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Prenatal maternal effects on daughter milk production in New Zealand dairy cattle

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Abstract

The impact of a cow's live weight and body condition score (BCS) during pregnancy on the milking performance of a resulting daughter was investigated using 4,021 Jersey and 9,329 Holstein Friesian dam-daughter pairs from the Livestock Improvement Corporation Sire Proving Scheme. Although the estimated maternal heritability of each trait in each breed was small (< 0.02), a 1 kg increase in dam weight was associated with 1.19 (± 0.25) and 0.43 (± 0.15) litres increase in daughter milk volume, a 61 (± 11) and 15 (± 6) gram increase in fat and a 55 (± 8) and 14 (± 5) gram increase in protein in Jersey and Holstein Friesian cows respectively. A one unit increase in BCS was associated with an increase in volume by 32 (± 19) litres in Jerseys and a 14 (± 14) litre decrease in Holstein Friesians. Fat increased by 1.91 (± 0.84) kg and 0.56 (± 0.55) kg and protein increased by 1.64 (± 0.63) kg and 0.06 (± 0.42) kg per unit BCS in Jersey and Holstein Friesian respectively. All daughter responses are per lactation. Although small changes in the daughters milking traits were observed, the lack of significant variation in the maternal heritability indicates that the sample size of the dataset may not be sufficient to detect if prenatal maternal effects truly exist.

Keywords: body condition score; live weight; lactation; prenatal; maternal effects; lactation

Introduction

Due to the nutritional demands placed on a New Zealand dairy cow by concurrent maintenance, growth, lactation and/or fetal development processes, energy requirements can exceed the amount of energy ingested at certain times of the year forcing the cow to prioritise the demands. Although the energy requirements of the developing embryo are low compared to the other physiological processes named, there is some evidence that fetal malnutrition in dairy cattle can influence the resultant progeny's performance later in life (Banos et al. 2007, Berry et al. 2008, Erdman et al. 2009).

Investigating prenatal maternal effects on the postnatal performance of the resulting daughters is complicated by the requirement to accurately differentiate between the variation caused by conventional genetic inheritance and that which is due to the prenatal maternal environment. Erdman et al. (2009) used a model that included a milk volume breeding value to correct for conventional genetic inheritance and total body tissue energy content, an index derived from dam body condition score (BCS) and live weight, as a covariate to represent the dam's nutritional status. This study found positive relationships between both dam lactation volume and total body tissue energy content during gestation and the milk volume produced by the resulting daughter. However, there is concern that this approach ignores any interactions that occur between conventional genetic inheritance and the prenatal maternal environment, because each effect is estimated in separate analyses. This issue can be overcome through the use of a statistical technique called the animal model, which can estimate both the additive genetic (conventional inheritance) and maternal genetic variances in a single analysis. The maternal genetic variance is assumed to represent the prenatal maternal environment in typical New Zealand dairy cattle because calves are separated from their dams soon after birth. This removes all opportunity for postnatal maternal effects and thus all of the maternal genetic variance can be logically assumed to have occurred prior to birth (Banos et al. 2007, Berry et al. 2008).

Using the animal model, Banos et al. (2007) found that British dairy cows had significant maternal effects for daughter calving interval and the 56 day non return rate but not for the number of inseminations per conception or milk yield. The regression coefficients for each of the daughter traits revealed that as dam BCS increased; there was an associated increase in each of the traits except milk yield, which decreased. Using a similar method, Berry et al. (2008) analysed Irish dairy cows and found significant maternal effects on daughter milk yield and somatic cell score but not on age at first calving or calving interval. The associated regression coefficients revealed that as dam milk yield increased; there was an associated increase in daughter somatic cell score and a decrease in daughter milk yield and survival to the second lactation. Also as the fat concentration of the dams' milk increased; there was an associated increase in daughter milk yield and a decrease in daughter somatic cell score and survival to the second lactation.

The objective of this study was to investigate whether the maternal environment to which a developing female fetus is exposed can affect its subsequent postnatal milking performance under

Table 1 Descriptive statistics for the dam body condition score and live weight included as a covariate in the analyses. All dams were in their first parity.

Statistic	Dam body condition score		Dam live weight (kg)	
	Holstein Friesian	Jersey	Holstein Friesian	Jersey
Mean	4.1	4.0	408	324
Standard deviation	0.5	0.5	43	37
Minimum	2.5	2.0	260	201
Maximum	6.5	6.5	646	550

Table 2 Variance components and heritabilities ± their associated standard errors for each of the daughter lactation yield traits expressed as production per lactation. The statistical models used to estimate these results did not contain either dam body condition score or dam live weight as covariates.

Breed	Daughter trait	Additive genetic variance (V_a)	Maternal variance (V_m)	Phenotypic variance (V_p)	Direct heritability (h^2)	Maternal heritability (m^2)
Jersey	Volume (L)	40,448	390	14,1721 ± 2,896	0.28 ± 0.07	0.00 ± 0.03
	Fat (kg)	97.96	4.90	286.8 ± 8.2	0.34 ± 0.08	0.02 ± 0.04
	Protein (kg)	31.40	1.23	156.9 ± 4.2	0.20 ± 0.07	0.01 ± 0.03
Holstein Friesian	Volume (L)	52,363	1,120	19,444 ± 3,400	0.27 ± 0.04	0.01 ± 0.01
	Fat (kg)	84.22	2.14	311.4 ± 5.5	0.27 ± 0.04	0.01 ± 0.02
	Protein (kg)	38.95	2.07	181.6 ± 3.1	0.22 ± 0.04	0.01 ± 0.02

New Zealand conditions. This will assist us to determine the ideal level of nutrition under which New Zealand dairy cows should be maintained during gestation for their female progeny to later achieve optimal performance.

Materials and methods

Separate analyses were conducted for both the Jersey and Holstein Friesian breeds, using 4,021 and 9,329 dam-daughter pairs available from the Livestock Improvement Corporation sire proving scheme respectively. The daughters were the progeny of 820 Jersey and 1,509 Holstein Friesian sires. A total of 4.5% of the Jerseys and 4.6% of the Holstein Friesians were in the dataset as both dams and daughters. Dams were in their first parity and all animals were born between 1995 and 2008. Body condition score was recorded visually on a 1 to 9 scale, where 1 is emaciated and 9 is obese. The data were edited to contain only daughters with known parentage and dams with live weights and body condition scores recorded on the dam during the first trimester of the daughter's gestation (~60% of the BCS and live weights on the National database were recorded during the first trimester). All dam–daughter pairings not born in the same herd and twins/embryo transfer progeny were omitted to ensure that no bias due to herd or abnormal reproduction occurred in the analysis. After these edits, the daughters in this study represented 5.9% of the total cows with BCS and live weight recorded in the Livestock Improvement Corporation sire proving scheme herds. Contemporary groups were defined by the daughter's birth herd and birth year. The lactation volume, and fat and protein yields for the whole lactation were recorded during the daughters first lactation as a two-year-old and were pre-corrected for variation in lactation length, milking frequency and the number and timing of herd tests (Johnson 1996). By pre-correcting the lactation traits, the statistical model was able to be simplified thus reducing computing requirements. The corrections were also likely to be more accurate as they were derived from the whole database not just those animals meeting the criteria of this study. A pedigree file containing all known relationships among animals in the study, including ancestors, was created and used in the analyses. The pedigree files contained 34,331 Jersey and 61,716 Holstein Friesian cows.

An animal model was used to obtain both additive genetic and maternal heritabilites, with their associated standard errors, for the daughter milk production traits using ASReml (Gilmour et al. 2009). The model included fixed effects for contemporary group and dam body condition score or dam live weight, as required, as covariates. The random effects of the daughter, dam and residual were also included so that the corresponding additive genetic, (v_a), maternal (v_m) and error or residual, variances (v_e) could be estimated. From these variances, the phenotypic variance was calculated using $v_p = v_a + v_m + v_e$, direct heritability using $h^2 = v_a/v_p$ and maternal heritability using $m^2 = v_m/v_p$.

Table 3 Maternal heritability estimates for daughter lactation traits from analyses including dam body condition score and live weight as fixed effects. All estimates were not significantly different from zero (P > 0.05).

Breed	Dam trait	Daughter lactation yield traits		
		Volume (L)	Fat (kg)	Protein (kg)
Jersey	Body condition score	0.00 ± 0.03	0.02 ± 0.04	0.01 ± 0.03
	Live weight	0.00 ± 0.03	0.03 ± 0.04	0.02 ± 0.04
Holstein Friesian	Body condition score	0.01 ± 0.01	0.01 ± 0.02	0.01 ± 0.02
	Live weight	0.01 ± 0.01	0.01 ± 0.02	0.01 ± 0.02

Table 4 Regression coefficients ± their associated standard errors for the effect of dam body condition score and live weight on the daughter first lactation traits. Bold text indicates the values are significantly different from zero (P < 0.05).

Breed	Dam trait	Daughter first lactation yield traits		
		Volume (L)	Fat (kg)	Protein (kg)
Jersey	Body condition score	32 ± 19	**1.9 ± 0.8**	**1.6 ± 0.6**
	Live weight	**1.5 ± 0.2**	**0.06 ± 0.01**	**0.06 ± 0.01**
Holstein Friesian	Body condition score	-14 ± 14	0.56 ± 0.55	0.06 ± 0.42
	Live weight	**0.4 ± 0.2**	**0.02 ± 0.01**	**0.01 ± 0.01**

The regression coefficients for dam body condition score or dam live weight were obtained from the ASReml solutions file when these traits were included in the statistical model.

Results

The descriptive statistics for the dam covariates (Table 1) illustrate the heavier average weight of the Holstein Friesian breed compared with the Jerseys. No significant difference between breeds in BCS was observed. Due to the daughter milk production traits being presented as yield deviations within contemporary groups, meaningful descriptive statistics could not be calculated for these traits.

Variance components estimated from statistical models, not including the dam traits, are shown in Table 2. All of the direct additive genetic effects and direct heritability estimates were significantly different from zero (P > 0.05) with heritability estimates varying between 0.20 (Jersey – protein yield) and 0.34 (Jersey – fat yield). The maternal heritabilities varied between 0.003 (Jersey – volume) and 0.02 (Jersey – fat yield) and were not significantly different from zero.

The addition of either dam BCS or live weight into the model reduced the direct genetic effect/heritability and increased the maternal genetic effect/maternal heritability for both protein and fat yield in the Jersey breed, though none of the effects were significantly different from zero (P > 0.05)(Table 3). The addition of either dam BCS or live weight had no apparent effect on the maternal heritability of milk volume in the Jersey dataset or on any of the Holstein Friesian traits. In the Jersey data, dam weight appeared to have a greater influence on the estimated variance components for milk fat and milk protein than dam BCS.

The regression coefficients for dam BCS or dam live weight revealed that an increase in dam weight or dam BCS was associated with an increase in all three traits in both breeds, with the exception of milk volume in the Holstein Friesian data set (Table 4). However, the associations between the dam BCS and daughter milk volume in the Jerseys, and the association between dam BCS and all three daughter traits in Holstein Friesians were not significantly different from zero (P > 0.05). The response of all three daughter traits to either dam BCS or live weight was greater in the Jersey breed than observed in the Holstein Friesian breed.

Discussion

This study showed that variation in dam BCS and live weight could influence the lactation performance of the progeny, though the differences were small. These results are similiar to those found by Banos et al. (2007), Berry et al. (2008) and Erdman et al. (2009) who found that dam traits, indicative of nutritional status, such as BCS, milk yield and fat content, body tissue energy and lactation volume, were associated with changes in a range of reproductive and milk production traits. Both of the Banos et al. (2007) and Berry et al. (2008) studies found evidence to suggest that the dam's nutritional status later in gestation had a greater influence upon their results than when measured closer to conception. Unfortunately for this study, the majority of the BCS and live weight data recorded by the New Zealand dairy industry are recorded closer to conception due to the association between BCS and fertility (Pryce & Harris, 2006). As a consequence there was insufficient data available to test the relationships in the other trimesters.

The response of daughter lactation traits to variation in dam BCS or live weight could be explained by genetic correlations. These are not accounted for in the model because the daughter traits were fitted as random effects and the dam traits were fitted as fixed effects. However, this is unlikely because Pryce & Harris (2006) found, using a related population, that the genetic correlations between body condition score/live weight and lactation volume, milk fat and protein yields were at the low end of the scale. Namely -0.03 to -0.13 for BCS and 0.28 to 0.36 for live weight.

The lack of significance in the maternal heritability estimates may be partly due to the structure of the data used. Ideally the estimation of maternal effects requires multiple progeny per cow so that per cow estimations can be formed from more than a single progeny's performance. As a response to these requirements, Banos et al. (2007) only included dams with multiple daughters in production. The disadvantage of this approach is that it introduces year/dam age/dam parity effects which must be accounted for in the model. For instance, Berry et al. (2008) found that the maternal genetic variances for milk yield were positively associated with parity.

The overall size of the data set also plays an important role in determining the size of the standard errors associated with each genetic parameter estimate. This study analysed ~4,000 and ~9,000 dam-daughter pairs in two separate analyses. Banos et al. (2007) analysed ~11,000 pairs and Berry et al. (2008) ~81,000 pairs. Erdman et al. (2009) analysed less than 600 dam-daughter pairs but their study used a different statistical model. Despite the variation in the data structures, the additive genetic and maternal genetic heritability estimates for lactation volume in this study were within the range given by Banos et al. (2007) and Berry et al. (2008). Only the study with the largest number of records (Berry et al. 2008) had maternal genetic heritability estimates that were significantly greater than zero. Unfortunately, the size of the dataset for this type of study reported here is severely limited by the requirement for BCS/live weight to be recorded during the pregnancy that results in a daughter that subsequently has her own production recorded. Hence the reason why only 5.9% of the cows with BCS and live weight recorded in Livestock Improvement Corporation sire proving scheme herds were able to be included in these analyses reported here.

Both Berry et al. (2008) and Erdman et al. (2009) discussed and used alternatives to the use of BCS/live weight as proxies for dam nutritional status. The accuracy of both BCS and live weight as proxies for nutritional status is adversely affected by variation between individual cows ability to mobilise their body reserves. In an ideal situation, subjecting pregnant cows to contrasting levels of nutrition would provide a direct and quantifiable nutritional effect which removes any inaccuracies associated with the use of proxies. However, lactation would be adversely affected in the low nutrition group. As a consequence, this approach is impractical in commercial settings similar to those from which these records were obtained.

This study revealed that the prenatal maternal environment can influence milk production in the subsequent daughters, though the effects are small. The difficulty in assessing dam nutritional status and the magnitude of the results make them difficult to detect using commercial data.

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References

Banos G, Brotherstone S, Coffey MP 2007. Prenatal maternal effects on body condition score, female fertility and milk yield of dairy cows. Journal of Dairy Science 90: 3490–3499.

Berry DP, Lonergan P, Butler ST, Cromie AR, Fair T, Mossa F, Evans AC 2008. Negative influence of high maternal milk production before and after conception on offspring survival and milk production in dairy cattle. Journal of Dairy Science 91: 329–337.

Erdman RA, Arias JA, Quinn-Walsh E, Fisher P, Stelwagen K, Singh K 2009. Putative *in utero* epigenetic impact of dam lactation yield and tissue energy sources on daughter first lactation milk production in dairy cattle. Journal of Dairy Science Supplement 1: 92.

Gilmour AR, Gogel BJ, Cullis BR, Thompson R 2009. ASReml User Guide Release 3.0. Hemel Hempstead, VSN International.

Johnson DL 1996. Estimation of lactation yield from repeated measures of test day yields. Proceedings of the New Zealand Society of Animal Production 56: 16–18.

Pryce JE, Harris BL 2006. Genetics of body condition score in New Zealand dairy cows. Journal of Dairy Science 89: 4424–4432.