The smaller number of tiny calves with adult performance also suggests that farmers are reluctant to use them as replacement heifers.

CS had a significant effect on all traits expressed as adult ($P \sim 0.001$). The results in Table 2 for CS categories are expressed as a deviation from the average sized calf. Tiny and small calves produced less milk and calved for the first time about 5 days later than the average.

On the other hand, big and huge calves produced more 305-day MY but had slightly longer CI. This may be because larger calves at birth are likely to be large cows as adults (Swali and Wathes, 2006). Calves scored as tiny and small had slightly lower (2%) survival than the average sized calves.

Table 1. Calf size (CS) categories, number of observations and proportion of data for calves with adult performance data and dams with CS and performance data.

Calf size		Calves born with CS and adult information		Cows calving with CS	
Categories	Weight	Number	Prop	Number	Prop
Tiny	30 kg	364	0.001	1231	0.005
Small	35 kg	8839	0.028	11793	0.045
Mean	40 kg	277233	0.892	225307	0.869
Big	45 kg	22850	0.074	19291	0.074
Huge	50 kg	1514	0.005	1715	0.007
Total		310800		259337	

Table 2. Effect of calf size at birth on age at first calving (AFC), milk yield (MY), calving interval (CI) and survival as adult.

Trait	Calf size category				
	Tiny	Small	Mean	Big	Huge
AFC, days	4.88 ± 2.38^{b}	1.10 ± 0.50^{a}	0.0^{a}	-0.55 ± 0.31^{a}	-0.18 ± 1.08^{a}
305-day MY, Litre	-57.7 ± 124.2^{ab}	-136.7 ± 25.7^{b}	0.0^{a}	62.3 ± 15.7^{c}	108.3 ± 55.6^{c}
150-day MY, Litre	-8.8 ± 18.6^{ab}	-105.8 ± 24.0^{b}	0.0^{a}	-25.0 ± 2.7^{ab}	-39.7 ± 9.5^{ab}
CI, days	2.19 ± 4.56^{a}	0.73 ± 0.96^{a}	0.0^{a}	2.49 ± 0.58^{b}	5.71 ± 2.10^{b}
Survival (%)	-2.04 ± 2.46^{ab}	-2.16 ± 0.52^{b}	0.0^{a}	-0.56 ± 0.32^{ab}	-1.29 ± 1.13^{ab}

^{a,b,c} Solutions designated with different letters in the same row are significantly different ($P<0.05$) from each other.

Calf size when treated as a trait of the cow had a statistically significant effect on all the performance traits of the cow considered ($P \sim 0.001$). Heifers that calved at a younger age (by up to 18 days) compared to cows that produced average sized cows produced tiny and small sized calves (Table 3). Cows that produced tiny and small calves produced less 305 and 150 day milk yields. Similarly cow with big and huge calves had longer CI. Surv from 1st to 2nd lactation was also reduced by 8 and 7% if the size of the calf was huge and tiny, respectively. Overall the effect of producing calves that are different from average affected the performance of the dam more than that of the performance of the calf as adult.

The genetic correlation between CS and performance as adults suggests (Table 4) that size at birth is negatively correlated with fitness traits (both survival and fertility). The genetic correlation between size at birth and milk yield traits as adult were effectively zero. When CS is treated as the trait of the cow the genetic antagonism between milk yield and fitness is clearly observed. Cows that produced larger calves are likely to have poor fitness expressed as delayed AFC, reduced fertility and Surv and increased milk yield. This is despite the somewhat non-linear relationship in Table 3 where, in particular, having tiny calves results in slightly longer CI and lower Surv. At the genetic level this means large cows produced large calves and have poorer fitness (Hansen 2000). All the residual correlations between CS and all the performance traits in both cases were close to zero so are not tabulated.

The results in this study show the effect of size at birth on performance as adult is small and agrees with the literature (Swali and Wathes, 2006). As our ability to estimate it without bias is hampered by the few number of tiny calves with adult performance, the possibility that intrauterine environment of the cow which has effect on CS may also affect the performance of calf as adult cannot be ruled out (Rutherford et al., 2012). The effect of CS on the performance of the cow reflects partly the genetic antagonism (Hansen 2000) between fitness on the one hand and size and MY on the other hand (Table 3 and 4). The low MY of cows that produced tiny and small calves may be due to the stressful environmental (e.g. sub-optimal nutrition) that the dam experiences during pregnancy (Rutherford et al. 2012) which result in reduced MY and Surv following calving. However, this needs to be examined, for example, by looking at the relationship of CS and MY over the lifetime of cows. Currently we are not aware of any literature that supports the effect of CS on MY of the dam. Due to the availability of large data measured on several traits over several generations, dairy cattle can serve as a model to study if the intrauterine environment influences the performance and health of both the offspring and mother following parturition.

Table 3. Effect of calf size as a trait of the cow on the performance of the cows that calved.

Trait	Calf size category				
	Tiny	Small	Mean	Big	Huge
AFC, days	-18.32±1.94[d]	-6.72±0.70[ab]	0.0[a]	0.39±0.54[a]	3.23±1.65[c]
305-day MY, Litre	-806.3±60.88[d]	-199.8±21.35[c]	0.0[a]	125.8±16.62[ab]	182.8±50.97[b]
150-day MY, Litre	-292.4±46.6[d]	-188.2±25.9[b]	0.0[a]	-50.0±24.6[c]	-47.0±24.1[c]
CI, days	2.11±2.16[ab]	-0.02±0.75[a]	0.0[a]	5.95±0.58[b]	7.59±1.82[b]
Survival (%)	-7.48±1.17[b]	-0.83±0.42[a]	0.0[a]	-2.69±0.32[a]	-7.61±0.98[b]

[a,b, c] Solutions designated with different letters in the same row are significantly different ($P<0.05$) from each other.

Table 4. Genetic correlations between calf size (CS) at birth and performance as adults and CS as the trait of the calving cow and her performance.

Traits	With performance as adult	With the cow calving
AFC	0.09±0.07	0.24±0.08
CI	0.31±0.06	0.29±0.09
Survival	-0.29±0.06	-0.23±0.08
305-day MY	0.0±0.05	0.17±0.08
150-day MY	0.03±0.04	0.12±0.07

A more practical implication of this study is that suboptimal conditions during pregnancy which may have influenced CS may have a long-term effect on the cow calving as well the calf itself as an adult. A detail study to understand the factors that cause variability in CS as the trait of the calf born and the cow calving and their inter-relation will require data from birth to 1st calving age, including information on recruitment of replacements in dairy herds, which is currently unavailable. This will help the effort to develop an overall herd improvement strategy.

ACKNOWLEDGEMENTS

We thank DataGene Ltd. for provision of data and Dr Phil Bowman (Agriculture Victoria) for extraction of the data. This research was funded by DairyBio, which is a co-investment of Dairy Australia with Agriculture Victoria.

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