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The relation of maternal fluid balance to offspring passive immunity

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HIGHLIGHTS

• Packed cell volume, osmolality, and plasma protein increase after parturition in the mare.
• The mare's water intake increases dramatically after parturition.
• The mare's water intake is positively correlated with the foal's post-suckling immunoglobulin levels.
• The mare's water intake increases still further during the first two weeks of lactation.

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ABSTRACT

The objectives were to measure changes in fluid balance of mares at parturition and relate those changes to the foals' acquisition of passive immunity.

Twelve Thoroughbred mares and their foals were observed for suckling behavior for the first 12 h post-partum. The mare's water intake, packed cell volume, plasma protein concentration, and plasma osmolality were measured pre- and post-partum. The foals' immunoglobulin concentrations were measured at birth and 24 h later. The median increase from pre- to post-foaling in mares' packed cell volume was 4.0% (interquartile range = 0.3–6.8). The median increases in plasma protein and plasma osmolality after foaling were 0.9 (0.5–1.4) g/dL and 2.5 (0.8–6.0) milliosm/kg, respectively. Median daily water intake was 13.8 (7.6–20.8) L before and 42.1 (26.2–61.4) L 24 h after foaling. The foals' IgG at 24 h was significantly correlated with their dam's water intake in the 12 h following parturition ($r = 0.66$, $P = 0.039$). The median duration of suckling during the first 4 h of the foals' lives was 20 (5–85) min and 85 (42–220) min during the first 12 h. The median number of suckling bouts was 34 (11–71) during the first 12 h after birth.

1. Introduction

The importance of colostrum consumption (and transfer of antibodies) to foal survival is well recognized [1]. In addition, other colostral trophic factors (such as epidermal growth factor-like activity) [2] are believed to stimulate intestinal development and aid in antibody transfer. However, 10% of normal foals and a larger percentage of weak or abnormal foals have seriously impaired transfer of passive immunity from their dams [3]. It is important, therefore, to determine which additional factors are involved in the successful transfer of immunoglobulins to the foals. It has already been established that gut closure (the time when immunoglobulins are no longer transported across the intestinal wall) begins within 3 h post-partum [4], which indicates that foals should begin to suckle soon after they are born. Thoroughbred foals in the U.K. suckled within 111 (range 35–420) min of birth [5] whereas American Saddlebred foals suckled within 89.5 (range 63–129) min [6] and ponies within 65 (range 45–135) min [7]. We wished to determine the association of several maternal and foal factors on the transfer of immunoglobulins from dam to offspring. The maternal factors were as follows: change in plasma protein, packed cell volume, and osmolality at foaling, and concentration of colostral immunoglobulins, and water intake in the immediate post-partum period. The foal factors were as follows: blood immunoglobulins at birth and at 24 h of age, time to first suckle, and number of nursing bouts.

Specifically, the questions to be answered were the following: 1) what is the effect of parturition on the fluid balance of the mare? 2) What is the relationship of the degree of dehydration following parturition of the mare to her water intake in the 12 h after parturition? 3) What is the effect of lactation on the mare's water intake over the first two weeks of nursing? 4) Is there a relationship between the mare's water intake and the foal's acquisition of passive immunity?

2. Methods

This study was approved by the Institutional Animal Care and Use Committee of Cornell University.

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2.1. Animals and sampling methods

A total of 12 Thoroughbred mares and their foals were observed for the first 12 h post-partum from a position just outside the box stall where foaling occurred. Data were not available from all 12 pairs for every measurement. The mares were fed ad lib hay and a 4.5 kg of sweet feed (a mixture of oats, corn, and molasses). The amount varied with their body weight and stage of lactation. They were released from their stalls for an hour or two in the morning, weather permitting, into a grassless paddock where water was not available.

The foal's behavior was recorded using an instantaneous sampling every minute [8]. Instantaneous sampling involves recording the behavior at a particular point in time. Many behaviors were recorded including standing, lying, and walking but only suckling will be reported here. Because a one-minute scan was used behaviors occupying less than 60 s might not be recorded. Suckling was recorded if the foa1's lips were contacting the udder. A pause of more than 2 min was considered an inter-bout interval. A pause of less than 2 min was considered an intra-bout interval following Carson and Wood-Gush [9].

Water was available ad libitum from calibrated plastic buckets hung in the stall. Water intake of the mare was recorded daily for seven days before and for the first 12 and 24 h after foaling, and then daily for 14 days. Blood samples were taken from the jugular vein of the mare before at 1800 h (6 to 9 h before foaling) and 1 h after parturition and analyzed for packed cell volume, plasma protein, and plasma osmolality. A sample of the mares' colostrum was taken before the foals suckled. Blood samples were taken from the jugular vein from 11 of these foals within an hour of their birth, before they had suckled, and 24 h after they first suckled.

2.2. Analytical methods

Blood samples were collected into pre-heparinized sterile tubes and immediately refrigerated. Packed cell volume (PCV) determinations were made in duplicate using a microhematocrit technique with a repeatability of ±0.1% (micro-capillary reader, Damon/IEC Division, Needham Heights, MA). Plasma protein concentration was estimated within ±0.1 g/dL with a hand held refractometer (Veterinary Refractometer, AO Veterinary Instruments). Plasma osmolality was determined in duplicate on a 2 mL plasma sample using a freezing point osmometer (Osmette A, Precision Systems, Inc.) with a precision of ±0.5 mosmol/kg H_2O. All measurements were made on the day the sample was taken.

Immunoglobulin concentrations were measured in colostrum and foal serum (before and after suckling) using a single radial immunodiffusion kit (VMRD, Pullman, WA) [10].

2.3. Statistical analysis

Because some of the variables were not normally distributed (or had unequal variances) and sample sizes were small nonparametric statistics were used. Descriptive statistics (foal weight, time to first suckle, and suckling duration) are presented as median values and interquartile ranges. The Wilcoxon signed-rank test was used to compare all pre- and post- partum blood parameters and water intake. The test statistic for the Wilcoxon signed-rank test is denoted in the results by the letter "S". Monotonic relationships between mare post-partum water intake and hematocrit, plasma protein and osmolality were analyzed using Spearman's rank correlation coefficients (Spearman's ρ). Monotonic relationships between mare water intake and foal IgG and between colostral and foal immunoglobulins (IgG, IgA, and IgM) at 24 h after birth were analyzed using Spearman's rank correlation coefficients (Spearman's ρ). All statistical analyses were performed using JMP 9.0.2 (SAS Institute, Cary, NC, USA).

3. Results

3.1. Effects of parturition on body fluid balance

There were significant increases in hematocrit ($n = 11$, $S = 23.5$, $P = 0.035$), plasma protein ($n = 11$, $S = 3$, $P = 0.0005$), and osmolality ($n = 9$, $S = 16$, $P = 0.031$) 1 h after foaling, indicating that parturition caused both a loss of blood volume (increase in plasma protein concentration and hematocrit) and an increase in blood solutes (osmolality) (see Table 1).

3.2. Pre- and post-partum water intake

There was no significant relationship between the degree of dehydration, based on hematocrit, plasma protein, or osmolality, of the mare to her water intake in the 12 h or 24 h after parturition. The median water intake of ten mares increased from 24.1(21.5–24.5.) L before parturition to 42.1(26.2–61.4) L 24 h after parturition ($S = 27.5$, $P = 0.002$). Fig. 1 illustrates the daily water intake of mares before and after parturition.

3.3. Foal suckling behavior

Foals ($n = 10$) suckled with a median latency from birth to first suck of 132 (34–275) min. During the first 4 h they suckled with a median total duration of 13 (6–390) min/4 h. During the first 12 h of the foals' life ($n = 10$), foals suckled for 85 min (73–141) in 34 (23–40) bouts. The median foal weight ($n = 10$) was 56.1 (47.1–58.9) kg at birth. The placentas ($n = 8$) weighed 10.5 (9.0–11.0) kg.

3.4. Transfer of passive immunity

Median foal IgG concentrations were 0 (0–200) mg/dL before and 1120 (800–1600) mg/dL 24 h after first suckling (see Table 2). There was a positive correlation between foal 24 h IgG and the mare's water intake in the 12 h after parturition ($r = 0.66$, $P = 0.039$). There was a significant correlation between the mare's colostral IgG concentration and that of the foal at 24 h post-suckling ($r = 0.66$, $P = 0.028$). Colostral IgM was positively correlated with foal 24 h IgM ($r = 0.64$, $P = 0.004$), and colostral IgA was correlated with foal 24 h IgA ($r = 0.77$, $P = 0.006$). There was no significant correlation between the time a foal spent suckling and its IgG level at 24 h post-partum.

4. Discussion

Parturition causes a considerable loss of blood volume and an increase in plasma osmolality of the mare. The size of the foal is between 5 and 10% of the mare's weight: combined with the weight of the placenta and fetal fluids, this represents a considerable and sudden loss of fluid. Broughton Pipkin et al. [11] have reported an increase in angiotensin in mares at the time of foaling, which is probably stimulated by the loss of body fluids. The increase in angiotensin [12], the decrease in plasma volume, and the increase in osmolality [13] would act as stimuli of thirst. Thus, it is not surprising that the mares in the present study drank over 40 L of water after parturition.

Table 1
Changes in fluid balance at parturition (median and interquartile range).

	Hematocrit % ($n = 11$)	Plasma protein g/dL ($n = 11$)	Osmolality mosmol/kg ($n = 9$)
Prepartum	39.8 (37.0–41.1)	6.9 (6.2–7.4)	289.5 (287.3–291.8)
Postpartum	42.1 (38.6–43.8)[a]	8.0 (7.1–8.2)[a]	291.5 (289.6–296.1)[a]

[a] Postpartum significantly greater than prepartum at $P < 0.05$.