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Original Research

The Effect of Temperature, Rainfall, and Light Conditions on Hair Cortisol Concentrations in Newborn Foals

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ABSTRACT

The aim of this study was to investigate the possible effects of environmental factors such as temperature, rainfall, and light conditions on hair cortisol concentrations in foals during the perinatal period. The study, performed during three consecutive foaling seasons from January to July, enrolled 219 foals from one farm. Hair samples were collected from each foal immediately after birth and at 30 days of age, and the samples were analyzed by radioimmunoassay to measure the cortisol concentrations. The mean cortisol concentration of hair collected at 30 days of age was significantly ($P < .01$) lower than that found at birth, but none of the evaluated environmental factors (temperature, rainfall, or day length) influenced the hair cortisol concentrations.

1. Introduction

Cortisol plays an important role in allostasis, the active process of maintaining and/or reestablishing homeostasis, which helps an animal adapt to a new situation and/or challenge [1]. In mammals, cortisol promotes adaptation in several pathological and physiological conditions, including pregnancy, parturition [2–4], early lactation, and fetal organ system maturation [5–8].

The changes in plasma cortisol during the peripartum period are well known. Basal fetal cortisol levels remain low until 4–5 days before term (<10 ng/mL) and rise exponentially only during the final 24–36 hours before birth (>50 ng/mL) [9], creating a peak that is essential for the final organ maturation of the foal. Plasma cortisol concentrations in normal foals further increase immediately after birth (>130 ng/mL) and subsequently decline 30 minutes after birth (20 ng/mL) [10].

This fall in cortisol concentrations has also been studied in the hair matrix [11]. Comin et al [11] noted a significant decline in foal hair cortisol concentrations from birth to 30 days of life.

Possible explanations for this drop in the cortisol levels include (1) the progressive adaptation to extra-uterine life; (2) the end of the feto–maternal relationship that occurred through the placenta; and (3) the effect of environmental factors on the foal after birth. Many studies take into account the first two hypotheses [10,12–18].

Human studies report that certain climatic factors (temperature, humidity, rainfall, and sunlight) may have important impacts on prenatal development that are manifested as differences in birth outcomes depending on the neonate's birth month [19]. According to Siniarska and Kozieł [19], external environmental factors are filtered by the mother

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through the placenta, thus making it impossible to determine whether the change in birth outcomes is because of a direct effect of environmental factors on the fetus.

In gilts, high temperatures have been shown to affect the onset of puberty [20], litter size, pregnancy rate [21,22], feed intake, body temperature, plasma cortisol concentration, and immune function [23,24]. Light intensity has also been shown to affect the age of onset for puberty [25] and cortisol [26,27]. Reports that parturition in hartebeest and other African herbivores is closely associated with the onset of rainfall [28,29] suggest that environmental factors have an important impact and are clearly related to survival mechanisms. Nathanielsz [30] discusses the dependence of the alpaca on sunshine for delivery, which in this species occurs in the early morning. Wildebeest also calve early in the day; large herds congregate prenatally and show striking synchrony in the timing of parturition [31,32]. In horses, because foaling occurs from January to July in the northern hemisphere, temperature and lighting conditions could affect the hypothalamic–pituitary–adrenal (HPA) axis and cortisol secretion in newborn foals during the process of neonatal adaptation.

There are many factors (e.g., the restraint techniques used during venipuncture, the ability to test the response for only one brief moment in time) that can make the interpretation of blood cortisol data challenging, making it difficult to study the effect of environmental factors on cortisol production. In fact, results for seasonal plasma cortisol secretion in horses do not always agree [33–36]. Hair samples have been recently proposed to avoid invasive sampling procedures. The cortisol measurement in hair samples, used in several species [37–40], provides a "retrospective picture" of previous hormone accumulation and incorporation from plasma over a period of time [42–44]. Because it is noninvasive, hair cortisol concentration measurements represent an interesting alternative for studies focused on the antenatal period, because it avoids blood collection from fetuses. A single measurement (i.e., from hair collected at birth) provides data from a wide but datable antenatal time frame. Therefore, the aim of this study was to investigate whether temperature, rainfall, and light conditions could influence hair cortisol concentrations in foals during the perinatal period.

2. Materials and Methods

Although hair sampling is a noninvasive and painless procedure, the study was carried out in accordance with the EC Directive 86/609/EEC for animal experiments.

2.1. Animals

This study was conducted during three consecutive foaling seasons (from January to July 2010–2012), and the study was conducted at one Standardbred farm (Allevamenti Toniatti s.a.s., S. Michele al Tagliamento, Venezia, Italy).

At term, only multiparous mares were allowed to foal spontaneously with no obstetric intervention; however, all foalings occurred under staff surveillance, and parturition and neonatal parameters were recorded. Foalings were included in this study when the normal parturition criteria [41,43,44] were satisfied; these criteria were defined as delivery in recumbency, allantochorion rupture and unassisted fetal delivery, dorsal anterior fetal presentation, a second stage of delivery (from allantochorion rupture to fetal expulsion) of no longer than 20 minutes, the spontaneous rupture of the umbilical cord, a placental expulsion time no longer than 120 minutes, and a normal gross appearance of the placenta. The criteria for including the newborn foals were normal maturity according to data reported by Rossdale et al [45], normal viability as assessed by an Apgar score >7 (8.1 $\pm$ 0.2) measured within 5 minutes of birth, a normal time to stand up (82.3 $\pm$ 20.2 minutes), and a normal time to first suckle (180.7 $\pm$ 50.4 minutes) [45]. Data concerning the pregnancy length (337.1 $\pm$ 9.8 days, mean $\pm$ standard deviation), age (11.7 $\pm$ 4.7 years), and parity (5.9 $\pm$ 3.6) for each mare were recorded, as was the sex of the foals (121 males and 98 females) and their birth weights (48 $\pm$ 4.0), which were measured within 30 minutes of birth, before nursing. To assess successful passive immune transfer, a mandatory prerequisite for the neonatal adaptation process, IgG was verified on serum collected from each foal at 24 hours after birth using the NAP Foal IgG test (IDEXX Laboratories, Inc).

The mares and foals were reared in single stalls during the first 5 days after birth. They were brought into common paddocks during the observation periods that followed the first five days after birth and were checked daily for health conditions and normal development during the first 30 days of life.

2.2. Environmental Data

The environmental data were recorded in collaboration with Osservatorio Meteorologico Regionale dell'ARPA, FVG (Agenzia Regionale per la Protezione dell'Ambiente del Friuli Venezia Giulia). A meteorological station that is recognized by the World Meteorological Organization regulations and located 15 km away from the Standardbred farm provided the environmental data for the temperature (°C), rainfall (mm), and light conditions (hours of light per day) throughout the study. The daily average for each factor was recorded.

2.3. Hair Sample Collection

Within 30 minutes of birth, hair samples from each study foal were carefully collected from the withers region, which was shaved close to the skin with clippers. The hair samples were collected at 30 days of life from the same area to obtain only regrown hair. The hair samples were stored in dry tubes at room temperature until the end of the study.

The mane and tail hair of horses grows 2.5 cm per month [46], but there are no studies that report the body hair growth rate. At the time of sample collection, hair length was measured, and the growth rate was approximately 1 cm per month, which is in agreement with the hair growth observed in dairy cows [47].

In the equine fetus, the hair begins to grow at 270 days of gestation [48,49], so that the cortisol concentrations measured in the hair samples collected at birth reflect the cortisol accumulated in the last third of pregnancy, but not