Validity of the Polar Team Pro® heart rate monitor to measure RR intervals at rest in horses

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Introduction

Heart rate variability (HRV) is a control of autonomic nervous system activity. The HRV is calculated by the time intervals between two peaks R (RR intervals) of the QRS complex of an electrocardiogram. Its non-invasive analysis dissociates the functioning of the parasympathetic nervous system (SNP), causing a slowing of the functions of the organism, from that of the sympathetic nervous system (SNS) to the antagonistic action (Taskforce, 1996). A high HRV reflects good adaptability to environmental fluctuations, whereas a small variation is associated with a negative health outcome (Wallen & al, 2012). HRV is a recognized measure for overtraining, recovery, endurance training, stress and welfare in animals (Visser et al 2002, Cottin & al 2005, Cottin & al 2006, Von Borell & al 2006, Schmidt & al 2010).

The electrocardiogram is the standard reference method for measuring HRV. At the same time, portable heart rate monitors have become an easier, less expensive tool and a valid measure of the RR interval in the horse. This is also true for HRV parameters derived from RR intervals, provided that both signals are processed with the same software (Nunan & al, 2008). The Polar S810 is a heart rate monitor most commonly used in equine studies (Cottin & al 2005, Cottin & al 2006, Parker & al 2010, Schmidt & al 2010, Von Lewinski et al 2013). Several studies show the benefit of adding a correction to the registered RR signal (Gamelin & al 2006; Parker & al 2010; Giles & al 2016). Indeed, an equine ECG has a pronounced T-wave, which can be confused with peak R by R-R detectors such as the Polar system (Von Borell et al, 2006). Parker (2010) demonstrates that uncorrected Polar data cannot be used interchangeably with ECG data in horses because of the presence of these errors.

The present study set out to validate the newly released Polar Team Pro, which has not yet been examined in the literature. This HRM is a new team sport performance sensor that can measure heart rate (HR) and HRV, which is not specifically designed for clinical or research application in sport horse, validating their ability to accurately and reliably record RR intervals is essential. The aim of the study was to assess the validity of the Polar Team Pro heart rate monitor to accurately measure RR intervals at rest, comparing: (1) resting raw data obtained from the Polar Team Pro HRM and the Televet 100, a 4 lead ECG recording; and, (2) corrected or uncorrected HRV parameters derived from both the Polar Team Pro and ECG.

Materials and methods

Animals

Eight healthy French Trotters, 2 females, 3 geldings and 3 mares (age, 3,9 years old, +/- 1,8 years) were used to obtain ECG and Polar Team Pro recordings. HRV of horses is measured at full rest in the box (4m x 4m) for 1 hours were provided ad libitum access to both hay and water.

Data acquisition

Data were acquired simultaneously from the subjects using two different systems, a Polar Team Pro Recorder (Polar Team Pro, Finland) with Polar equine belt, and a telemetric ECG system (Televet 100, Engel Engineering Services GmBH, Offenbach am Main, Germany) with four self-adhesive electrodes. The coat was first clipped at all ECG electrode sites, this was necessary to promote conductivity. The ECG electrodes were attached on the ventral midline, 2 electrodes at the withers and 2 electrodes in the lower belly. The Polar equine belt was attached to the ventral midline previously wet (Fig. 1). Polar Team Pro and ECG recordings were started simultaneously, by specifying the departure time. Each record lasts 1 hour, to ensure a minimum of 5 minutes of stable state acquisition.

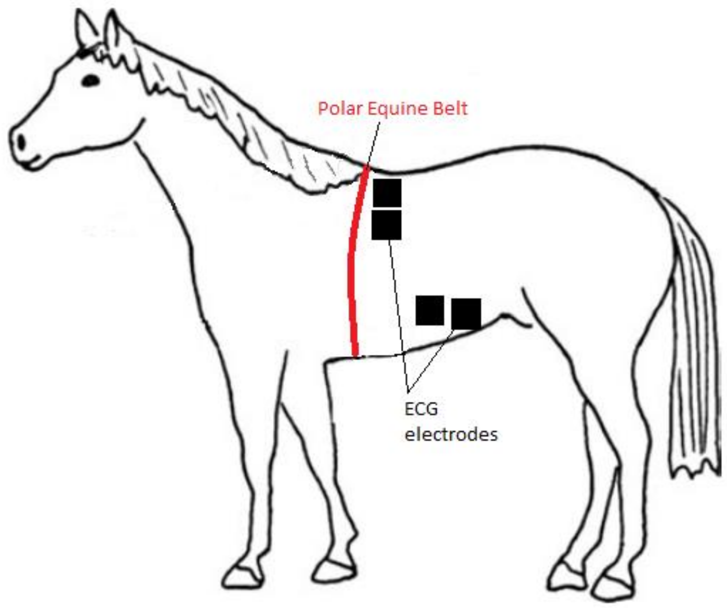

FIGURE 1 - Electrodes and Polar Equine belt placement

After stopping the recording, the ECG data was saved for each horse. The Televet 100 software platform includes an algorithm to automatically detect R-waves, so R-R data from ECG tracks has been saved to a separate file for each horse. The Polar Team Pro data is automatically transmitted at the end of each registration period on the Polar Team Pro internet service. The raw ECG files are checked, and the correct identification of each R-wave has been checked visually by a person acclimatized to the software. The software Televet 100 places a vertical mark on the R-wave, allowing the verification of the proper functioning of the integrated algorithms. Televet 100 software also allows manual R-wave correction, as incorrect detection of an R-wave can occur on artefacts. Subsequently, the R-R intervals were exported in the ASCII format. The R-R intervals of the Polar Team Pro signal have been exported in ASCII format.

Data preparation and analysis

ASCII files are transferred to the Kubios HRV software (University of Kupio, Kupio, Finland). ECG and Polar recordings have been aligned with time. A data range of 5 min is selected on a stable state. Type 1-5 errors, according to Marchant-Forde (2004), are avoided. On some recordings, several 5-minute tracks are selected.

For HRV analysis, time domain, frequency domain and nonlinear indices were calculated. These measurements are chosen because they are the most used in equine research. The following time domain parameters were calculated: mean RR interval, RR interval standard deviation (SDRR), and root mean square of successive differences (RMSSD).

Frequency domain indices was performed with the fast Fourier transform (FFT) to quantify the power spectral density of the low frequency (LF; 0.01–0.07 Hz), and the high frequency (HF; 0.07–0.6 Hz) bands expressed in normalized unit (i.e., in a percentage of LF + HF) (Kuwahara & al, 1996). Additional calculations included Total Power (TP = LF + HF), and the ratio LF/HF.

The Poincare plot is a scattergram in which each RR interval is plotted against the previous one. SD1 represents the dispersion of the points perpendicular to the line of identity, it is an index of the activity of SNP. SD2 represents the scatter of points along the identity line and represents a global SNS and SNP activity. The ratio SD2 / SD1 is then calculated and indicates the sympathovagal balance.

A filter is then added to the 5 min data range of Polar recordings. If an RR interval differs from the locale average more than a specified threshold value, the interval is identified as an artefact and is marked for correction. 4 measurements were added, without correction (NONE, 0s), very low correction (VL, 0.45s), low correction (L, 0.35s) and medium correction (M, 0.25s).

Statistical analysis

For statistical analysis, the XLSTAT software (Addinsoft, version 2017.2) is used. Mean RR, SDRR, RMSSD, LF, HF, TP, LF / HF, SD1, SD2 and SD2 / SD1 measurements are analysed. The normal distribution was verified by the Shapiro-Wilk test. The differences between NONE, VL, L, M correction and ECG are examined by a paired T-test or, if applicable, a paired Wilcoxon pair test. Finally, Bland-Altman graphs of all the measurements of both systems were constructed (Bland & Altman, 1986). The standard deviation of the differences (Bias) and 95% limits of agreement (LoA) were calculated. Statistical significance was set at $p = 0.05$ for all analyses.

Results

28 records of 5 min were collected. The number of R-R intervals detected was 4339 for the ECG, and 4341 for the Polar Team Pro. The data ranges were selected without error type 1-5. The means and standard deviation revealed that the data of the Polar Team Pro NONE, VL and L are identical, only the data with correction M vary. Only the NONE identifier is considered.

T-tests revealed that the R-R intervals NONE and M were different from the ECG R-R intervals ($p < 0.05$, for both). Figures 1 and 2 show the Bland-Altman curves of the RR NONE and M intervals with respect to RR intervals of the ECG. No significant difference was noted for HRV time domain, frequency domain and nonlinear plot parameters, except for a trend between Polar M data and ECG data for RMSSD and SD1 ($p = 0.07$ and $p = 0.07$, respectively). The bias and the 95% confidence interval for the bias are presented in Tables 1 and 2.

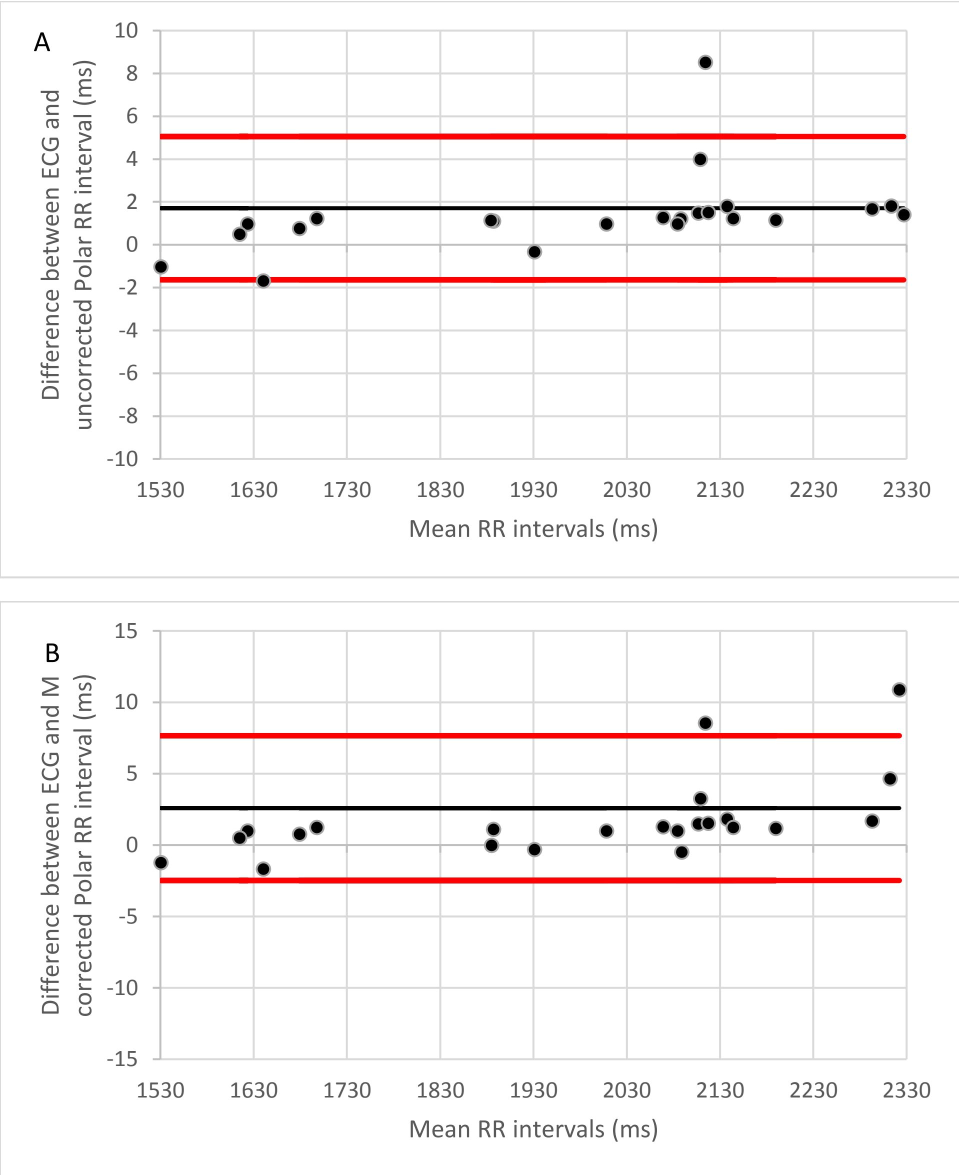

FIGURE 2—Representative Bland–Altman plot for electrocardiogram (ECG) and Polar NONE R–R intervals (A) and for ECG and M corrected Polar R–R intervals (B). Center solid line equals mean difference between the two devices to detect R–R intervals and outer dot-dash lines equal +/- 1.96 standard deviations (SD) of the mean.

TABLE 1. Heart rate variability parameters obtain from the electrocardiogram (ECG) and uncorrected Polar Team Pro (Polar NONE) signal (means +/- SD), bias, and limit of agreement (LoA).

	ECG	Polar NONE	Bias	LoA
Mean RR (ms)	1962,53 +/- 226,08	1961,21 +/- 225,32**	1,71	-1,63 to 5,05
SDRR (ms)	86,41 +/- 32,03	87,04 +/- 31,25	2,83	-2,71 to 8,36
RMSSD (ms)	62,05 +/- 39,29	62,12 +/- 39,49	0,85	-0,81 to 2,51
LF (n.u.)	76,77 +/- 12,46	76,67 +/- 12,54	0,71	-0,68 to 2,11
HF (n.u.)	23,23 +/- 12,46	23,33 +/- 12,54	0,71	-0,68 to 2,11
TP (ms^2)	8291,66 +/- 6691,41	8329,35 +/-6677,03	198,86	-190,90 to 588,62
LF/HF	4,38 +/- 2,45	4,35 +/- 2,42	0,13	-0,12 to 0,37
SD1 (ms)	44,03 +/- 27,89	44,08 +/- 28,04	0,6	-0,57 to 1,77
SD2 (ms)	111,48 +/- 43,57	112,44 +/- 42,11	4,8	-4,61 to 14,20
SD2/SD1	3,04 +/- 1,52	3,08 +/- 1,50	0,21	-0,20 to 0,63

*Bias: Difference between ECG and Polar parameters. LoA: 95% limits on bias. SDRR, standard deviation of all RR intervals; RMSSD, root mean square of differences; SD1 represents the dispersion of the points along the line of identity and is thought to be an index of the instantaneous beat-to-beat variability of the data; SD2 represents the dispersion of the points along the line of identity and is thought to represent the slow variability of heart rate; LF, low frequency; HF, high frequency; nu, normalized unit (% LF + HF); TP, Total Power. **Significantly different from the ECG parameter (p<0.05).*

TABLE 2. Heart rate variability parameters obtain from the electrocardiogram (ECG) and medium corrected Polar Team Pro (Polar M) signal (means +/- SD), bias, and limit of agreement (LoA).

	ECG	Polar M	Bias	LoA
Mean RR (ms)	1962,53 +/- 226,08	1960,91 +/- 224,62**	2,59	-2,48 to 7,65
SDRR (ms)	86,41 +/- 32,03	85,99 +/- 29,99	3,97	-3,81 to 11,75
RMSSD (ms)	62,05 +/- 39,29	60,55 +/- 35,63*	5,53	-5,31 to 16,37
LF (n.u.)	76,77 +/- 12,46	76,63 +/- 12,58	0,93	-0,89 to 2,75
HF (n.u.)	23,23 +/- 12,46	23,36 +/- 12,58	0,93	-0,89 to 2,75
TP (ms^2)	8291,66 +/- 6691,41	8108,37 +/-6296,30	632,79	-607,48 to 1873,07
LF/HF	4,38 +/- 2,45	4,35 +/- 2,38	0,39	-0,36 to 1,11
SD1 (ms)	44,03 +/- 27,89	42,98 +/- 25,30*	3,93	-3,77 to 11,62
SD2 (ms)	111,48 +/- 43,57	111,54 +/- 41,25	5,43	-5,21 to 16,08
SD2/SD1	3,04 +/- 1,52	3,08 +/- 1,49	0,21	-0,20 to 0,63

*Bias: Difference between ECG and Polar parameters. LoA: 95% limits on bias. SDRR, standard deviation of all RR intervals; RMSSD, root mean square of differences; SD1 represents the dispersion of the points along the line of identity and is thought to be an index of the instantaneous beat-to-beat variability of the data; SD2 represents the dispersion of the points along the line of identity and is thought to represent the slow variability of heart rate; LF, low frequency; HF, high frequency; nu, normalized unit (% LF + HF); TP, Total Power. **Significantly different from the ECG parameter (p<0.05). * Tendency to a difference from the ECG parameter (p<0.1)*

Discussion

The purpose of this study was to compare the RR interval signals of the Polar Team Pro with RR intervals of the ECG. The results show that the recordings obtained with the Polar Team Pro seem to be consistent with those recorded by the ECG. The rest method used in this study, specific to horses, seems correct. One hour of recording helps stabilize the psychological state of horses and reduces the risk of artefact.

A significant difference in RR intervals, on uncorrected and corrected, is detected ($p < 0.05$ for both). Several studies also show the same result (Gamelin & al 2006, Giles & al 2016). This difference is minimized by bias and low limits of agreement, less than 20ms (see Table 1 and 2).

Adding a correction to the Polar Team Pro signal increases bias and limits of agreement. Even if these statistics remain relatively low and acceptable (bias = 2.59, LoA between -2.49 and 7.65), this suggests that the addition of a filter decreases the accuracy of the Polar Team Pro signal. Unlike humans and pigs, studies show that the addition of a filter is beneficial for the validation of the Polar measurement (Marchant-Forde & al 2004, Gamelin & al 2006). But in some species like the dog, filter additions to remove artefacts are not effective. Indeed, according to Jonckheer-Sheehy & al (2012), the filters exposed in HRV analysis software are not recommended for dogs, as these filters are designed to detect abnormalities in human ECG data. In our study, the maximum RR interval difference in ECG signal over a 5 min data range may vary from an average of 464ms, and from a minimum of 150ms to a maximum of 756ms depending on the horse. A very low correction (correction if the RR interval differs by more than 450ms from the previous one) can already modify the signal recorded in some horses. These filters are probably not valid for horses, as the difference between RR intervals is greater than those reported in humans or pigs.

No significant differences were found in HRV time domain, frequency domain, and nonlinear analysis, except for RMSSD and SD1 with M correction. One possible explanation for this difference is that RMSSD and SD1 are indices of the short-term variability of the parasympathetic system. Therefore, it is more sensitive to the small variations in the RR intervals between the Polar Team Pro and the ECG (Gamelin & al 2006).

In conclusion, the low bias and the reduced limits of agreement indicate that the use of the Polar Team Pro as a measure of the variability of the resting heart rate in the horse seems acceptable. A recording of a horse in stable for one hour, away from all stimuli, allows to obtain stable state data and reduce the presence of artefact. Special attention should be paid to the use of filters to counter artefacts in horses, due to the use of software for the human species. The set of calculated HRV parameters seem similar between the Polar Team Pro and the ECG, additional studies can be performed to describe the relevance of each parameter in the study of cardiac variability.

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