Endocrine profiles of periparturient mares and their foals

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ABSTRACT: The aim of this study was to characterize concentrations of leptin, IGF-I, and thyroid stimulating hormone (TSH) in the blood serum of mares pre- and postpartum, in the milk serum of mares postpartum, and in the blood serum of their foals. Nine pregnant Quarter Horse mares and their offspring were used in this study. Once weekly between 1000 and 1200 h for 2 wk before their predicted parturition date, mares were weighed, assigned a BCS, and blood was sampled via jugular venipuncture. Within 2 h of parturition and before the foals nursed (d 0), blood samples were obtained from the mares and foals, and a milk sample was collected from the mares. Blood from the foals and blood and milk from the mares were collected again at 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 12, 19, 26, 33, and 61 d postpartum. Mares and foals also were weighed and assigned a BCS on d 0, 5, 12, 19, 26, 33, and 61. Additionally, on d 5, 33, and 61, ultrasound images of fat depth and area of the LM immediately cranial to and parallel with the last rib on the left side of the foals were measured to characterize changes in fat depth and LM area over time. There were no changes in mare blood concentrations TSH (P = 0.15), nor were there any changes in foal blood concentrations of leptin (P = 0.54) or TSH (P = 0.10) during the trial period. Mare blood concentrations of IGF-I tended to change over time (P = 0.07), whereas leptin changed over time (P < 0.001), initially decreasing and then remaining relatively stable after d 5. Foal blood concentrations of IGF-I increased initially, peaked at d 19, and stabilized thereafter (P < 0.001). Milk concentrations of leptin and TSH were greatest on d 0 and decreased over time (P < 0.007), reaching nadir concentrations at d 61. Milk concentrations of IGF-I also changed over time (P = 0.02), being greatest on d 0 and undetectable by d 12. There was no difference in BCS (P = 0.94) in mares over time, but there was a difference between pre- and postpartum BW (P < 0.001) due to foaling. However, no differences were detected in pre- (P = 0.70) or postpartum BW (P = 0.76) of mares over time. Mean ultrasonic fat depth and LM area increased (P < 0.04) as the foals aged, as did BCS and BW (P < 0.001). Recognizing changes in metabolic hormones surrounding the time of parturition in the mare and foal provides a basis for further determination of the role, if any, these hormones play in the milk, as well as in the neonate.

Key words: foal, insulin-like growth factor-1, leptin, mare, milk, thyroid stimulating hormone

INTRODUCTION

Successful transition of the animal from the fetal to the neonatal state involves tremendous physiological adaptations on the part of the neonate and the dam. The success or failure of this transition process equally dictates the survival of the offspring and subsequent recovery of the dam. Various hormones and growth factors present in colostrum and milk of many species may serve to program the endocrine system of the neonate in the acute postpartum period and therefore shape the response of the body to feeding and stress later in life (de Moura and Passos, 2005). Identification and elucidation of the roles of various milk compounds passed to the newborn may provide insight into the development of obesity-related maladies in horses.

Hormones previously identified in mares' milk include insulin, IGF-I (Hess-Dudan et al., 1994), leptin (Salimei et al., 2002; Romagnoli et al., 2006), progesterone (Laitinen et al., 1981), and triiodothyronine (Słebodziński et al., 1998). However, limited information is available on acute changes in metabolic hormones relative to parturition in mares and their foals.

Therefore, our objective was to characterize some of the endocrine changes occurring in periparturient mares and their offspring. We quantified concentrations of leptin, IGF-I, and thyroid stimulating hormone (TSH) in the blood serum of mares pre- and postpartum, in the milk serum of lactating mares postpartum, and in the...


Table 1. Composition of concentrate fed to mares and foals at 1% of BW daily

<table>
<thead>
<tr>
<th>Item</th>
<th>%, as-fed basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient</td>
<td></td>
</tr>
<tr>
<td>Cracked corn</td>
<td>37.40</td>
</tr>
<tr>
<td>Whole oats</td>
<td>40.90</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>9.00</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>5.00</td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td>0.50</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>0.70</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.70</td>
</tr>
<tr>
<td>Vitamin A/D/E premix</td>
<td>0.80</td>
</tr>
<tr>
<td>Molasses</td>
<td>5.00</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
<tr>
<td>Analyzed composition, %</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>12.24</td>
</tr>
<tr>
<td>Fat</td>
<td>3.93</td>
</tr>
<tr>
<td>CP</td>
<td>13.44</td>
</tr>
<tr>
<td>Ca</td>
<td>0.61</td>
</tr>
<tr>
<td>P</td>
<td>0.56</td>
</tr>
</tbody>
</table>

1 Vitamin premix provided per kilogram of grain concentrate: vitamin A, 5,000 IU; vitamin D₃, 408 IU; and vitamin E, 132 IU.

blood serum of their foals. Additionally, ultrasound images of fat depth and area of the LM immediately cranial to and parallel with the last rib on the left side of the foals were measured to estimate changes in fat depth and LM area over time.

**MATERIALS AND METHODS**

The research protocol was approved before the study by the University of Missouri Animal Care and Use Committee.

**Management of Animals**

Nine pregnant Quarter Horse mares, aged 4 to 21 yr, and their subsequent offspring were used in this study. All mares, with the exception of one, were multiparous. The mares foaled March through May of 2004. Sixty days before expected parturition, the mares were removed from their winter pasture of tall fescue grass and maintained in a 4-acre dry paddock at the University of Missouri Horse Research and Teaching Farm. Mares had ad libitum access to orchardgrass/alfalfa hay, fresh water, and a plain salt block. Additionally, mares were fed a concentrate (Table 1) at 1% of their BW daily, according to NRC requirements (1989).

Two weeks before the expected parturition date, the mares were monitored daily between 1600 and 1800 h for any changes in physical characteristics related to parturition (udder distention, teat secretions, and tone and appearance of the croup muscles). Mammary secretions (1 mL) were obtained from the mares at this time and mixed with 6 mL of deionized water to determine water hardness using Baker test strips (BVA Scientific, San Antonio, TX). Test strips for water hardness have been utilized as a predictor for impending parturition in the mare, as demonstrated by Ley et al. (1989). Once there was a color change in at least 4 of the 5 zones on the test strip, indicating increased water hardness, the mares were brought into 3.6 × 7.3-m stalls to be monitored for parturition throughout the night. If the mare did not foal, she was turned back out into the 4-acre paddock and checked daily until parturition. If the mare foaled, the pair was maintained in the same stall through d 5 postpartum, with ad libitum access to fresh water, a plain salt block, and orchardgrass/alfalfa hay. Mares were fed 1% of their BW in concentrate daily, according to NRC requirements (1989). On d 6 postpartum, the mares and foals were turned out onto a 20-acre orchardgrass pasture, with access to fresh water and a plain salt block, and were fed 1% of their BW in concentrate daily.

The mares were vaccinated against rhinopneumonitis type 1 with a killed vaccine (Fort Dodge, Fort Dodge, IA) at the 5th, 7th, and 9th months of gestation. Five weeks before expected parturition, mares were vaccinated against Eastern and Western equine encephalitis, tetanus, influenza (Bayer, Shawnee Mission, KS) and West Nile Virus (Fort Dodge, Fort Dodge, IA). The mares were dewormed every 2 mo with alternating anthelmintic products [January and July with pyrantel pamoate (Pfizer Animal Health, Exon, PA), March and September with ivermectin (Farnam, Phoenix, AZ), and May and November with moxidectin (Fort Dodge, Fort Dodge, IA)]. The foals were dewormed with pyrantel pamoate at 1 mo of age, with ivermectin at 2 mo of age, and then adapted to the same deworming program as the broodmares.

**Data Collection**

A blood sample (10 mL) was collected via jugular venipuncture from pregnant mares once weekly between 1000 and 1200 for 2 wk before their predicted parturition date. Mares were also weighed and assigned a BCS at these times. Body condition scoring was performed by the same individual throughout the trial period using a 1 to 9 scale, according to Henneke et al. (1983). Within 2 h of parturition and before the foal nursed (d 0), a blood sample (10 mL) was collected via jugular venipuncture from the foal, and a blood sample (10 mL) and milk sample (5 mL) were collected from the mare. Body weights were obtained for mares and foals within 24 h of parturition. Blood from foals and blood and milk from mares were collected again at 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 12, 19, 26, 33, and 61 d postpartum. Additionally, on d 5, 12, 19, 26, 33, and 61, mares and foals were weighed and assigned a BCS. Ultrasound measurements of fat depth and LM area of the foal immediately cranial and parallel to the last rib on the left side were taken on d 5, 33, and 61.

Blood samples were collected into serum separation, vacuum collection tubes (Benton Dickinson, Franklin Lakes, NJ), were allowed to clot for 20 min at room temperature, and were centrifuged for 25 min at 3,000 × g. Serum was harvested immediately and frozen at
−20°C for later analysis. Whole milk samples were collected into polyurethane tubes, immediately frozen at 0°C, and later centrifuged at 100,000 × g at 6°C for 1 h to obtain milk serum. The clear supernatant was collected and stored at −20°C for later analysis. Blood and milk samples were analyzed for leptin, IGF-I, and TSH by using the RIA procedures described in the following section.

Radioimmunoassays

Blood and milk serum concentrations of leptin were quantified using the double-antibody leptin radioimmunoassay procedures described by Delavaud et al. (2000), with one modification consisting of the substitution of the reported primary antiserum with rabbit, antiovine, leptin primary antiserum #7105.

Briefly, standard concentrations of recombinant ovine leptin (Gertler et al., 1998; 0.1, 0.2, 0.3, 0.5, 0.8, 1.2, 2.0, 3.5, 5.0, and 7.5 ng in 300 μL/tube) and increasing volumes of serum (25, 40, 60, 100, 175, 250, and 300 μL) from a pool of serum collected from a fat mare were added to the assay tubes in triplicate, and the total volume was balanced to 300 μL per tube with buffer consisting of 0.1% gelatin, 0.01 M EDTA, 0.9% NaCl, 0.01 M PO₄, 0.01% sodium azide, and 0.05% Tween-20, pH = 7.1 (PABET). Likewise, 200 μL of the serum samples to be quantified were added to the assay tubes in triplicate, and the volume was balanced to 300 μL per tube with PABET. Immediately thereafter, 100 μL of rabbit, antiovine, leptin primary antiserum (final tube dilution of 1:15,000 in PABET) was added and the samples and standards were incubated at 4°C for 24 h. After the initial incubation, 100 μL of 125I-ovine leptin (20,000 cpm) were added to each tube and incubation continued for an additional 24 h at 4°C. The antigen-antibody complex was then precipitated after a 15 min, 22°C incubation with 100 μL of a precipitated, sheep, antirabbit, secondary antiserum by centrifugation at 3,000 × g for 30 min, and the supernatant was removed by aspiration. Assay tubes containing the antigen-antibody pellet were counted for 1 min on an LKB1277 gamma counter (LKB Wallac, Turku, Finland).

Standards and pooled aliquots of serum from a single source of fat-mare serum were linear (log/logit transformation, R² > 0.98) and parallel over a mass of 0.1 to 7.5 ng/tube and a serum volume of 25 to 300 μL, respectively. Total specific binding was 42%, the minimum detectable concentration was 0.1 ng/tube, the percentage recovery of mass was >99% across the range of 25 to 300 μL of sample, and the inter- and intrasay CV were <10%.

Equine blood and milk serum concentrations of IGF-I were measured in triplicate after acidified extraction via a double antibody RIA validated for use in our lab (Lamberson et al., 1995). Assay sensitivity was 8.6 ng/mL and the specific binding 41.8%. The intra- and interassay CV were 6 and 9%, respectively.

Equine blood and milk serum concentrations of TSH were performed in triplicate with a double-antibody RIA using equine TSH antiserum (AFP-C33812) and equine TSH antigen (APFB-5144B) provided by A. F. Parlow (Harbor-UCLA Medical Center, Torrance, CA). This assay was previously validated in horses (Buff et al., 2006). The intra- and interassay CV were <10%, and the sensitivity was 0.02 ng/mL.

Ultrasound Imaging

Ultrasound images were captured using the AUSkey System Software (Animal Ultrasound Services: AUS, Ithaca, NY) using a 500-V Aloka (Corometrics Medical Systems Inc., Wallingford, CT) ultrasound machine with a 3.5-MHz transducer fitted to a custom standoff (a gel fitted to contour the shape of the foal immediately cranial to the last rib). Area of the LM and fat depth images were captured immediately cranial to and parallel with the last rib on the left side of each foal. Generous amounts of commercial vegetable oil were applied to the ultrasound site to reduce soundwave attenuation associated with the hair coat. The same ultrasound technician performed the measurements throughout the study, and the final ultrasound images were approved by an AUS-trained technician.

Statistical Analysis

The data consisted of repeated measurements of mares and foals over time to evaluate changes in leptin, IGF-I, and TSH concentrations in mare blood and milk, and in foal blood, in mare and foal BW and BCS, as well as in fat depth and LM area of foals over time. Data were analyzed using PROC GLM (SAS Inst. Inc., Cary, NC), and the linear statistical model contained the effects of animal and time. Differences between means were determined using Fisher’s least significant difference test. The results are expressed as means ± SEM.

RESULTS

Leptin

There was a significant day effect on mare blood and milk serum concentrations of leptin (P < 0.001), but not on foal blood serum concentrations of leptin (P = 0.54; Figure 1). Mean milk serum concentrations of leptin in mares were greatest at 14 d prepartum (10.34 ± 1.38 ng/mL), declined until d 2, and stabilized thereafter. Milk serum concentrations of leptin were 34.13 ± 1.45 ng/mL on d 0 (presuckle), dropped to 7.36 ± 1.37 ng/mL by d 5, and declined to nadir concentrations by d 61.

Insulin-Like Growth Factor-1

Mare blood serum concentrations of IGF-I tended (P = 0.07) to change as a result of day, whereas there was a significant day effect on milk serum concentrations of IGF-I (P = 0.02) and foal blood serum concentrations of IGF-I (P < 0.001; Figure 2). Milk serum concentrations of IGF-I were greatest at d 0 (76.31 ± 13.63 ng/mL) and
Endocrine profiles in mares and foals

Figure 1. Mean (±SEM) concentrations of leptin in mare blood serum, mare milk serum, and foal blood serum over time. There was a significant day effect for leptin in mare blood ($P < 0.001$) and milk ($P < 0.001$), but not in foal blood ($P = 0.54$). The inset within the panel provides details of d −14 to 5 on an expanded scale.

Figure 1. Mean (±SEM) concentrations of leptin in mare blood serum, mare milk serum, and foal blood serum over time. There was a significant day effect for leptin in mare blood ($P < 0.001$) and milk ($P < 0.001$), but not in foal blood ($P = 0.54$). The inset within the panel provides details of d −14 to 5 on an expanded scale.

undetectable by d 12. Foal blood serum concentrations of IGF-I increased initially, peaked at d 19 ($257.70 ± 10.96$ ng/mL), and stabilized thereafter ($P < 0.001$).

Thyroid Stimulating Hormone

There was no significant day effect on mare ($P = 0.15$) or foal ($P = 0.10$) blood serum concentrations of TSH, but there was a significant day effect on milk serum concentrations of TSH ($P < 0.001$; Figure 3). Milk serum concentrations TSH were greatest on d 0 ($18.01 ± 0.67$ ng/mL), decreased over time, and reached nadir concentrations on d 61.

Body Weight, BCS, and Ultrasound Measurements

As expected, pre- and postpartum BW of mares differed ($P < 0.001$) due to foaling (Table 2). Within the prepertum interval, no differences were detected in BW over time ($P = 0.70$), and similarly, within the postpartum interval, BW did not differ over time ($P = 0.76$). Body condition score did not change in mares over time ($P = 0.94$; Table 2). Among foals, mean ultrasonic fat depth and LM area (Table 2) increased ($P = 0.03$ and $P < 0.001$, respectively) as foals aged, as did BW and BCS ($P < 0.001$; Table 2).

DISCUSSION

It has been suggested that the presence of hormones and growth factors in colostrum and milk may contribute to neonatal GI tract development, feed intake regulation, thermoregulation, as well as metabolic programming in the newborn (McFadin et al., 2002; de Moura and Passos, 2005; Romagnoli et al., 2006). We found peak concentrations of leptin, IGF-I, and TSH in the colostrum (d 0) compared with milk samples taken 12 h postpartum and thereafter. This pattern is similar to that described in other studies of leptin and IGF-I in milk serum of mares where presuckle concentrations of hormone were the greatest and gradually declined to nadir concentrations within days (Hess-Dudan et al., 1994; Salimei et al., 2002; Romagnoli et al., 2006). Similar endocrine profiles have been reported to exist in ewes (McFadin et al., 2002) and cows (Taylor et al., 2004; Pinotti and Rosi, 2006). Coincidentally, the equine neonatal gut is able to readily absorb whole proteins within the first 24 h of life (Jeffcott, 1975), corresponding with peak hormone concentrations in the milk. The elevated concentration of leptin and IGF-I found in equine colostrum may be due to increased local production in the mammary gland; expression of leptin (Smith-Kirwin et al., 1998; Aoki et al., 1999; Bonet et al., 2002) and IGF-I (Forsyth et al., 1999; Berry et al., 2003) mRNA in mammary tissues has been reported in other species. It has also been speculated that the reason for peak hormone concentrations in colostrum is due to a pooling effect of the proteins in the milk before suckling by the neonate (McFadin et al., 2002).

The values of leptin in the presucked mare milk serum in our study differed from values found by Salimei...
Figure 2. Mean (±SEM) concentrations of IGF-I in mare blood serum, mare milk serum, and foal blood serum over time. Mare blood concentrations of IGF-1 tended ($P = 0.07$) to change over time, whereas there was a significant day effect for IGF-I in milk ($P = 0.02$) and foal blood ($P < 0.001$). The inset within the panel provides details of d –14 to 5 on an expanded scale.

et al. (2002) and Romagnoli et al. (2006). They reported presuckle milk serum leptin concentrations of 9.05 and 11.7 ng/mL, respectively, whereas we found presuckle concentrations of 34 ng/mL. This discrepancy may be due to a number of factors. First, Salimei et al. (2002) and Romagnoli et al. (2006) used a commercial multispecies leptin RIA kit, whereas we used double antibody RIA procedures to determine leptin concentrations. These variations in assay procedures may contribute to the differences among reported leptin concentrations in milk. Additionally, although BCS of equine have been positively correlated with peripheral leptin concentrations (Buff et al., 2002; Gentry et al., 2002), dissimilarities in BCS of horses sampled in Salimei et al. (2002), Romagnoli et al. (2006), and the current study may explain alterations in milk leptin concentrations among them. Finally, nutritional status at the time of sampling (irrespective of BCS) has also been shown to affect blood serum leptin concentrations in mares (McManus and Fitzgerald, 2000; Buff et al., 2005); therefore, it is possible that nutritional status at the time of sampling may affect the concentration of leptin in milk as well.

The blood leptin concentration profiles for the mares in our study were similar to those reported by others (Heidler et al., 2003; Romagnoli et al., 2006). Despite unchanging BCS or BW in mares, serum leptin concentrations were less in the postpartum period and remained there throughout the duration of the study (61 d). This postpartum reduction in blood serum leptin may be due to a loss of placental leptin because placental leptin mRNA expression has been reported in humans (Ben et al., 2001; Jakimiuk et al., 2003), rats (Kawai et al., 1997), and sheep (Thomas et al., 2001). However, a postpartum reduction in blood serum leptin concentrations has been reported in humans (Ben et al., 2001; Jakimiuk et al., 2003) and Japanese monkeys (Wang et al., 2005), but not in rats (Kawai et al., 1997) or sheep (Thomas et al., 2001).

It has been reported that peripheral concentrations of leptin are positively correlated with BCS in horses (Buff
Figure 3. Mean (±SEM) concentrations of thyroid stimulating hormone (TSH) in mare blood serum, mare milk serum, and foal blood serum over time. There was a significant day effect for TSH in milk (P = 0.02) but not in mare blood (P = 0.15) or in foal blood (P = 0.10). The inset within the panel provides details of d −14 to 5 on an expanded scale.

et al., 2002; Gentry et al., 2002). However, it has also been demonstrated in equine that feed restriction of up to 48 h decreases leptin secretion regardless of BCS (McManus and Fitzgerald, 2000; Buff et al., 2005), supporting the role of leptin as an indicator of acute energy status in horses. During the fed state, leptin has an inhibitory effect on orexigenic neuropeptide Y (NPY) and agouti-related peptide (AgRP) gene expression and a stimulatory effect on anorexigenic proopiomelanocortin (POMC) gene expression in the hypothalamus of rodents (Cone, 2005). During the fasted state, however, expression of AgRP and NPY mRNA are upregulated and expression of POMC mRNA is downregulated (Cone, 2005). Although we saw no difference in BW or BCS in mares postpartum, the decrease in blood serum leptin may serve as a means to protect mares against negative energy balance by encouraging feed intake in mares during early lactation. Erlanson-Albertson and Zetterström

Table 2. Mean BW and BCS of mares and foals over time, as well as estimates of mean ultrasonic fat depth and area of the LM of foals over time

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Days relative to parturition</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mare BW, kg</td>
<td>−14</td>
<td>642.9</td>
<td>12.0</td>
</tr>
<tr>
<td>Mare BCS³</td>
<td>−14</td>
<td>6.14</td>
<td>0.19</td>
</tr>
<tr>
<td>Foal BW, kg</td>
<td>−14</td>
<td>51.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Foal BCS³</td>
<td>−14</td>
<td>0.069</td>
<td>0.03</td>
</tr>
<tr>
<td>Estimated fat depth in foals,² cm</td>
<td>−14</td>
<td>2.210</td>
<td>6.156</td>
</tr>
<tr>
<td>Estimated area of LM in foals,² cm²</td>
<td>−14</td>
<td>5.000</td>
<td>6.156</td>
</tr>
</tbody>
</table>

³Body condition scoring was performed by the same individual throughout the trial period using a 1 to 9 scale, according to Henneke et al. (1983).
²Fat depth over the LM and area of the LM immediately cranial to and parallel with the last rib on the left side of foals.
Hormone secretion independent of TSH, as well as in-
ternal rat.

These latter data provide evidence that leptin may play
a role in feed intake and thermoregulation in the neona-
tal rat pups, reduced food intake as demonstrated by
leptin in the stomach and subcutaneous adipose tissue
colostrum and milk resulted in decreased production of
the amount of leptin ingested normally from maternal
milk and autonomous fetal sources of hormone
administration has a subsequent effect on neonatal hor-

Although we saw an increase in fat depth and BCS over
time, albeit small, there was no correlated increase in
leptin concentrations in foals. The fact that blood
leptin fails to rise in rapidly growing foals may indicate
that decreased leptin secretion is a signal to permit food
intake in order for foals to ingest adequate energy for
rapid early growth (similar to mares in early lactation).
Furthermore, the low adipose tissue reserves a foal has
when born could also account for decreased blood leptin
concentrations compared with mares. Buff et al. (2002)
examined serum leptin concentrations by age classifica-
tion and found horses less than 2yr old had lower serum
leptin concentrations than their older contemporaries.
Body condition scores of specific age groups were not
reported in the Buff et al. (2002) study; however, the
authors concede that the lower leptin concentration
found in the younger, growing animals may be a function
of lower body fat reserves than in more mature, typically
less active equine.

To our knowledge, this study is the first to report blood
leptin and TSH concentrations in foals during the acute
neonatal period. Interestingly, leptin and TSH in the
foal blood were at nadir concentrations before nursing
at time 0, and concentrations had increased at least
2- and 4-fold, respectively, after nursing. Although we
cannot delineate cause-and-effect relationships between
maternal milk and autonomous fetal sources of hormone
based on these data, in other species, exogenous hormone
administration has a subsequent effect on neonatal hor-
mones concentrations (Tenore et al., 1980; Lins et al.,
2005; Sánchez et al., 2005). Sánchez et al. (2005) demon-
strated that a significant quantity of leptin is readily
absorbed in the GI tract of rat pups through d 4 postpar-
tum. Additionally, supplementing rat pups with 5 times
the amount of leptin ingested normally from maternal
colostrum and milk resulted in decreased production of
leptin in the stomach and subcutaneous adipose tissue
of rat pups, reduced food intake as demonstrated by
decreased gastric content compared with controls, and
reduced thermogenic capacity in brown adipose tissue.
These latter data provide evidence that leptin may play
a role in feed intake and thermoregulation in the neo-
tal rat.

Leptin has been reported to directly stimulate thyroid
hormone secretion independent of TSH, as well as in-
crease the transfer of iodine through milk in early lacta-
tion in rodents (Lins et al., 2005). This action of leptin
on thyroid hormones may serve to augment thermogene-
sis in the neonate.

A study by Ślebodziński et al. (1998) reported that
concentrations of triiodothyronine (T3) in the milk of
mares peaked 4d postpartum (0.74 ng/mL), then de-
clined and stabilized at d 7 to 21 (0.46 ng/mL).
Thyroid hormones are known to play important roles in
growth regulation, cellular function, and metabolism
and are especially critical for postpartum neonatal ther-
ogenesis (Chen and Riley, 1981; Irvine, 1984; Silva,
2006). Hypothyroid foals may exhibit hypothermia, mus-
culoskeletal weakness, lethargy, and a poor sucking re-
flex (Irvine, 1984). Murray and Luba (1993) reported
blood serum concentrations of thyroxine (T4) and T3 in
foals to be greater within 1h of parturition in samples
obtained before foals nursed. Similarly, Irvine and Ev-
ans (1975) found postnatal blood serum concentrations
of total T4 and T3 in foals to be 14 and 12 times greater,
respectively, than in the blood of the mature horse. It was
not specified when blood samples were taken relative to
nursing.

No previous reports of TSH concentrations in milk of
mares could be found; however, TSH is present in the
colostrum of humans and rodents (Tenore et al., 1980,
1981). It has been reported that oral administration of
bovine TSH to suckling rats caused a subsequent rise
in blood serum T4 and T3 concentrations in rat pups,
providing evidence that TSH is absorbed as a whole,
biologically active protein in rats (Tenore et al., 1980).
Thus, although elevated T4 and T3 blood serum concen-
trations have been reported in neonatal foals before hav-
ing nursed, the presence of TSH in maternal milk may
further stimulate the neonatal thyroid axis which is cru-
ial for thermogenesis and normal development.

We saw a tendency for mare blood serum concentra-
tions of IGF-I to change over time, and the pattern of
IGF-I secretion was similar to other reports in mares
(Hess-Dudan et al., 1994; Heidler et al., 2003). Prepar-
tum IGF-I concentrations increased during the week be-
fore parturition, decreased gradually postpartum, and
stabilized thereafter. This is in contrast to the abrupt
decline in IGF-I seen postpartum in dairy cattle (Taylor
et al., 2004).

The presence of IGF-I in colostrum and milk has been
reported in a number of species, including horses (Hess-
Dudan et al., 1994; Cymbaluk and Laarveld, 1996), and
has been reported to play a role in neonatal gut develop-
ment in some species (Grosvenor et al., 1992; Xu, 1996).
Administration of porcine colostrum to piglets markedly
enhanced intestinal development (which was not appar-
ent compared with water administration), and oral ad-
ministration of IGF-I to piglets tended to increase intes-
tinal epithelial cell proliferation (Xu, 1996). Similar work
in rats resulted in enhanced GI tract growth, increased
brain and liver weights, and increased overall BW gain
in rat pups supplemented with a rat milk substitute.
plus IGF-I vs. rat pups supplemented with a rat milk substitute lacking IGF-I (Philippss et al., 1997).

The endocrine profile and values of IGF-I concentrations in foal blood exhibited during the 2 mo postpartum is in agreement with other work conducted in horses (Hess-Dudan et al., 1994; Cymbaluk and Laarveld, 1996). It is likely that the rapid increase of IGF-I concentrations seen during the first 2 wk in the life of foals is associated with rapid growth occurring during that time, as has been demonstrated in other species (Nosbush et al., 1996; Dunshea et al., 2002). Plasma concentrations of IGF-I have been reported to decrease gradually as foals age from 2 to 10 mo (Thomas et al., 1996), and upon stabilization, have been used as an indicator for the end of puberty in Thoroughbred horses (Fortier et al., 2005).

Cymbaluk and Laarveld (1996) reported lower serum IGF-I concentrations that persisted until 1 yr of age in foals fed milk replacer compared with wholly mare-nursed foals, demonstrating that preweaning nutrition affected the metabolic programming of IGF-I in foals. Foals fed milk replacer did receive maternal colostrum but were removed from their dams by 24 h postpartum and fed milk replacer until weaning at approximately 2 mo of age. Additionally, foals in the mare-nursed group gained more rapidly and had greater serum IGF-I concentrations than milk-replacer foals in the first 2 wk postpartum. The difference in gain seen between the 2 groups may be partially attributed to the stress of early weaning in milk-replacer foals because the weight difference was negligible by 1 yr of age.

Recognizing changes in hormones surrounding the time of parturition in the mare and foal provides a basis for further determination of the role hormones may play in the milk, as well as in the neonate. It is apparent in a number of species, including equine, that gestation and lactation can profoundly affect the metabolic profile. IGF-I concentrations that persisted until 1 yr of age of age. Additionally, foals in the mare-nursed group gained more rapidly and had greater serum IGF-I concentrations than milk-replacer foals in the first 2 wk postpartum. The difference in gain seen between the 2 groups may be partially attributed to the stress of early weaning in milk-replacer foals because the weight difference was negligible by 1 yr of age.

LITERATURE CITED


