RELATIONSHIPS BETWEEN ENERGY BALANCE, INSULIN-LIKE GROWTH FACTOR-I AND ESTROUS BEHAVIOR DURING EARLY LACTATION IN DAIRY COWS

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Story in Brief

Relationships between energy balance, concentrations of insulin-like growth factor-I in serum and estrous behavior were investigated in dairy cattle. From 0 to 12 weeks of lactation, 11 Holstein cows were individually fed a total mixed diet, and to estimate energy balance, individual feed intake and milk production were recorded daily while milk composition and body weight were measured weekly. Cows with positive energy balance during the first 12 weeks postpartum had greater concentrations of insulin-like growth factor-I in serum and greater luteal-phase progesterone secretion than in cows with negative energy balance. Interval to first ovulation or first estrus did not differ between cows with positive versus negative energy balance. However, 60% of the first postpartum ovulations in cows with positive energy balance exhibited estrus compared to only 16.7% for those in negative energy balance. We conclude that reduced estrous and luteal activity that accompanies negative energy balance may be associated with reduced serum concentrations of insulin-like growth factor-I.

(Key Words: Insulin-like Growth Factor-I, Energy Balance, Estrous Behavior.)

Introduction

Increased milk production is associated with decreased reproductive performance in lactating dairy cows (Butler and Smith, 1989). Recent studies have concentrated on evaluating the association between energy balance and reproduction (Butler and Smith, 1989). Energy balance (EB) is quantified using measures of milk production (quantity and composition), dietary intake (quantity and composition) and body weight. Since many high producing cows are unable to consume enough feed to meet energy demands during early

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lactation, they must rely on their ability to mobilize body energy reserves to meet energy requirements.

Although studies have implicated EB as a regulator of ovarian function, the hormone(s) or metabolite(s) mediating the effects of EB on ovarian function is unknown. Since in vitro studies have suggested insulin-like growth factor-I (IGF-I) is a stimulator of ovarian cell steroidogenesis (Hammond et al., 1988), it holds potential as a hormonal mediator of ovarian function. In addition, IGF-I in blood of cattle, predominantly of liver origin, is modified by variations in protein and(or) energy intake (Houseknecht et al., 1988). The objective of this study was to determine the relationships among EB, ovarian function, and IGF-I in lactating dairy cows.

Materials and Methods

From parturition to 85 days postpartum, 11 pluriparous Holstein cows were milked twice daily (3:00 a.m. and 3:00 p.m.) and individually fed a total mixed diet of sorghum silage, alfalfa hay, whole cottonseed and concentrate (30, 15, 8.5 and 53.5% on DM basis). Net energy for lactation fluctuated between .76 and .71 Mcal/lb DM throughout the trial and was adequate to support an average of approximately 79.4 lb milk per day. Milk samples were collected weekly during consecutive afternoon and morning milkings for analysis of fat and solids-not-fat composition. Body weights (BW) and body condition scores (1 to 9; 9 = fat) for each cow (Aalseth et al., 1983) were recorded weekly.

Daily energy balance was calculated each week as (NE_l intake - net energy required for maintenance - energy secreted in milk). Net energy intake was calculated as the average daily DM intake for the week, multiplied by the NE_l concentration of the diet. Net energy (Mcal) required for daily maintenance of the animals was calculated as $(44.218(\text{lb BW}^{.75}))/1{,}000$ (NRC, 1988). Energy balance was expressed as megacalories of NE per day for each week and could be positive (PEB) or negative (NEB). Cows were divided into two groups depending on their average EB during the 12-week experiment: PEB cows (n = 5) had a 12-week EB greater than .2 Mcal/day, whereas NEB cows (n = 6) had a 12-week EB less than .2 Mcal/day. Data were analyzed as a completely randomized split-plot design with EB group as a main plot and week postpartum as a subplot.

Cows were observed twice daily for estrous behavior. Estrus was defined as the day a cow stood to be mounted by another cow. Days to first and second ovulation were defined as the days to first and second rise in serum progesterone >1.5 ng/ml. For this, blood was collected twice weekly from 1 to 12 weeks postpartum. To be defined as an ovulation, each serum progesterone rise had to be maintained for two consecutive sampling days. Serum concentrations of IGF-I were also quantified.

Luteal function was evaluated using area under progesterone curve. Multiple regression was utilized to best fit a curve through progesterone concentrations from the initial to terminal low values of each estrous cycle, and progesterone area was calculated as the definite integral of the equation used to generate the curve. Proportions of ovulations associated with estrus were compared between groups using Chi-square analysis.

Results

The various components that were used to calculate EB and their average values for PEB and NEB cows are presented in Table 1. Average daily EB during the 12-week study was 3.43 ± .71 Mcal/day (range .74 to 6.42) and -1.69 ± .66 Mcal/day (range -2.60 to .16) for PEB (n = 5) and NEB (n = 6) cows (P<.001). In both groups of cows, EB became progressively more positive (P<.01) with week of lactation (Figure 1A). Cows in PEB group were in negative EB only during weeks 1 and 2 postpartum whereas NEB cows were in negative EB from week 1 through week 7.

Table 1. Mean components (± SE) of energy balance calculations for negative energy balance (NEB) and positive energy balance (PEB) cows.

	NEB	PEB
Body weight, lb	1578 ± 61	1460 ± 65
Net energy for maintenance, Mcal/day	11.08 ± .35	10.44 ± .37
DM intake, lb/day	50.9 ± 1.8	51.1 ± 2.0
Net energy intake, Mcal/day	36.85 ± 1.35	37.09 ± 1.45
Milk yield, lb/day	85.1 ± 6.6	72.9 ± 7.3
Milk fat, %	3.58 ± .18	3.68 ± .18
Milk SNF, %	8.94 ± .17	8.80 ± .19
Milk energy, Mcal/day[a]	27.46 ± 1.55	23.23 ± 1.66
Energy balance, Mcal/day[b]	-1.69 ± .66	3.43 ± .71

[a] Means are different (P<.10).

[b] Means are different (P<.001).

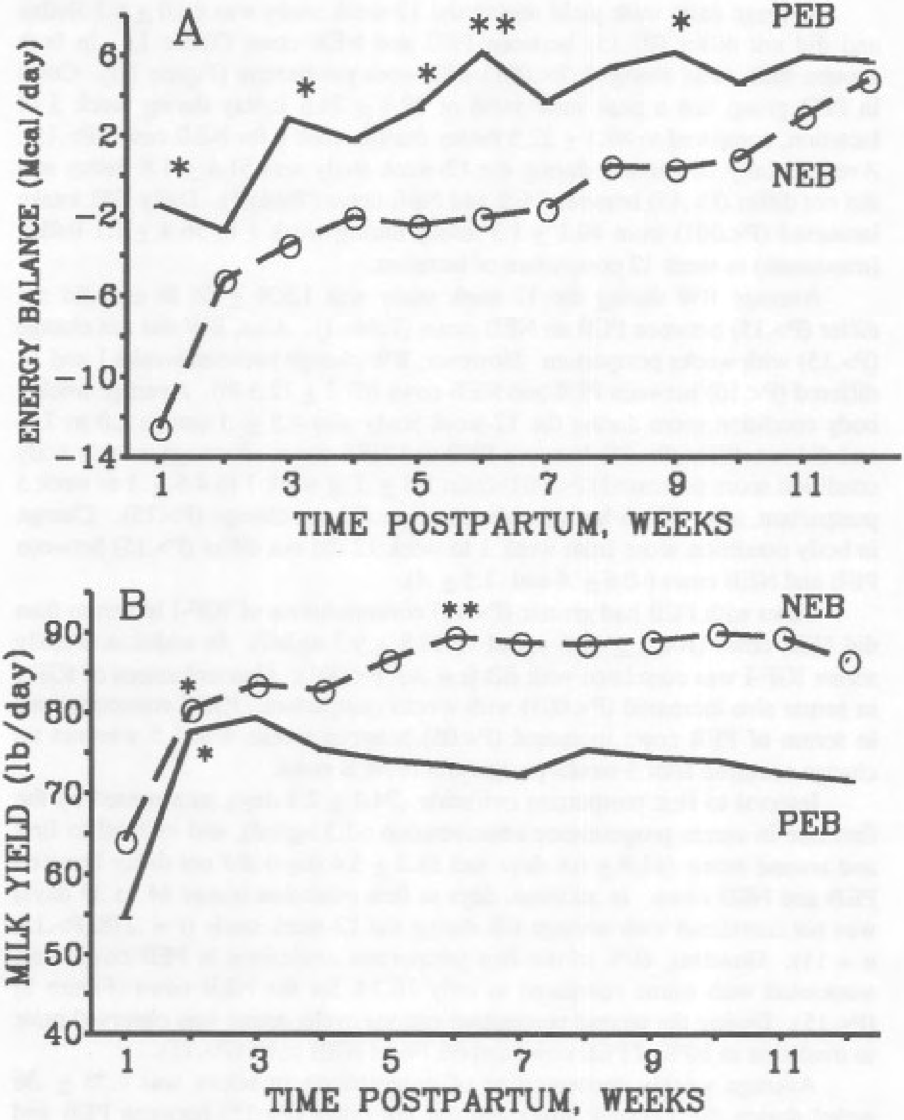

Figure 1. Changes in energy balance (Panel A) and milk yield (Panel B) during the first 12 weeks postpartum in positive energy balance (PEB) and negative energy balance (NEB) cows. Panel A: Asterisks indicate mean for that week differs (*P<.10, **P<.05) from NEB cows. Panel B: (*) indicates first mean within group that differs from week 1 (P<.05); (**) indicates first mean within group that differs from week 2 (P<.05).

Average daily milk yield during the 12-week study was 80.0 ± 6.8 lb/day and did not differ (P>.15) between PEB and NEB cows (Table 1). In both groups, milk yield changed (P<.001) with week postpartum (Figure 1B). Cows in PEB group had a peak milk yield of 79.4 ± 24.5 lb/day during week 3 of lactation, compared to 89.5 ± 22.5 lb/day during week 6 for NEB cows (P>.15). Average daily DM intake during the 12-week study was 51.4 ± 1.8 lb/day and did not differ (P>.15) between PEB and NEB cows (Table 1). Daily DM intake increased (P<.001) from 40.1 ± 1.3 lb/day during week 1 to 56.4 ± 1.1 lb/day (maximum) in week 12 postpartum of lactation.

Average BW during the 12-week study was 1,526 ± 64 lb and did not differ (P>.15) between PEB an NEB cows (Table 1). Also, BW did not change (P>.15) with weeks postpartum. However, BW change between weeks 1 and 12 differed (P<.10) between PEB and NEB cows (67.2 ± 12.3 lb). Average weekly body condition score during the 12-week study was 4.8 ± .1 (range 2.0 to 7.0) and did not differ (P>.15) between PEB and NEB cows. Average weekly body condition score decreased (P<.001) from 5.8 ± .1 at week 1 to 4.6 ± .1 at week 5 postpartum, after which body condition score did not change (P>.15). Change in body condition score from week 1 to week 12 did not differ (P>.15) between PEB and NEB cows (-0.6 ± .4 and -1.5 ± .4).

Cows with PEB had greater (P<.15) concentrations of IGF-I in serum than did NEB cows (102.5 ± 10.6 ng/ml vs 78.8 ± 9.7 ng/ml). In addition, weekly serum IGF-I was correlated with EB (r = .43, P<.001). Concentrations of IGF-I in serum also increased (P<.001) with weeks postpartum. IGF-I concentrations in serum of PEB cows increased (P<.05) between weeks 4 and 5 whereas no change occurred after 3 weeks postpartum in NEB cows.

Interval to first postpartum ovulation (24.4 ± 2.3 days, as assessed by the first rise in serum progesterone concentration >1.5 ng/ml), and interval to first and second estrus (41.9 ± 6.6 days and 58.2 ± 5.4 days) did not differ between PEB and NEB cows. In addition, days to first ovulation (range 14 to 39 days) was not correlated with average EB during the 12-week study (r = .278, P>.15, n = 11). However, 60% of the first postpartum ovulations in PEB cows were associated with estrus compared to only 16.7% for the NEB cows (Figure 2) (P<.15). During the second postpartum estrous cycle, estrus was observed prior to ovulation in 80% of PEB cows and 66.7% of NEB cows (P>.15).

Average weekly concentration of progesterone in serum was 4.56 ± .36 ng/ml during the 12-week study and did not differ (P>.15) between PEB and NEB cows. Average progesterone in serum increased (P<.05) from .55 ng/ml on week 1 to 7.86 ng/ml on week 12. Progesterone area was 1.8-fold greater (P<.10) in PEB than NEB cows during the first and second estrous cycles (data not shown).

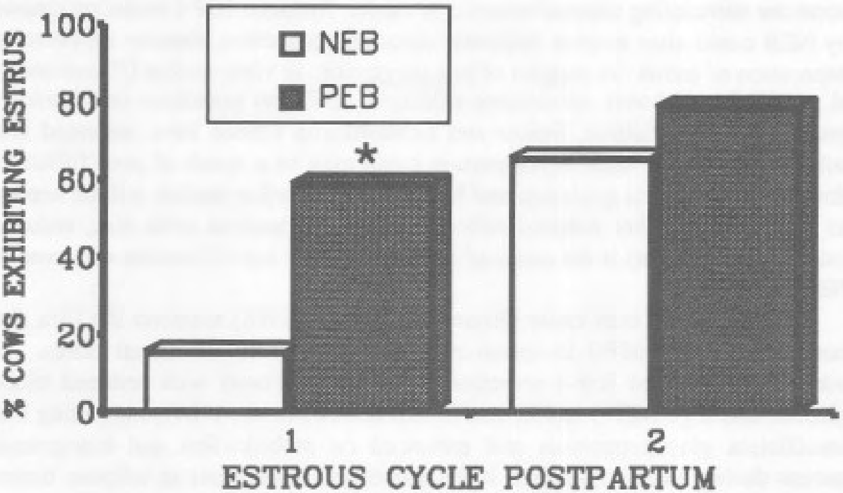

Figure 2. The percentage of negative energy balance (NEB) and positive energy balance (PEB) cows exhibiting estrus during their first and second estrous cycle postpartum. Asterisk (*) indicates mean differs from NEB (P<.15).

Discussion

Previous studies have linked negative EB with reduced ovarian activity during early lactation (Butler and Smith, 1989). Similarly, we observed that progesterone concentrations in serum during diestrus of the first and second estrous cycles, as measured by area under the curve, were significantly greater in PEB than NEB cows.

The hormonal and(or) metabolic signals that mediate adverse effects of NEB on luteal function have not been elucidated. In the present study, we found that EB was positively associated with concentrations of IGF-I in serum. Because IGF-I is a potent stimulator of progesterone production by bovine luteal cells (McArdle and Holtorf, 1989) and IGF-I secretion is decreased during NEB (present study), IGF-I holds potential as a hormonal mediator of the effects of EB on luteal function.

Cows in NEB exhibited a lower frequency of estrus expression before the first postpartum ovulation (but not the second postpartum ovulation) than did cows in PEB. Similarly, lactating dairy cows exhibiting estrus at their first postpartum ovulation had a less severe NEB than did cows not exhibiting estrus (Berghorn et al., 1988). Estradiol, produced by ovarian follicles, is the primary hormone stimulating estrous behavior in cattle. Reduced IGF-I secretion caused by NEB could alter ovarian follicular estradiol production, thereby suppressing expression of estrus. In support of this suggestion, in vitro studies (Hammond et al., 1988) have shown stimulatory effects of IGF-I on granulosa cell estradiol production. In addition, Spicer and Echternkamp (1986) have indicated that subnormal corpora lutea in postpartum cattle may be a result of poor follicular development prior to ovulation and luteinization. Further studies will be needed to determine whether reduced differentiation of granulosa cells (i.e., reduced estradiol production) is the cause of subsequent poor luteal function observed in NEB cows.

A study with beef cattle (Houseknecht et al., 1988) supports the idea that concentrations of IGF-I in serum may be an index of nutritional status. In addition to reduced IGF-I secretion, NEB is associated with reduced blood glucose and high NEFA and ketone bodies (Collier et al., 1984), suggesting that insufficient gluconeogenesis and enhanced fat mobilization and ketogenesis occurs during NEB. Although IGF-I stimulates lipogenesis in adipose tissue, the role of IGF-I, if any, in mobilizing energy stores awaits further elucidation.

In summary, results of the present study demonstrate that: 1) an increase in EB is associated with an increase in concentrations of IGF-I in serum during early lactation; 2) an increase in concentration of IGF-I is associated with increased progesterone secretion during diestrus of the first and second postpartum estrous cycles; and 3) fewer NEB than PEB cows exhibit estrus during their first estrous cycle. Thus, reduced ovarian activity that accompanies negative EB may be due, in part, to a decrease in concentration of IGF-I in serum. The potential exists to develop IGF-I-related techniques for enhancing estrus expression and, ultimately, improving reproductive efficiency in lactating dairy cattle.

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