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Short Communication

Heart rate and salivary cortisol concentrations in foals at birth

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ABSTRACT

Heart rate (HR), HR variability (HRV) and salivary cortisol concentrations were determined in foals ($n = 13$) during the perinatal phase and until 5 months of age. In the fetus, HR decreased from 77 ± 3 beats/min at 120 min before birth to 60 ± 1 beats/min at 5 min before birth ($P < 0.01$). Within 30 min of birth, HR increased to 160 ± 9 beats/min ($P < 0.01$). Salivary cortisol concentrations immediately after birth were 11.9 ± 3.6 ng/mL and within 2 h increased to a maximum of 52.5 ± 12.3 ng/mL ($P < 0.01$). In conclusion, increases in HR and salivary cortisol concentrations in foals are not induced during parturition, but occur immediately after birth.

In human babies (Irestedt et al., 1982) and calves (Aurich et al., 1993), parturition stimulates sympathoadrenal activity. Sympathetic activity can be evaluated not only by analysis of catecholamine concentrations, but also indirectly by heart rate (HR) and HR variability (HRV). HRV represents the fine tuning of the cardiac beat-to-beat (RR) interval; it increases during parasympathetic stimulation and decreases with sympathetic dominance (Von Borell et al., 2007). The activity of the hypothalamus–pituitary–adrenal (HPA) axis can be determined by analysis of cortisol in saliva, which avoids potential stress through repeated blood sampling.

Mares give birth in a state of relaxation (Nagel et al., 2014). However, stress responses in the foal may differ from the parturient mare. Therefore, we investigated HR and HRV in the fetus and foal during and after foaling, and determined salivary cortisol concentrations after birth until foals were 5 months old. We hypothesised that parturition induces a stress response in the fetus.

Thirteen mature, healthy, Warmblood foals were studied from 120 min before birth until 20 weeks of age. Parturition was observed in all mares and no obstetrical intervention was needed. The second stage of parturition lasted 16.6 ± 1.5 min (mean ± standard deviation).

When foaling was considered to be imminent, fetomaternal electrocardiographic recordings were instituted and continued until 2 h after birth. Until 8 weeks of age, HR in foals was recorded once weekly for 1 h between 0600 and 0900 h, and once monthly thereafter. HR was determined for 5 min periods at 120, 90, 60, 30, 15 and 5 min before birth, and at 5, 15, 30, 60, 90 and 120 min after birth. For HRV analysis, the last 5 min before and after birth were omitted to avoid inclusion of artefacts. After birth, HR and HRV were calculated as means of three 5 min intervals recorded during a 1 h period.

Cardiac recordings were made with the Televet 100 system (Engel Engineering) in fetuses and the Polar S 810i system (Polar) in foals (Nagel et al., 2012). In non-exercising horses, RR intervals obtained by electrocardiogram and Polar monitors were strongly correlated ($r = 0.999$) and near-identical (Ille et al., 2014). From the RR intervals, HR and HRV variables standard deviation of the RR interval (SDRR) and root mean square of successive RR differences (RMSSD) were calculated.

For cortisol analysis, saliva was collected immediately and at 15, 30, 60 and 120 min after birth. Saliva was then sampled weekly at 0600, 1200 and 1800 h on the same days as HR recordings. Salivary cortisol was analysed according to Schmidt et al. (2010). Since not all animals could be included at all times, numbers at individual time points varied (Table 1). The study was approved by the Brandenburg State Landesamt für Umwelt, Gesundheit und Verbraucherschutz (license V3-2347-14-2011).

The statistical programme SPSS (IBM) was used for statistical analysis. Due to the differing numbers of animals, the analysis was split into three intervals: (A) before birth; (B) the first 2 h after birth; and (C) weeks 1–20 after birth. Changes in salivary cortisol concentrations within intervals A, B and C, and within sampling day (i.e. between 0600, 1200 and 1800 h) were compared using Friedman test. For all parameters, mean values of intervals A, B and C were compared with the Wilcoxon test. Values given are means ± standard errors of the means (SEM).

Fetal HR decreased from 77 ± 3 beats/min at 120 min before birth to 60 ± 1 beats/min at 5 min before birth ($P < 0.01$). After birth, HR

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Table 1
Number of foals from which data were obtained at each time point.

	Time relative to end of the second stage of parturition (min)												Weeks of age			
	−120	−90	−60	−30	−15	−5	+5	+15	+30	+60	+90	+120	1–8	12	16	20
HR	6	6	6	6	6	6	9	9	9	9	9	9	10	10	10	10
HRV	6	6	6	6	6	–	–	9	9	9	9	9	10	10	10	10
Cortisol	–	–	–	–	–	–	9	9	9	9	–	9	10	10	10	10

increased to a maximum of 160 ± 9 beats/min within 30 min ($P < 0.05$). SDRR and RMSSD remained unchanged from 120 min before to 120 min after birth (Fig. 1). Salivary cortisol concentrations in foals were 11.9 ± 3.6 ng/mL immediately after birth and increased to a maximum of 52.5 ± 12.3 ng/mL at 120 min ($P < 0.01$; Fig. 2).

HR decreased from 1 to 20 weeks of age ($P < 0.05$), whereas there was no significant change in SDRR nor RMSSD (Fig. 1). Salivary cortisol concentration at 0600, 1200 and 1800 h on each sampling day decreased from 1 to 20 weeks of age ($P < 0.05$; Fig. 2). Compared to the immediate postnatal period, HR and salivary cortisol concentrations were lower ($P < 0.05$), while SDRR and RMSSD were higher ($P < 0.05$), between 1 and 20 weeks of age.

In this study, salivary cortisol was suitable for use as a non-invasive tool to evaluate HPA activity in neonatal foals. The marked rise in salivary cortisol concentration and in HR during the immediate postnatal period indicated a pronounced stress-like response once the foal was born.

The free cortisol fraction in plasma of foals at birth is nearly 10-fold higher than in adult horses and approximates 60% of total plasma cortisol (Hart et al., 2011). Only free cortisol diffuses into saliva (Kirschbaum, 2000); therefore, higher salivary cortisol concentrations in foals at birth than in adults do not necessarily indicate a pronounced release of cortisol during parturition. In contrast, the subsequent increase in salivary cortisol concentrations is mainly due to cortisol release. Maximum salivary cortisol concentrations were found when foals were standing and sucking. In contrast to foals, plasma cortisol and catecholamine release in calves increase during parturition and decrease after birth (Aurich et al., 1993). This may be explained by a longer duration of parturition in cattle, with fetal hypoxia stimulating catecholamine and cortisol release. In our study, salivary cortisol concentrations had declined in foals by 1 week after birth and a diurnal rhythm existed.

Parturition is not associated with acidosis in the foal (Rose et al., 1982) and the short expulsive phase of parturition does not appear to induce major activation of the fetal HPA axis. Although some stimulation of cortisol release during parturition cannot be excluded, a pronounced increase in salivary cortisol concentration occurs only once the foal has been born, and is accompanied by an increase in HR.

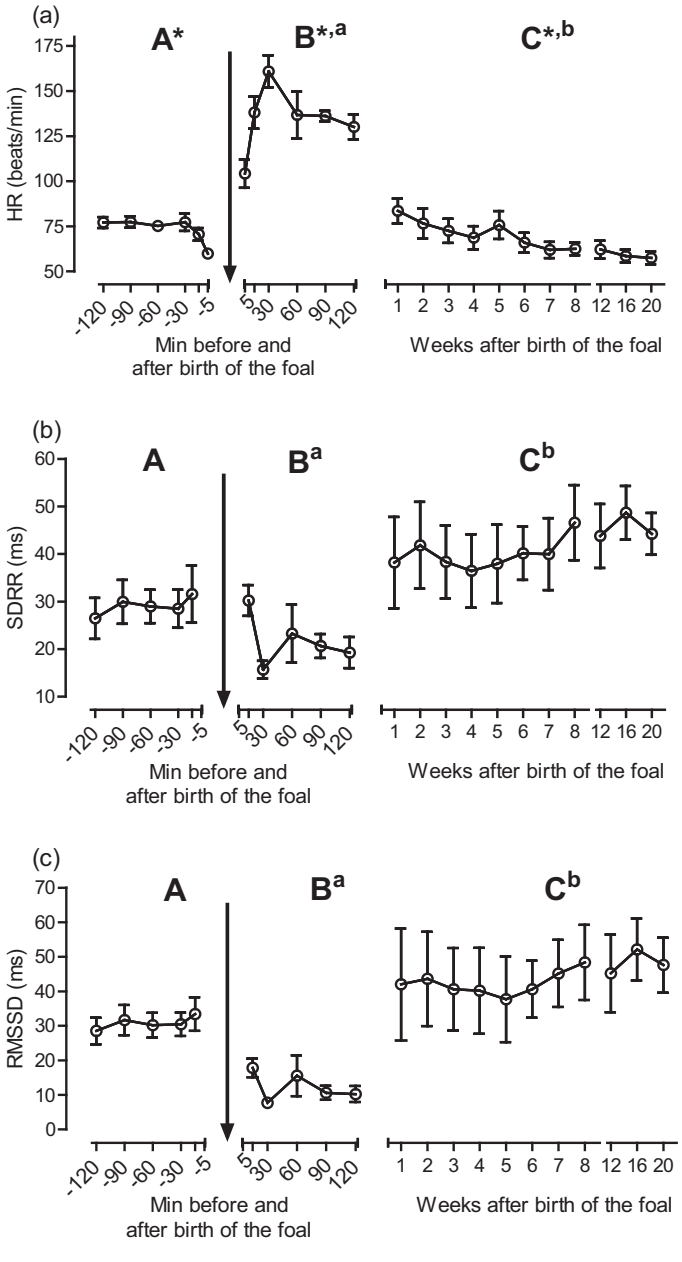

Fig. 1. Heart rate (a), standard deviation of the RR interval (SDRR) (b) and root mean square of successive RR differences (RMSSD) (c) 120 min before (interval A; $n = 6$) and 120 min after (interval B; $n = 9$) birth of the foal (arrow = birth) and on individual days in weeks 1–8, 12, 16 and 20 of life (interval C; $n = 10$). * Significant differences within respective time interval ($P < 0.05$). [a,b] Significant differences between time intervals (B vs. C; $P < 0.05$). Values are means ± standard errors of the means (SEM).

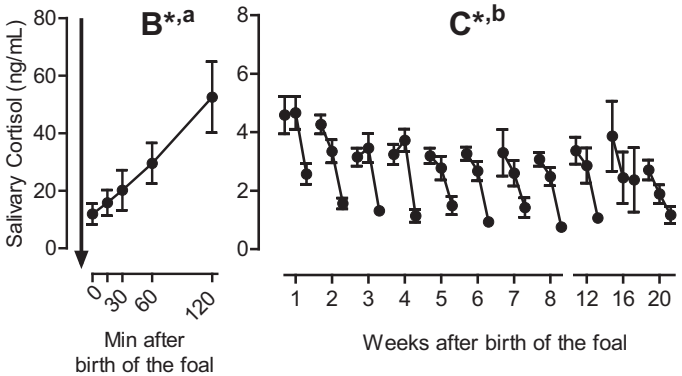

Fig. 2. Salivary cortisol concentrations in the first 120 min after birth of the foal (interval B; $n = 9$; arrow = birth) and at 0600, 1200 and 1800 h on individual days in weeks 1–8, 12, 16 and 20 of life (interval C; $n = 10$). * Significant differences over time during the first 120 min after birth, and within each day of sampling at 1–20 weeks after birth ($P < 0.05$). [a,b]Significant differences between time intervals (B vs. C; $P < 0.05$). Values are means ± standard errors of the means (SEM).

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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