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The effects of body posture and temperament on heart rate variability in dairy cows

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HIGHLIGHTS

- The posture (lying, standing) of the cow affected heart rate variability.
- The emotional reactivity of the cow was related to heart rate variability.
- Linear and non-linear methods measuring heart rate variability complement each other.

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ABSTRACT

Reactivity of cattle affects many aspects of animal production (e.g. reduced milk and meat production). Animals have individual differences in temperament and emotional reactivity, and these differences can affect how animals react to stressful and fear-eliciting events. Heart rate variability (HRV) is a good indicator of stress and balance of the autonomous nervous system, and low parasympathetic activity is connected with higher emotional reactivity. The study had two specific aims: (1) to compare HRV in dairy cows for standing and lying postures (no earlier results available), and (2) to assess whether dairy cows' emotional reactivity is connected to their HRV values. Eighteen dairy cows were subjected twice to a handling test (HT): morning (HT1) and afternoon (HT2), to evaluate emotional reactivity (avoidance score, AS). HRV was measured during HT (standing). HRV baseline values, both standing and lying down, were measured one week before HTs. HRV was analyzed with time and frequency domain analyses and with the Recurrence Quantification Analysis (RQA). Heart rate (HR), low-frequency/high-frequency band ratio (LH/HF), % determinism (%DET) and longest diagonal line segment in the recurrence plot (L_{max}) were higher ($p < 0.05$) while the cows were standing than when lying down, whereas the root mean square of successive R–R intervals (RMSSD) ($p < 0.05$) and power of the high-frequency band (HF) ($p < 0.1$) were higher while the animals were lying down. HR, the standard deviation of all interbeat intervals (SDNN), RMSSD, HF, power of the low-frequency band (LF), % recurrence (%REC), %DET, Shannon entropy ($p < 0.05$), and HF ($p < 0.1$) were higher during the handling test compared to standing baseline values. AS (i.e. tendency to avoid handling) correlated positively with SDNN ($r = 0.48$, $p < 0.05$), RMSSD ($r = 0.54$, $p < 0.05$), HF, RMSSD ($r = 0.46$, $p < 0.1$) and LF ($r = 0.57$, $p < 0.05$), and negatively with %DET ($r = -0.53$, $p < 0.05$), entropy ($r = -0.60$, $p < 0.05$) and Lmax ($r = -0.55$, $p < 0.05$) in the baseline HRV measurements. AS correlated positively with SDNN ($r = 0.43$, $p < 0.1$) and HF ($r = 0.53$, $p < 0.05$) during HT. Some HRV parameters (HR, LF, %REC, %DET) indicated that the handling test may have caused stress to the experimental cows, although some HRV results (SDNN, RMSSD, HF, entropy) were controversial. The correlations between HRV variables and AS suggest that the emotional reactivity of the cow can be assessed from the baseline values of the HRV. It is debatable, however, whether the handling test used in the present study was a good method of causing mild stress in dairy cattle, since it may have even induced a positive emotional state. The posture of the cow affected HRV values as expected (based on results from other species), so that while standing a shift towards more sympathetic dominance was evident. Our results support the idea that linear (time and frequency domain) and non-linear (RQA) methods measuring HRV complement each other, but further research is needed for better understanding of the connection between temperament and HRV.

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1. Introduction

The heart rate (HR) of a healthy individual is irregular [1]. This irregularity, i.e. heart rate variability (HRV), is due to beat-to-beat variation [2]. The autonomic nervous system (ANS) controls the heart's sinoatrial node (SA), which is the pace-making unit of the heart [3]. Parasympathetic activity (often referred as vagal tone) dominates during rest and sympathetic activity dominates during activity. Thus HRV can be used as an indicator of the sympathovagal balance of the ANS [2]. Changes in HRV can be detected already in the anticipatory state when behavioral evidence of stress is not yet visible [4]. HRV is known to be a valid indicator of stress [5] and it has been used in many studies with production animals to assess stress [4,6]. In calves the use of HRV as an indicator of sympathovagal balance has been validated with autonomic blockade tests [7]. HRV has also proved to be a useful tool, for instance in assessing pain in animals [e.g. 8–10]. Research with other species of animals [4,11] and humans [2,12] show that physical activity and body posture (standing vs. lying down) also affects heart rate variability.

Temperament or reactivity is described as 'consistent differences in behavior between individuals' [13] and it is evident that animals have individual differences in temperament [14–17]. These temperament traits are consistent over time (e.g. agitated behavior: [18]) and different situations (e.g. reactivity to various stimuli: [15,19]). Reactivity of cattle affects many aspects of animal production. Highly reactive animals can be a risk for people handling those animals [18]. High reactivity and fear of humans can also be linked to reduced production (milk: [20, 21]; meat: [22]). Bourguet et al. (2010) [23] discovered that more reactive cows, as indicated by a separation test and human exposure test during rearing, had higher stress responses (e.g. heart rate, behavior, post mortem muscle temperature) during the slaughter procedure. They concluded that emotional reactivity can predict the stress level of animals during aversive events.

Low parasympathetic activity (and high sympathetic activity) is connected with higher emotional reactivity [24], and it is possible that HRV and temperament are associated [25]. In quail, tonic immobility responses to restraint are genetically linked with changes in sympathovagal balance, and it is possible to affect behavioral responses to stress using genetic selection [25].

In cattle, HRV variables differ between various breeds and it has been speculated that these differences may arise either from metabolism or temperament of the animals [26]. Generally, individuals with low vagal tone are possibly more vulnerable to stress [4]. Kovács et al. (2014) [27] concluded that HR and short-term HRV are effective tools for assessing stress in human–cattle relationships.

In previous studies with cattle, HRV measurements have been done either when animals are lying down or standing. However, none of the publications present comparison of HRV between lying and standing postures [e.g. 9,26,28,29]. In this study we compared HRV while animals were standing and lying down. Another aim of the study was to assess whether the emotional reactivity of dairy cows, as measured by a handling test, is connected to its HRV values. In both tests we wanted to use an extensive set of HRV variables as suggested in previous studies with cattle [26,29].

2. Materials and methods

2.1. Housing and management of experimental animals

The study was conducted at MTT Agrifood Research Finland (Maaninka, Finland) from December 2010 to January 2011. The experimental animals were 14 Holstein-Friesian and 4 Ayrshire cows, both primiparous and multiparous, all in their late-lactation period. Outside the experiments the cows were loose-housed in a curtain-wall barn with rubber-matted cubicles and automatically scraped passageways. They were fed with 6–8 kg of concentrate (barley-rapeseed meal mixture 80:20 in kg, dry matter approximately 86% and 92% respectively) per day and grass silage (energy content 10.8 MJ ME/kgDM) ad libitum. The cows were routinely milked twice daily at 6.00–8.00 and 16.00–18.00.

2.2. HRV measurements

The experiment included baseline HRV measurements and a handling test (HT) with HRV measurement (Table 1).

Polar Equine RS800CX Science (Polar Electro Oy, Finland) was used to measure the heart rate variability (R–R interval). It contained a measuring belt with two electrodes, a transmitting unit and a receiving data logger. This system is designed especially for scientific use and primarily for horses.

Baseline values of HRV were measured one week prior to the handling test (Table 1). Cows were divided into three groups of six cows and measurements for these groups were conducted on three successive days, one group per day. After the morning milking one group was moved to the experimental cubicles and tethered. A Polar measuring belt was attached around the cow as described in Hopster and Blokhuis (1994) [30] and secured with a girth. To improve conductivity the electrodes were wetted with water. HRV was measured for 2 h, both in the morning and in the afternoon. Cows were tethered during the whole period between morning and afternoon measurements. Measuring belts were removed after the morning measurement and attached again before the afternoon measurement. The data for the first 30 min were ignored, this being considered the time required for the cattle to habituate to the measuring belts. Simultaneously, the behavior of the cows was video recorded (Axis Q1755-E, Axis communications AB, Sweden) from up behind. The video-recordings were used for selecting both standing and lying bouts for the HRV analyses.

The Handling Test (HT, see below) was carried out one week after the baseline HRV measurement (Table 1). A Polar measuring belt was attached half an hour before HT (habituation) and HRV were measured during HT. The test was conducted twice, once in the morning (HT1) and once in the afternoon (HT2). The cows were tethered during the whole time between the HT1 and HT2 measurements.

2.3. The handling test

In the HT the cows were tethered with the same procedure as during the HRV baseline measurements. The cows were standing during the HT. The experimenter (female), previously unknown to the experimental cows, handled a cow from both sides. Handling included touching and pinching of the cow and it started from the head and moved towards the rear of the cow. Every area of the body (head/ears, side/back/front legs, rear/hind legs/tail) was handled for 1 min on both sides and the total test time was 6 min. The behavior of the cows was video recorded as in the HRV baseline measurements and also with a hand-held camera behind the cow. The behavior of the cows during the six-minute handling period was scored from the video material by the handler before analyses of the HRV data. An eight-point ordinal scale was used to evaluate the reactions of the cows (Table 2). The reactions were first scored separately during the handling of each of the six body areas (head/ears, side/back/front legs and rear/hind legs/tail from the both sides). Finally, the scores from the morning and the afternoon were totalled to create an avoidance score (AS) with a theoretical

Table 1
The schedule of the experiment. The first test day of each test week was Monday. HRV = heart rate variability measurements, HT = Handling test.

Test week	Day[a]	Group 1 (n = 6)	Group 2 (n = 6)	Group 3 (n = 6)
1	1	Baseline HRV		
	2		Baseline HRV	
	3			Baseline HRV
2	1	HT & HRV		
	2		HT &HRV	
	3			HT & HRV