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The Effect of Calfhood Diseases on Growth of Female Dairy Calves During the First 3 Months of Life in New York State

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ABSTRACT

Our objective was to study the effects of pneumonia (cumulative incidence, 25%), diarrhea (29%), umbilical infection (14%), and umbilical hernia (15%) on BW and height gains during the first 3 mo of life. Female dairy calves ($n = 410$) born from January to December 1990 in 18 commercial herds in New York state were used. Average daily gains during the 1st, 2nd, and 3rd mo were 374, 596, and 719 g, respectively; average gain was 565 g during the 3-mo period. Average monthly height gains during the 1st, 2nd, and 3rd mo were 4.4, 5.6, and 5.7 cm, respectively.

Use of multiple linear regression, with farms treated as random effects, indicated that treated, verified pneumonia was associated with a reduction in average daily gain of 66 g and that failure of passive transfer reduced average daily gain by 48 g during the 1st mo. During the 2nd mo, neither disease nor failure of passive transfer affected average daily gain. During the 3rd mo, each additional week of pneumonia reduced average daily gain by 14 g, and umbilical infection reduced average daily gain by 96 g. Each additional week of diagnosed pneumonia reduced total BW gain during the first 3 mo by 0.8 kg. Similarly, each week of pneumonia reduced total height gain by 0.2 cm and failure of passive transfer by 0.9 cm. Prevention of chronic pneumonia and umbilical infection may improve average daily gain of calves.

(**Key words:** calf, disease, growth, failure of passive antibody transfer)

Abbreviation key: ADG = average daily gain, BVD = bovine virus diarrhea, FPT = failure of passive antibody transfer, IBR = infectious bovine rhinotracheitis, PI-3 = parainfluenza-3.

INTRODUCTION

The growth rate of female calves from birth to sexual maturity determines age at first calving. Holstein heifers, for example, experience puberty at 250 to 273 kg of BW (8). Growth rate of heifers also affects milk production. For Red Danish, Black and White Danish (Holstein type), and Jerseys, milk production during first lactation was greater for cows that gained about 600 g daily in the prepubertal period than for cows that grew either faster or slower (3); the prepubertal period was defined to be from about 100 kg to sexual maturity. In contrast, Foldager and Krohn (2) failed to demonstrate a significant effect of a very high average daily gain (ADG) during the first 6 to 8 wk of life on subsequent milk production. With only 7 and 11 cows in the comparison groups, lack of power to detect this difference was possible in their study.

Disease reduces growth. Schmoltdt et al. (19) showed with 341 female dairy preweaned calves that pneumonia alone, diarrhea alone, and both together decreased BW gain daily by 1.3, 3.0, and 4.8 g/kg, respectively, during a 44- to 60-d follow-up period. The corresponding relative declines in growth rate were 8, 18, and 29%, respectively. Those calves originated from 28 farms and were reared at one follow-up unit. Calves were studied from between 5 and 70 d of age to 49 to 120 d of age. The breed of calves was not reported. Calves were inspected daily; not reported were who made the inspections and what criteria were used to diagnose pneumonia and diarrhea (14% were treated for pneumonia, 15% for diarrhea, and 11% for both). Kleiner et al. (10) recorded birth and end BW at ages ranging from 5 to 37 d for 803 male calves from three different dairy cattle units (breed was not reported). The occurrence of diarrhea was also recorded, but diagnostic criteria were not. For 755 of these calves, information was obtained about the dates and duration of veterinary treatments for diarrhea and pneumonia as well as the BW up to 140 d of age. The sick calves were treated from the occurrence of first clinical signs until disappearance of the

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signs, and the treatment duration was considered to be the duration of the disease. During this period, the ADG of calves that were treated for pneumonia, diarrhea, or both for >22 d (group 3) was 110 g less than the ADG of calves that had <11 d of illness (reference group). Calves that were sick for 11 to 21 d (group 2) gained daily 50 g less BW than did calves in the reference group. The calves in groups 2 and 3 could not compensate for reduced growth by 140 d of age. Moreover, Hartmann (6) reported the effect of time of diarrhea onset in neonatal calves on the duration of diarrhea by observing 2092 diarrheic calves from three different dairy cattle units during the first 2 wk of life. A 1-d delay in the onset of diarrhea reduced the duration of the disease by about 0.2 d and improved ADG by about 10 g. Healthy controls were not used in that study.

The effect of absorbed colostral antibodies on ADG also has been studied. Donovan et al. (1) compared results for calves in two herds that were deprived of colostrum (serum total protein concentration <5 g/100 ml) or provided with it. Donovan et al. (1) reported that the calves provided with colostrum grew at least 100 g/d faster than did their deprived herd-mates. The serum total protein was collected at 2 to 10 d of age. Robison et al. (16) reported that serum Ig concentration at 24 to 48 h was a significant factor that influenced ADG from birth to 180 d. The higher the total serum Ig, as measured with radial immunodiffusion, the greater was the ADG.

Van Donkersgoed et al. (22) followed 325 calves from birth to 1.5 to 6 mo of age and reported that calves with pneumonia, either diagnosed and treated by the owner or diagnosed by the semimonthly clinical examinations of the calves by the research veterinarian, had reduced girth growth during the 1st mo of life. Van Donkersgoed et al. (22) also reported that calves with failure of passive antibody transfer (FPT), defined as total IgG in serum \leq 800 mg/dl, had reduced girth growth during the 1st mo, but possibly some calves were misclassified as having FPT. Their first blood samples were collected between 1 and 14 d of age, when the older calves had already experienced some natural decline in the maternal antibody, and no adjustment for half-life was made. Van Donkersgoed et al. (22) found no association between treatment for diarrhea and girth growth, but did find that girth growth of calves during the 1st mo of life was associated positively with postcolostral serological titers to *Pasteurella haemolytica* and to *Mycoplasma dispar*.

The purpose of this study was to determine the impacts of pneumonia, diarrhea, umbilical infection, umbilical hernia, and postcolostral serum IgG on

ADG of heifer calves raised in commercial dairy farms during the 1st, 2nd, and 3rd mo of life and on the total BW and height gains during the entire 3-mo period. Furthermore, the study examined the effects of serological titers to common respiratory pathogens on growth.

MATERIALS AND METHODS

Study Population

The study population was a sample of 410 female dairy calves that originated from 18 commercial farms. This study population was a convenience sample because the farms had to be willing to cooperate and had to be situated in the vicinity of the New York State College of Veterinary Medicine, Cornell University, which was in the practice area of the study veterinarian, G. D. Mechor, hereafter referred to as the clinician.

From these farms, the first 35 new calves of each month that were alive at the first visit of the clinician to the farm that month were selected in birth order, starting from the alternating ends of the farm visitation route each week (at the first visit, calves were on average 5.5 d old; 95% CI, 5.2 to 5.8 d; median, 5 d; range, 1 to 16 d). There was no other restriction about the maximum number of calves per farm. The calves were enrolled into the study between January 1, 1990 and December 31, 1990. Each calf was followed for 3 mo; the clinician examined each individual calf weekly.

The actual study design, data collection, and the descriptive epidemiology of morbidity and mortality of the calves have been explained elsewhere (A.-M. K. Virtala et al., 1995, unpublished).

Calf Background

The following information about calf management clarifies the background of these calves. Most of the calves (91%) received an initial feeding of colostrum within 6 h after birth. At least 2 wk before calving, most of the dams (81%) received a vaccine containing chemically altered strains of infectious bovine rhinotracheitis (IBR) and parainfluenza-3 (PI-3) viruses, modified live bovine respiratory syncytial virus, liquid adjuvant preparation of inactivated cytopathic and noncytopathic viruses causing bovine virus diarrhea (BVD), and *Leptospira canicola*, *Leptospira grippotyphosa*, *Leptospira hardjo*, *Leptospira icterohemorrhagiae*, and *Leptospira pomona* bacterin with aluminum hydroxide adjuvant. Furthermore, 23% of the dams had received *Escherichia coli* K99 bacterin with killed rota and corona viruses. One

third of the dams were of first parity, and half of the dams were of third or greater parity. After 2 d of colostrum feeding, on average, 71% of the calves began to receive fresh and discarded milk, and 21% received discarded milk and milk replacer. Eight percent received fresh milk only. Most calves (85%) were fed twice daily. Eighty-seven percent of the calves received coccidiostat in calf starters. Median weaning age was 12 wk (range, 7 to 13 wk). Forty-six percent of the calves were housed in hutches at least half of the time either before contracting respiratory disease or before the end of the study, 13% were confined in a barn with calves or cows, 20% were housed in a barn in individual pens, and 22% were housed in a barn in group pens. Twenty-six percent of the calves had FPT.

Measurements and Laboratory Examinations

Measurements of heart girth and height at withers were taken from each calf at the first visit and monthly thereafter by the clinician. The BW was estimated from heart girth measurements using a commercial tape (cattle tape; Nasco, Fort Atkinson, WI). Total IgG was determined from the serum sample of the first visit based on the single radial immunodiffusion method (4). The IgG values were transformed to d-2 values, assuming an 11.5-d half-life for plasma IgG (18). Possible classification errors in diagnosing pneumonia and umbilical conditions were minimized by weekly clinical examinations by the clinician.

When the clinician diagnosed respiratory disease in a calf, a herd- and age-matched control (± 2 wk) was chosen. From only these calves and their controls (105 and 59, respectively), serum samples were taken at the time of acute disease (acute phase) and 3 wk later (convalescent phase). There were fewer control calves because of the lack of healthy calves on some farms. Serum samples during these phases as well as the serum samples (postcolostral) that had been taken from these calves at the first visit were analyzed for ELISA antibodies against *P. haemolytica* leukotoxin, *Pasteurella multocida*, and *Haemophilus somnus*; for virus neutralizing antibodies against BVD, IBR, and PI-3 viruses; and for indirect hemagglutinating antibodies against *Mycoplasma bovis* and *M. dispar* (A.-M. K. Virtala et al., 1996, unpublished). The differences in these titers between cases and controls have been explained elsewhere (A.-M. K. Virtala et al., 1996, unpublished).

Definitions

Pneumonia, as diagnosed by the clinician, was defined as detection of abnormal clinical signs related to

the respiratory tract, such as inducible cough on tracheal massage, abnormal auscultation sounds on auscultation of the respiratory tract, evidence of elevated body temperature ($>39.5^{\circ}\text{C}$), depression, and a lack of involvement of other body systems that might explain the fever. A calf was not required to have all of these abnormalities for the diagnosis of respiratory disease. Pneumonia, as diagnosed by the caretaker, was defined as treatment by the calf caretaker for respiratory disease as marked in the treatment follow-up sheets unless treatment was done at the advice of the clinician. The caretaker diagnosis was considered to be false if, during the next visit, the clinician did not diagnose respiratory disease and if there were ≤ 14 d between the clinician visits. Pooled diagnosis of pneumonia also included those cases of pneumonia that had been diagnosed by the caretaker and for which the clinician requested treatment. Treated, verified pneumonia was pneumonia treated by the caretaker and verified by the clinician during the following visit.

Umbilical infection was defined as a palpably enlarged umbilicus, a painful umbilicus, or both. Umbilical hernia was defined as a palpable opening >1 cm in the umbilical area. Diarrhea was defined as any condition that the caretaker treated as diarrhea or that the clinician diagnosed as diarrhea (loose or watery feces or evidence of at least 5% dehydration and abnormal attitude). Total IgG in serum ≤ 800 mg/dl was chosen to indicate FPT (22). Crude morbidity was defined as pneumonia (treated and verified), diarrhea, umbilical infection, or any other disease that was treated with antibiotics. Duration of disease was defined as the time in weeks from 1 d before the visit, when the clinician first diagnosed the disease, until 1 d after the last visit, when the disease was still diagnosed in the calf.

Statistical Analysis

The association of BW gain with several independent variables was assessed using maximum likelihood multiple linear regression; ADG, total BW, or height was the outcome (7 separate regressions). Only the first occurrences of the diseases and only occurrences during that particular month and during preceding months were considered in the modeling. Farm was forced into the models and was declared to be a random effect. Although farms were not a random sample, they were considered as such because we were not interested in these particular farms. The BW or height at the first visit was used as a covariable in the models.

Independent variables used initially in the disease models were from the following groups: calf and colostrum management at birth and shortly after birth, calf care and feeding (such as frequency and volume of milk or milk replacer feeding) after the colostrum feeding period up to 3 mo of age, dam factors (such as presence at first feeding, age, and vaccinations received), first calf housing after the birth and the housing most used during the follow-up period, contacts with different age groups of animals immediately after birth and most common exposure to a specific age group during the follow-up period, and number of housing changes during the follow-up period. Duration of treated pneumonia was considered only in the models of total gain and of ADG of the 3rd mo. If the calf was not diagnosed as having pneumonia during the 3-mo observation period, duration of pneumonia was considered to be 0. The year was divided into four seasons: winter (from December to February), spring (from March to May), summer (from June to August), and fall (from September to November). In the models, winter was further divided into two categories because January through February 1990 and December 1990 were parts of separate season-years.

The association of antibodies with growth was studied regressing last BW either on the logarithmic transformations of the reciprocals of the postcolostral antibody titers to BVD, IBR, PI-3, and *M. dispar*, and of the ELISA readings for *P. haemolytica* leukotoxin, *P. multocida*, and *H. somnus* (*M. bovis* could not be used because of insufficient observations), or on the logarithmic transformations of the ratio of acute phase to postcolostral phase values and the ratio of convalescent phase to acute phase values (21). In these models, the only independent variables used, other than antibody titers, were the diseases.

Outliers were searched for before modeling with checks and by plotting time-dependent variables against time. Outliers were checked against original values on the calf sheets and corrected if necessary. The variable selection was performed in three main steps: univariable analysis, in which the independent variable was excluded if Wald's *P* test was >0.15 ; multivariable analysis, in which the independent variables were excluded if Wald's *P* test was >0.05 ; and study of the appropriateness of the model. The appropriateness was assessed with Akaike's information criterion, Schwartz's Bayesian criterion, and log likelihood calculated with REML (17). Inclusion or elimination of the variables was also based on the following criteria: scatter plots of outcome versus each independent variable that showed any indication of

relationship, multicollinearity diagnostics [the threshold for condition number of any principal components did not exceed 30 (5, 9)], and inclusion or exclusion of a possible confounding variable that did not change the coefficients of the disease estimates in the models for ADG by >20 g, in the model for total BW gain by >0.1 kg, and in the model for height gain by >2 cm. Moreover, an *F* test in the form of extra sums of squares was used to test the marginal reduction in the error sum of squares when one variable was added to the regression model (12). Plausible interaction terms were tested with Wald's *P* test after selection of the main effects. The assumptions of the models were assessed with residual plots and normal probability plots (12). The preliminary checking of the data, including preliminary least squares linear regressions, was done with SPIDA (5). All of the models were fitted with the Mixed procedure of SAS (17). Disease effects were considered significant at $P \leq 0.05$.

RESULTS

Descriptive Statistical Results

The ADG during the 1st mo of life was 374 g (95% CI, 357 to 391 g), during the 2nd mo, 596 g (95% CI, 575 to 617 g), and during the 3rd mo, 719 g (95% CI, 692 to 747 g). Mean BW at the first visit was 42 kg (95% CI, 41.6 to 42.4 kg) and at the last visit at about 3 mo of age was 93 kg (95% CI, 91.6 to 94.4 kg). The ADG during the whole 3-mo period was 565 g (95% CI, 552 to 578 g). The mean monthly ADG and mean total BW gain of the calves according to the presence or absence of diseases or FPT are presented in Table 1. Although the absolute ADG was not our focus and although this kind of simple comparison may often be misleading, this table is provided to give a general idea of possible disease effects and also as a description of the ADG that were experienced by these calves.

The calves gained a mean 5 cm in height monthly (95% CI, 4.9 to 5.1 cm). Height gain was 4.4 cm (95% CI, 4.1 to 4.6 cm) during the 1st mo, 5.6 cm (95% CI, 5.4 to 5.9 cm) during the 2nd mo, and 5.7 cm (95% CI, 5.4 to 5.9 cm) during the 3rd mo. Calf height at first visit was a mean 75 cm (95% CI, 74.7 to 75.3 cm), and height at the last visit was 90.9 cm (95% CI, 90.6 to 91.4 cm).

ADG During 1st, 2nd, and 3rd mo of Life

During the 1st mo of life, incidence of verified pneumonia that required treatment reduced BW gain by 66 g and FPT reduced BW gain by 48 g (Table 2). As age of the dam increased (from 2 to 11 yr), the

BW of calves also increased. The BW at first visit was not a significant predictor or confounder. Season was not a confounder in this model but seemed to be a significant predictor and was left in the model. If pneumonia as diagnosed by the caretaker was used in the model instead of treated, verified pneumonia, pneumonia was not a significant predictor ($P = 0.06$) for ADG (data not shown). If parity was used instead of age of the dam, calves of dams of third or greater parity grew most, and calves of first parity heifers grew least (data not shown).

During the 2nd mo of life, neither disease nor FPT was associated with ADG (Table 2). Crude morbidity had the smallest probability value of all disease variables in Wald's test ($P = 0.12$; data not shown).

During the 3rd mo of life, each week of pneumonia seemed to reduce ADG by 14 g, and occurrence of umbilical infection reduced ADG by 96 g (Table 3). Each additional year of dam age (from 2 to 11 yr) decreased ADG by 20 g. Some collinearity was introduced to the model when BW at first visit was

included in the model. When BW at first visit was not included in the model, the detrimental effect of umbilical infection on BW gain was only 79 g.

Total BW Gain During the First 3 mo of Life

When the outcome was BW at the end of the 3-mo follow-up period (Table 4), the only significant disease predictor left in the model was duration of pneumonia. Each week of pneumonia reduced the total BW gain by 0.8 kg. Season was a confounder and had to be kept in the model. The probability value for umbilical infection and FPT was 0.07, indicating that these variables reduced total BW gain significantly ($\alpha = 0.10$), umbilical infection reduced BW gain by 2.5 kg, and FPT reduced BW gain by 2.1 kg.

When treated, verified pneumonia was added to a model that already contained duration of pneumonia, treated, verified pneumonia was not a significant predictor by either Wald's test or the F test. When duration of pneumonia was added to a model that

TABLE 1. Mean average daily gain (ADG) and mean total BW gain according to the presence or absence of disease or failure of passive antibody transfer (FPT) in female dairy calves born between January 1990 and December 1990 in 18 New York dairy herds.

Disease present	ADG												Total BW gain, first 3 mo			
	1st mo of life				2nd mo of life				3rd mo of life				Yes		No	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No		
	(g)												(kg)			
	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
Diarrhea	349 (102) ¹	182 (281)	383 (281)	166 (281)	566 (97)	200 (267)	607 (267)	207 (267)	738 (100)	228 (270)	709 (270)	280 (270)	50 (101)	11 (280)	51 (280)	12 (280)
Umbilical hernia	365 (51)	192 (332)	375 (332)	168 (332)	582 (57)	204 (307)	598 (307)	207 (307)	703 (57)	315 (313)	720 (313)	258 (313)	50 (58)	15 (323)	51 (323)	11 (323)
Umbilical infection	410 (54)	158 (329)	368 (329)	172 (329)	586 (52)	169 (312)	597 (312)	212 (312)	673 (56)	256 (314)	725 (314)	268 (314)	50 (57)	11 (324)	51 (324)	12 (324)
Pneumonia																
Treated, verified	296 (36)	133 (347)	382 (347)	173 (347)	542 (57)	203 (307)	606 (307)	205 (307)	706 (64)	252 (306)	719 (306)	270 (306)	48 (66)	13 (315)	51 (315)	12 (315)
Diagnosed by caretaker	312 (20)	127 (363)	378 (363)	173 (363)	579 (34)	216 (330)	598 (330)	205 (330)	735 (38)	257 (332)	715 (332)	268 (332)	50 (41)	12 (340)	51 (340)	12 (340)
Diagnosed by clinician, untreated	NR ²		NR		NR		NR		693 (37)	194 (333)	720 (333)	274 (333)	50 (39)	10 (342)	51 (342)	12 (342)
FPT ³	338 (100)	167 (282)	388 (282)	170 (282)	573 (92)	225 (271)	603 (271)	199 (271)	675 (95)	270 (274)	731 (274)	265 (274)	47 (101)	11 (279)	52 (279)	12 (279)
Crude morbidity ⁴	358 (170)	175 (213)	387 (213)	167 (213)	571 (176)	190 (188)	619 (188)	218 (188)	709 (185)	241 (185)	726 (185)	291 (185)	49 (189)	11 (192)	52 (192)	12 (192)

¹Numbers of observations are in parentheses. Diseases during previous months were counted; the number of observations during the next month may be smaller than that during the previous month because of missing BW records for some calves.

²Not reported.

³Serum IgG ≤ 800 mg/dl in d-2 sample.

⁴First occurrence of diarrhea, pneumonia, umbilical infection, or any other disease that was treated with antibiotics.

already contained treated, verified pneumonia, only duration of pneumonia stayed in the model, which showed that the variable for duration of pneumonia contained more information than did that for treated, verified pneumonia.

To compare the effects of pneumonia as diagnosed by the caretaker with that as diagnosed by the clinician, models were used with treated, verified pneumonia or pneumonia diagnosed by the caretaker instead of duration of pneumonia. If treated, verified pneumonia was in the model, pneumonia reduced the total BW gain of calves by 3.8 kg ($P = 0.01$). If pneumonia as diagnosed by the caretaker was in the model, the effect of pneumonia on the total BW gain was not significant ($P = 0.47$). Conversely, the BW gain was reduced by 3.6 kg for calves with pooled diagnosis of pneumonia as diagnosed by the caretaker ($P = 0.01$; in this it was assumed that the caretaker would have detected the pneumonia anyway). Finally, if the cases of pneumonia diagnosed by a clinician but never treated were used in the model, the effect of pneumonia was not significant ($P = 0.34$). No matter which pneumonia variable was used, FPT

reduced the total BW gain by 2.5 to 2.8 kg ($P = 0.02$ to 0.04). These data are not shown.

Total Height Gain During the First 3 mo of Life

When the outcome was height at the end of the 3-mo observation period (Table 5), duration of pneumonia reduced the total height gain by 0.2 cm, and FPT reduced height gain by 0.9 cm. Season was not a serious confounder and could have been left out of the model. Umbilical infection was nearly significant and reduced height gain by 0.7 cm ($P = 0.07$).

Antibodies and BW Gain

None of the postcolostral antibody titers to BVD, IBR, PI-3, *P. haemolytica* leukotoxin, *P. multocida*, *H. somnus*, and *M. dispar* were significant predictors. Also, none of the logarithmic transformations of the ratios between acute phase and postcolostral titers or between convalescent phase and acute phase titers were significant in the models for BW gain. These

TABLE 2. Multiple linear regression models¹ using maximum likelihood to predict the effect of disease on 1st mo (model 1) and 2nd mo (model 2) average daily gain of female dairy calves born between January 1990 and December 1990 in 18 New York dairy herds.

Model and independent variable	Estimate	95% CI	ddf ²	P
	(g)			
Model 1				
Intercept	332	240 to 423	357	<0.01
Season				
Jan-Feb	-130	-198 to -62	357	<0.01
Mar-May	-102	-166 to -39	357	<0.01
Jun-Aug	-163	-228 to -98	357	<0.01
Sep-Nov	-21	-86 to 44	357	0.52
Dec	0	NR ³	NR	NR
Treated pneumonia ⁴	-66	10 to 121	357	0.02
FPT ⁵	-48	12 to 84	357	0.01
Age of dam, yr ⁶	8	0.3 to 15	357	0.04
Model 2				
Intercept	466	240 to 692	341	<0.01
First visit BW, kg	7	2 to 11	341	0.01
Season				
Jan-Feb	-215	-302 to -129	341	<0.01
Mar-May	-222	-305 to -140	341	<0.01
Jun-Aug	-153	-236 to -69	341	<0.01
Sep-Nov	-44	-127 to 39	341	0.29
Dec	0	NR	NR	NR

¹Eighteen farms were included as random effects in the models; estimates for farms are not shown.

²Denominator degrees of freedom (17).

³Not reported.

⁴First occurrence of disease within this observation period.

⁵Failure of passive antibody transfer (serum IgG ≤ 800 mg/dl in d-2 sample).

⁶Model is appropriate from 2 to 11 yr.

TABLE 3. Multiple linear regression model¹ using maximum likelihood to predict the effect of disease on 3rd mo average daily gain in female dairy calves born between January 1990 and December 1990 in 18 New York dairy herds.

Independent variable	Estimate	95% CI	ddf ²	P
	(g)			
Intercept	32	-278 to 342	344	0.84
First visit BW, kg	15	9 to 21	344	<0.01
Season	NR ³	NR	344	0.01
Duration of pneumonia, wk	-14	-23 to -5	344	<0.01
Umbilical infection ⁴	-96	-164 to -28	344	0.01
Age of dam, yr ⁵	-20	-32 to -8	344	<0.01

¹Eighteen farms were included as random effects in the models; estimates for farms are not shown.

²Denominator degrees of freedom (17).

³Not reported.

⁴First occurrence of disease within this observation period.

⁵Model is appropriate from 2 to 11 yr.

antibody models are not shown but are available from the senior author.

DISCUSSION

The BW at 3 mo of age for these calves ($\bar{X} \pm SD$, 93 \pm 14 kg) were about the same as that of Holstein calves in the northeast US (99 \pm 16 kg) (7). The BW at 1 mo of age seemed to be lower (53 kg) for these calves than the standard (62 kg). The ADG during the 1st mo was lower (374 g) than that reported in a Dutch study (450 g) in which most of the calves were Dutch-Friesian \times Holstein crossbreds and in which 11.4% of the calves were male (13). (In our study only females were used.)

There was severe multicollinearity among farms and many of those independent variables that described calf management. Thus, most of these variables were eliminated from the primary models. Also, some of the variables were eliminated because of insufficient observations. Season was used as a control for confounding in the models. However, the seasonal effects were reported for comparison with other studies. These estimates might not be valid because the study period was 1 yr and contained only single observations of seasons.

The R² values of the model (as obtained from least squares linear regression models that considered farms as fixed effects; these models are not shown but are discussed here for easier interpretation of R²) were low (<0.50), indicating that the proportion of variation in the BW gain that was due to the included independent variables was small. This effect was understandable because detailed nutrition data were not collected; only the amount and frequency of colostrum and milk feeding were recorded, and all feeding data

were collinear with the farm variable. The farm variable in the models did control for feeding programs, and the true effect of within-farm differences in nutrition was not studied.

Our aim was to look for the effects of diseases on BW gain, not to predict BW gain per se. The possible interaction between diseases and, in particular, a higher level of milk feeding could not be studied with these data because of severe multicollinearity of any feeding programs with the farm variable. When the BW gain of 795 Holstein calves during the first 4 mo of life was investigated in Pennsylvania, DMI, housing, season, and farm were the most important predictors with a model R² of 0.64 (14). The main difference between these two studies was that in the Pennsylvania study, nutrition data were collected carefully, and in our study, disease data were collected carefully. In this respect, a combination of the data from the Pennsylvania study and from our study would provide more realistic data for predicting BW gain than data from either of these studies alone.

On average, calves in the Pennsylvania study (14) were visited for the first time later than in our study (1.7 wk vs. 5 d). The mean weaning age in the Pennsylvania study was 10.6 \pm 4.3 wk. In our study, the weaning age was not normally distributed because only 58% of the calves were weaned by the end of the study, but, for comparison, mean weaning age was 11.7 \pm 1.5 wk. In the Pennsylvania study, farms were considered as fixed effects in the data analyses, and, in our study, farms were considered as random effects, producing wider confidence intervals for the estimates in our study. Because the Pennsylvania study was conducted for 18 mo, replications of seasons were not sufficient to estimate properly the seasonal effect on BW gain, but calves that were born

TABLE 4. Multiple linear regression models¹ using maximum likelihood to predict the effect of disease on last BW during the first 3 mo of life of female dairy calves born between January 1990 and December 1990 in 18 New York dairy herds.

Independent variable	Estimate	95% CI	ddf ²	P
	(kg)			
Intercept	29.3	17.6 to 42.0	354	<0.01
First visit BW, kg	1.5	1.2 to 1.7	354	<0.01
Season				
Jan-Feb	-7.1	-11.4 to -2.7	354	<0.01
Mar-May	-6.3	-10.4 to -2.1	354	<0.01
Jun-Aug	-3.3	-7.5 to 0.9	354	0.12
Sep-Nov	4.3	0.2 to 8.5	354	0.04
Dec	0	NR ³	NR	NR
Duration of pneumonia, wk	-0.8	-1.1 to -0.4	354	<0.01
Umbilical infection ⁴	-2.5	-5.1 to 0.2	354	0.07
FPT ⁵	-2.1	-4.4 to 0.2	354	0.07

¹Eighteen farms were included as random effects in the models; estimates for farms are not shown.

²Denominator degrees of freedom (17).

³Not reported.

⁴First occurrence of disease within this observation period.

⁵Failure of passive antibody transfer (serum IgG \leq 800 mg/dl in d-2 sample).

in the winter had the highest ADG, and calves born in the summer season had the lowest overall ADG. Calves born during fall and early winter (December) in our study seemed to grow best, and calves born in late winter (January and February) grew least. This disagreement between the studies was most likely due to the lack of replications of seasons, because Pennsylvania and New York are geographically and climatically similar.

In the Pennsylvania study, the effect of housing was significant, and calves housed in hutches grew best. We could not detect a significant housing effect for our study, which might have been due to the small sample size (lack of power). Differences in housing category in these studies might have existed also.

Ploeger et al. (15) studied the growth performance of calves during winter housing and demonstrated that antibody titers for *Ostertagia* spp., as measured in fall, were significantly correlated negatively with growth performance. In the Pennsylvania study, the fecal samples were examined for coccidiosis and cryptosporidiosis, but not for ostertagiosis. In our study, fecal samples were not taken, but data regarding provision of coccidiostats were collected. Because most farms used coccidiostats, no differences were found in the data in this respect, but coccidiostats have no effect on nematodes, such as *Ostertagia* spp.

Of the diseases considered in this study, pneumonia had the largest estimate for its effect on growth reduction, and this effect was significant for all but the model for ADG during the 2nd mo. The absence of the effect of pneumonia for the ADG during the 2nd

mo might have been due to insufficient observations (lack of power). However, the incidence of pneumonia was not importantly lower during the 2nd mo of life than during the 1st or 3rd mo of life, and, also, occurrences of pneumonia during the 1st mo of life were considered in the model for ADG during the 2nd mo. Rather, there might be compensation for the effect of pneumonia during this period (or there might not be a reducing effect). Duration of pneumonia was included in the model for total BW gain and was even more significant than pneumonia itself, indicating that the chronic nature of the disease increased its effect in reducing BW. Interestingly, if the clinician had diagnosed disease but the caretaker had not, the effect of this kind of pneumonia on BW gain was not significant. Such calves were not treated for pneumonia. This result may indicate that respiratory disease that is subclinical to the caretaker, even though detectable to the clinician, may not be of practical importance. Conversely, our sample size might have been too small to detect that association (lack of power). We think that the lack of effect of pneumonia as diagnosed by the caretaker was due to false positive diagnoses. However, we were not able to uncover the true difference, if any, between the effects of pneumonia diagnosed by the clinician and the effects of pneumonia diagnosed by the caretaker with these data; the effects of pooled diagnosis of pneumonia diagnosed by the clinician and pneumonia diagnosed by the caretaker were the same. Diarrhea did not have a significant effect on estimates of growth, which might indicate the ability of the calf to compensate within 1 mo for any loss in growth from diarrhea,

TABLE 5. Multiple linear regression models¹ using maximum likelihood to predict the effect of disease on last height during the first 3 mo of life of female dairy calves born between January 1990 and December 1990 in 18 New York dairy herds.

Independent variable	Estimate	95% CI	ddf ²	P
	(cm)			
Intercept	48.5	41.5 to 55.5	353	<0.01
First visit height, cm	0.6	0.5 to 0.6	353	<0.01
Season				
Jan-Feb	-1.6	-2.9 to -0.4	353	0.01
Mar-May	-0.3	-1.5 to 0.9	353	0.61
Jun-Aug	-0.3	-1.5 to 0.8	353	0.56
Sep-Nov	-0.7	-1.9 to 0.5	353	0.23
Dec	0	NR ³	NR	NR
Duration of pneumonia, wk	-0.2	-0.3 to -0.1	353	<0.01
Umbilical infection ⁴	-0.7	-1.4 to 0.1	353	0.07
FPT ⁵	-0.9	-1.5 to -0.2	353	0.01

¹Eighteen farms were included as random effects in the model; estimates for farms are not shown.

²Denominator degrees of freedom (17).

³Not reported.

⁴First occurrence of disease within this observation period.

⁵Failure of passive antibody transfer (serum IgG \leq 800 mg/dl in d-2 sample).

or that diarrhea had no effect. The 18% decline in growth rate that Schmoltdt et al. (19) reported might not have been the same if all calves in that study had been followed for as long as the calves in this study.

The only other disease that significantly reduced growth was umbilical infection, which reduced ADG during the 3rd mo. Umbilical infection was nearly significant ($\alpha = 0.05$) in the models for total BW and height gain. The detrimental effect on BW gain has never been reported before, and we think that the chronic inflammatory response of this slowly resolving condition is associated with the effect on growth. Duration of umbilical infection significantly reduced growth also. These two variables could not be kept in the model simultaneously because of multicollinearity. The effect of umbilical hernia on growth was not significant.

The FPT seemed to reduce primarily the ADG during the 1st mo, as expected, because the calf relies mainly on passive transfer of Ig during the 1st mo of life. In the model for total BW gain during the 3 mo, FPT was quite close to being significant and reduced BW gain by 2.1 kg. This reduction was not practically important and demonstrated the diminishing impact of passively transferred Ig after the 1st mo of life, as the calf develops active immunity. The effect of FPT on total height gain during the 3 mo was significant, but the height was only reduced by 0.9 cm, which was far from practical importance. In this study, concentrations of serum IgG at the first visit were transformed to d-2 values, which should have minimized the possible classification error caused by collection of the initial serum samples at different ages (between 1 and 16 d).

We could not find an association between serological titers to common putative respiratory pathogens and BW gain. Martin et al. (11) reported for feedlot calves that seroconversion from arrival to 28 d post-arrival to *P. haemolytica* cytotoxin, bovine respiratory syncytial, and BVD viruses were predictive of respiratory disease. However, Martin et al. (11) also concluded that BW gain or relapse could not be predicted accurately from the serological data. Results from their study and from ours were not comparable, though, because, in their study, the beef calves were weaned and thus were older than calves in the present study.

An interesting detail was the significant effect of age of the dam in 1st and 3rd mo models for ADG. In the 1st mo model, the calves of the older dams gained more BW than did the calves of the younger dams, but older dams seemed to have a detrimental effect on the ADG of the 3rd mo. These effects might have been related to FPT or could have been due to genetic differences between heifers and older cows (we are arguing that the FPT overwhelmed the genetic improvement during the 1st mo of life). However, serum Ig as such did not have a significant effect when used instead of FPT. The interaction between BW at first visit and parity of the dam was not significant in either 1st mo or 3rd mo models. For the total BW gain, the effect of age of the dam was missing. In field studies, one has also to consider Type 1 error (finding a significant effect that actually does not exist, i.e., rejecting a null hypothesis when that hypothesis is true) (20).

Van Donkersgoed et al. (22) indicated that they were not able to determine whether reduced girth growth increased risk of pneumonia or resulted from pneumonia. We, also, stress that the effects found in our study were only associations, because multiple regressions cannot identify direct causes. Inferences about the calves in this study can be made to calves raised in similar conditions.

CONCLUSIONS

In this study, the longer duration of pneumonia reduced BW gain of calves the most. Umbilical infection also seemed to reduce the total BW gain during the first 3 mo of life, especially ADG during the 3rd mo. Those cases of pneumonia that were subclinical to the caretaker did not seem to be of practical importance. Effects of diseases on height gain were not of practical importance. The FPT and umbilical infection had similar effects on BW gain. Preventing chronic pneumonia and umbilical infection may improve ADG of calves.

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