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Effect of Exposure to Various Durations of Light on Serum Insulin-Like Growth Factor-I in Prepubertal Holstein Heifers

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Abstract: Our objective was to determine if prolonged exposure to various durations of light (i.e., photoperiod) would affect serum IGF-I concentrations in heifers. Thus, 16 Holstein heifers, 2 to 4 mo of age, were exposed during a 5-wk pretreatment period to 12 h of cool-white fluorescent light (L) at an intensity of 1200 lux and 12 h of dark (D). At 5 wk, photoperiods were adjusted to 24 L: 0 D (24 L), 20 L: 4 d (20 L), 16 L: 8 D (16 L) or 8 L: 16 D (8 L) per 24 h (n=4 heifers per photoperiod treatment). Blood was sampled at 5 wk and monthly for 4 mo. During each sampling period, blood was collected at 16-h intervals for 48 h and serum IGF-I was determined by RIA. Photoperiod treatment, month of experiment and their interactions affected serum IGF-I concentrations. Averaged over months, concentrations of serum IGF-I was greatest in heifers on 16 L; heifers on 20 L had IGF-I concentrations similar to 8 L, 16 L and 24 L and heifers on 24 L had concentrations similar to that of heifers on 8 L. Heifers in all treatment groups exhibited an increase in serum IGF-I concentration during the 4 mo of treatment. Heifers on 16 L and 20 L exhibited the greatest difference in serum IGF-I concentrations compared with 8L heifers after 3 mo of treatment. In conclusion, 16 L increases concentrations of serum IGF-I above that seen for heifers treated with 8 L or 24 L.

Key words: Photoperiod, heifers, growth factor, prepubertal

INTRODUCTION

Increased duration of light (i.e., photoperiod) increases body growth in dairy heifers[1,2] and milk production in lactating dairy cows[3,4]. Of the hormones that are affected by photoperiod in domestic animals, melatonin and prolactin reveal the most dynamic changes. Melatonin secretion is characterized by a diurnal rhythm with increased concentrations during darkness[5,6]. Prolactin secretion is very episodic within a given 24-h period and displays increased concentrations during months of ≥ 16 h of photoperiod[7,8]. Although it is known that bST and insulin secretion are not affected by photoperiod in cattle[1,9], whether IGF-I is altered by photoperiod in dairy heifers is unknown. Research with male reindeer indicates that IGF-I secretion is increased in deer exposed to 16 h light: 8 h dark above that observed for 8 h light: 16 h dark[10]. Furthermore, melatonin increases IGF-I secretion in male Syrian hamsters[11,12]. Because long-day (i.e., 16 h) photoperiods stimulate body growth and carcass protein accretion in dairy heifers versus short-day (i.e., 8 h) photoperiods[1,7] and exogenous IGF-I stimulates protein accretion in sheep[13], we hypothesized that increased IGF-I secretion may be involved in the photoperiodic growth response. Thus, the objective of the present study was to determine if prolonged exposure to various durations of light would affect serum IGF-I concentrations in dairy heifers.

MATERIALS AND METHODS

Animals and experimental protocol: Sixteen Holstein heifers, 2 to 4 mo of age, were exposed during a 5 wk pretreatment period to 12 h of cool-white fluorescent light (L) at an intensity of 1200 lux and 12 h of dark (D) as previously described as Experiment 2 in Buchanan *et al.*.[6]. At 5 wk, photoperiods were adjusted to 24 L: 0 D (24 L), 20 L: 4 D (20 L), 16 L: 8 D (16 L), or 8 L: 16 D (8 L) per 24 h (n = 4 heifers per photoperiod treatment). Blood was sampled at 5 wk and monthly for 4 mo. During each sampling period, blood was collected at 16-h intervals for 48 h, serum harvested and stored at -20°C until analyzed for concentrations of IGF-I after acid-ethanol extraction as previously described[14].

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Statistical analysis: Body weight data were analyzed via ANOVA using GLM procedure of SAS (Statistical Analysis System, Cary, NC). Hormonal data were analyzed using a split plot ANOVA for repeated measures over time utilizing the MIXED model of SAS (Statistical Analysis System, Cary, NC). The model of the covariate structure for repeated (i.e., hourly and monthly) measurements was an autoregressive with lag equal to one. If any interaction was significant ($P < 0.05$), simple effects were analyzed using slice option for the LSMEANS statement. Conversely, main effects were analyzed using LSMEANS with the DIFF option if the interaction was not significant ($P > 0.10$).

RESULTS AND DISCUSSION

Body weight and ADG: Initial body weight (117.0 $\pm$ 8.5 kg) did not differ ($P > 0.10$) among treatment groups. Also, body weight at 4 mo of treatment did not differ ($P > 0.10$) among treatment groups and averaged 193.5 $\pm$ 6.0 kg. Similarly, ADG did not differ ($P > 0.10$) among 8 L (0.38 $\pm$ 0.04 kg/d), 16 L (0.46 $\pm$ 0.04 kg/d), 20 L (0.48 $\pm$ 0.04 kg/d) and 24 L (0.45 $\pm$ 0.04 kg/d) treatment groups.

Serum IGF-I: Photoperiod treatment ($P < 0.07$), month of experiment ($P < 0.01$) and their interaction ($P < 0.01$) affected serum IGF-I concentrations. Heifers in all treatment groups exhibited an increase ($P < 0.05$) in serum IGF-I concentration during the 4 mo (i.e., 3 and 8 mo of age) of treatment and heifers on 16 L and 20 L exhibited greater ($P < 0.05$) serum IGF-I concentrations than 8 L and 24 L heifers after 3 mo of treatment (Fig. 1). Heifers on 8 L, 16 L, 20 L and 24 L exhibited a 1.4-, 1.4-, 2.1- and 1.8-fold increase, respectively, in serum IGF-I during the 4 mo of treatment (Fig. 1). Averaged over months, concentrations of serum IGF-I were greatest ($P < 0.05$) in heifers on 16 L (Fig. 2). Heifers on 20 L had IGF-I concentrations similar to 8 L, 16 L and 24 L and heifers on 24 L had concentrations similar to that of heifers on 8 L (Fig. 2). Thus, the IGF-I response to photoperiod exhibited a parabolic pattern (i.e., quadratic response curve).

Results of the present study indicate that serum IGF-I increases between 3 and 8 mo of age in all treatment groups and 16 L increases serum concentrations of IGF-I above that seen for heifers treated with 8 L and 24 L. This is the first report to show an effect of photoperiod on systemic IGF-I concentrations in prepubertal dairy heifers. Previously reported for this same study, serum concentrations of melatonin were significantly greater in 8 L versus 16 L,

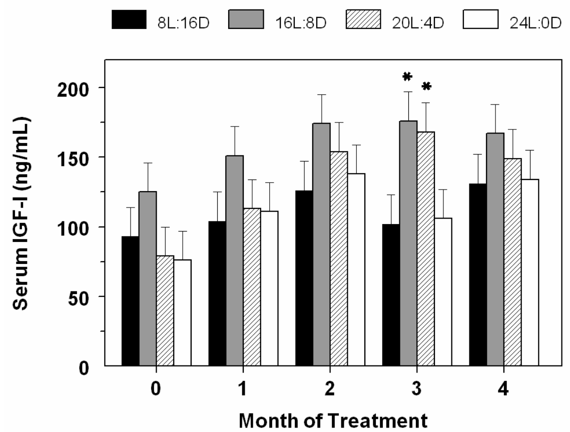

Fig. 1: Least-squares means of serum concentrations of IGF-I in heifers treated with either 8 L, 16 L, 20 L or 24 L at monthly intervals during the 4-month treatment period. Values are averages of four samples collected over a 48-h interval each month during the study. * Mean differs ($P < 0.05$) from 8L:16D and 24L:0D means

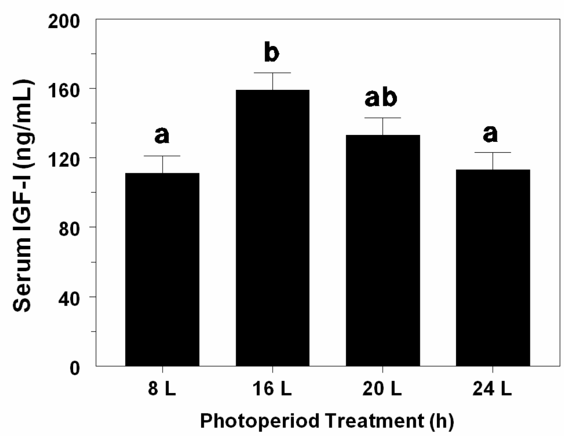

Fig. 2: Least-squares means of serum concentrations of IGF-I in heifers treated with either 8 L, 16 L, 20 L or 24 L averaged over the 4-month treatment period. Values are averages of 20 samples collected over the four month study. a,b Means without a common superscript differ ($P < 0.05$)

20 L and 24 L heifers and 24 L heifers had lower serum melatonin concentrations than 16 L and 20 L heifers and serum prolactin concentrations were significantly greater in 16 L, 20 L and 24 L heifers versus 8 L heifers[6]. Consistent with the present study, dairy cows exposed to 18 L: 6 D had greater plasma concentrations of IGF-I than cows exposed to ambient natural photoperiod ($\leq$ 13 L)[15]. Similarly, research with male reindeer indicates that IGF-I secretion is increased in deer exposed to 16 h light: 8 h dark above that observed for 8 h light: 16 h dark[10]. In addition, melatonin treatment increased systemic IGF-I concentrations in Syrian hamsters[11,12] and pinealectomized rats[16]. Thus,

in mammals melatonin may, in part, be involved in the photoperiodic changes in systemic IGF-I concentrations. Heifers treated with 24 L had similar concentrations of IGF-I as those treated with 8 L and thus, either melatonin has a parabolic effect on IGF-I secretion or heifers become refractory to constant light as reported in sheep[17]. Others have recently reported a negative correlation between systemic melatonin and IGF-I concentrations in dairy heifers and further supports the idea that melatonin may regulate IGF-I secretion[18]. IGF-I may also enhance mammary gland development and secretion[2,19,20] and increased IGF-I may be involved in photoperiod-induced increases in lactational performance[15].

Similar to the present study, increases in IGF-I during prepubertal development has been reported for cattle[21,22]. This prepubertal increase in systemic IGF-I likely plays a role in body growth[23,24] and mammary gland development[19,25]. In support of this latter statement, prepubertal exposure to long days (e.g., 16 L) increases subsequent lactational performance[2,26].

CONCLUSION

Serum IGF-I increases in a parabolic pattern in response to photoperiod such that 16 L but not 24 L increases serum IGF-I concentrations above those seen in 8 L heifers. Thus, of the photoperiods tested, 16 L has maximal effects on the IGF-I secretion in heifers.

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