Theriogenology 100 (2017) 126–133

Contents lists available at ScienceDirect

Theriogenology

journal homepage: www.theriojournal.com

# Artificially extended photoperiod administered to pre-partum mares via blue light to a single eye: Observations on gestation length, foal birth weight and foal hair coat at birth

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ARTICLE INFO

*Article history:*
Received 3 March 2017
Received in revised form
19 May 2017
Accepted 6 June 2017
Available online 9 June 2017

*Keywords:*
Pre-partum
Photoperiod
Gestation length
Blue light
Birth weight
Hair coat

ABSTRACT

In seasonally breeding animals, photoperiod perception is crucial for timing of important physiological events. In the horse, long day photoperiod influences the onset of ovulation and cyclicity, shedding of the heavier winter coat and the timing of parturition. In this compilation of studies, conducted across three breeding seasons and two countries, the impact of artificially extended day length was investigated on gestation length, foal birth weight and foal hair coat at birth. The light therapy was administered to pre-partum mares via mobile head worn masks which provided short wavelength blue light to a single eye. In Study 1, reductions in gestation lengths were observed following administration of artificially extended day length (124.8 ± 15.11 days) in the final months of pregnancy to a group of Thoroughbred mares compared to controls ($P < 0.05$; 339.7 ± 9.56 days vs 350.6 ± 9.13). Study 2 revealed that pre-partum exposure to artificially extended day length (104.6 ± 9.89 days) increased foal birth weight compared to controls (47.13 ± 2.93 kg vs 43.51 ± 6.14 kg; $P < 0.05$) in mares bred early in the year. In Study 3, artificially extended day length (87.53 ± 19.6 days) administered to pre-partum mares affected the coat condition of foals at birth with respect to hair weight ($P < 0.0001$) and hair length ($P < 0.0001$) compared to controls (0.34 ± 0.20 μg vs 0.59 ± 0.12 μg and 1.93 ± 0.56 cm vs 2.56 ± 0.32 cm, respectively). Collectively, these studies serve to highlight the influential role of the circa-annual changes in photoperiod length on the pre-partum mare for normal foetal development during the natural breeding season. It also emphasizes the potential that exists to improve breeding efficiency parameters by artificially simulating this important environmental cue in the latter stages of gestation against the backdrop of an economically driven early breeding season.



## 1. Introduction

The domestic horse mare (*Equus caballus*), as a seasonal breeder, has an endogenous circa-annual reproductive rhythm and the main role of seasonal cues appears to be to synchronize the endogenous rhythm to winter and summer [1]. The natural physiological breeding season occurs approximately from April to September in the northern hemisphere and is stimulated by increases in day length, temperature and food availability [2]. The primary regulator is the increased daylight hours associated with spring that provide a seasonal cue for reactivation of the hypothalamic-pituitary-ovarian axis via reductions in melatonin secretion from the pineal gland [3]. The exposure to artificial light to extend day length to approximately 16 h total during winter is a common management tool on commercial horse breeding farms to advance seasonal reproductive activity [4]. When started in early December, this regime successfully advances the onset of ovarian activity in the non-pregnant mare [5] and allows breeders to meet industry imposed breeding timelines and a market demand for foals born earlier in the year created by the arbitrary January 1 birth date for many horse breeds. A common observation of light-treated mares is early shedding of the heavier winter coats [6]. Photoperiod is

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http://dx.doi.org/10.1016/j.theriogenology.2017.06.012
0093-691X/

known to exert a dominant influence on seasonal pelage and there is significant evidence to demonstrate that prolactin is involved [7].

Recent research indicates that short wavelength light within the blue spectrum is particularly effective at suppressing melatonin secretion in the horse [8]. Studies in Thoroughbreds have shown that melatonin can be suppressed to daytime levels using low-intensity blue light (468 nm) from light emitting diodes (LED) directed at a single eye and has been used to effectively advance the ovulatory season of the mare [8,9].

Similar to other seasonally breeding animals [10, 11, 12], photoperiod is also important for the pregnant mare. Gestation lengths have been found to decrease as the natural foaling season progresses and the daily length of daylight gets longer [13–15]. Links between increasing daylight hours and concurrent decreases in gestation lengths were first reported in 1938 [16] and have since been supported by further studies [17,18]. The first study to investigate the effect of artificially extended photoperiod on pregnant mares reported a significant shortening of gestation length and a trend towards higher birth weights [19]. Moreover, photoperiod changes have been linked to variability in the gestation length of deer [11,12]. This provides support for the suggestion by Perez et al. [14] that light to the pregnant mare may modify the rate of foetal maturation during the final trimester.

Foal birth weight is an important factor for horse breeders as it has been found to correlate to the weight and size of the horse as a yearling [13] and therefore has a perceived influence on a horse's potential earnings and future athletic ability. Foals born later in the year (April, May and June), during the natural breeding season for the horse, have comparably higher birth weights than foals that are born in January, February and March [13]. This increase in birth weight has been shown to correlate with a decrease in gestation length [13–15].

Consequently, three studies were conducted across three breeding seasons in Ireland and KY, USA to determine if long-day photoperiodic stimulation of mares during the final third of gestation using mobile blue light directed at one eye influenced gestation length, foal birth weight and foal coat at birth.

## 2. Materials and methods

All animal experiments complied with the ARRIVE guidelines and were carried out in accordance with the U.K. Animals (Scientific Procedures) Act, 1986 and associated guidelines, EU Directive 2010/63/EU for animal experiments (Study 1 and Study 3), and the National Institutes of Health guide for the care and use of Laboratory animals (Study 2; IACUC 2012-0928).

### 2.1. Study 1 – Ireland - gestation length

#### 2.1.1. Animals and environment

Fifteen pregnant Thoroughbred mares (*Equus caballus*), ranging in age from 5 to 18 (12 ± 4.19) years, with a history of prolonged gestation lengths (mean gestation length of 350 days for previous gestations where available) were used in a study conducted from December 1, 2011 through May 2012 on a single commercial Thoroughbred breeding farm located in Kildare, Ireland at longitude W 54.51 and latitude N 9.22. The natural day length at the beginning and end of the study period was 8 h 01 m and 16 h 30 m, respectively, with a temperature range of 2.5–16.4 °C.

All mares were maintained at pasture during the day and in individual stalls at night during the study period. All mares grazed *ad libitum* during the day and had *ad libitum* access to hay during the night. The mares' diets were supplemented with a commercially prepared concentrate feed mix according to their individual requirements as assessed by farm management and in accordance with feed manufacturer guidelines. Access to water was *ad libitum* at all times. Beginning on December 1, Group 1 (n = 6) received individual light therapy from head worn masks (Equilume® Light Masks, Equilume Ltd. Kildare, Ireland) that provided 50 lux of blue light (468 nm) to the right eye. The light turned on at 16:30 each day and turned off at 23:00 nightly, providing an initial 14.5 h day, gradually increasing to a maximum day length of 16 h 15 min as the natural hours of daylight advanced.

Group 2 (n = 9) continued to be maintained under lighting conditions that reflected the natural photoperiod for the time of year at this location.

Records were collected following parturition for each mare and foal. These included; sire of foal, sex of foal, weight of foal within 12 h of birth (where available), gestation length, historical gestation lengths for two previous breeding seasons (where available), mare age and parity. Gestation length was calculated as the number of days from date of last breeding to date of parturition.

#### 2.1.2. Statistical analysis

For each Group, the mean and SD were calculated for number of days in foal at initiation of treatment, number of days from initiation of treatment to parturition, gestation length and foal birth weight for each resulting foal. Data were analysed using a Mixed Model in Graph Pad Prism Version 7.01 for Windows (Graph Pad Software, San Diego, CA, USA). In the Mixed Model, parity, age of mare, and sex of foal were considered as fixed effects and mare within treatment was treated as a random effect. A paired T test was used to compare the gestation length of five mares in Group 1 with the average gestation from their previous two gestations. Data are presented as means ± SD. P-values $\leq 0.05$ are considered statistically significant. Statistically significant results are presented graphically.

### 2.2. Study 2 – KY –gestation length and foal birth weight

#### 2.2.1. Animals and environment

Twenty-nine pregnant light breed mares, ranging in age from 5 to 18 (9.8 ± 4.3) years and their subsequent offspring were used in a study conducted from December 1, 2012 through April 30, 2013 on a single institutional research farm in KY, USA at longitude N 37.5, latitude W 85. The natural day length at the beginning and end of the study period was 9 h 44 m and 12 h 53 m respectively, with a temperature range of −7 to 26 °C. In the preceding season, all mares were inseminated with mixed semen collected from two Quarter Horse stallions (X and Y) between the period March 23 and April 28, 2012. All subsequent foals were born in the period from February 18 to April 6, 2013. Of the 29 foals born, 25 were born in March 2013.

The mares were divided into two groups and blocked for age, parity, body condition score (BCS) and bodyweight. Beginning December 1, Group 1 (n = 15) received an artificially extended photoperiod using 50 lux blue light (468 nm) directed at a single eye from dusk until 23:00 daily via individual head worn commercially available light masks (Equilume Ltd, Kildare, Co. Kildare, Ireland). Group 2 (n = 14) were maintained under natural photoperiod. All mares were maintained outdoors in two large paddocks with *ad libitum* access to hay and water and each mare received 1.4 kg of mare nuts (Winchester Feed & Supply, KY, USA) once a day. Gestation length was calculated as the number of days from insemination to parturition. FBW in kg was measured within 24 h of birth using a freestanding animal weighbridge (Horse-Weigh®, Kentucky, USA). Paternity testing was conducted on all foals following birth using a commercial Equine Parentage Test based on hair follicle DNA typing at the Animal Genetic Testing & Research Laboratory, University of Kentucky.