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Comparison of Polar® RS800CX heart rate monitor and electrocardiogram for measuring inter-beat intervals in healthy dogs

Ann Essner [a,b,*], Rita Sjöström [c,d], Erik Ahlgren [b], Pia Gustås [e], Laurie Edge-Hughes [f], Lena Zetterberg [a], Karin Hellström [a]

[a] Uppsala University, Department of Neuroscience, Uppsala, Sweden
[b] Evidensia Djurkliniken Gefle, Gävle, Sweden
[c] Strömsund Health Centre, Jämtland County Council, Strömsund, Sweden
[d] Department of Health Sciences, Mid Sweden University, Östersund, Sweden
[e] Swedish University of Agricultural Sciences, Uppsala, Sweden
[f] The Canine Fitness Centre, Calgary, Canada

HIGHLIGHTS

- Series of inter-beat intervals from Polar® RS800CX were compared to electrocardiogram.
- Polar® RS800CX validity and reliability measures varied in the dogs studied.
- Polar® RS800CX agreement varied in the dogs studied.
- Detection of measurement errors is fundamental.

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ABSTRACT

The aim of the present study was to assess the criterion validity, relative reliability and level of agreement of Polar® RS800CX heart rate monitor measuring inter-beat intervals (IBIs), compared to simultaneously recorded electrocardiogram (ECG) in dogs.
Methods: Five continuous minutes of simultaneously recorded IBIs from Polar® RS800CX and Cardiostore ECG in 11 adult healthy dogs maintaining standing position were analyzed. Polar® data was statistically compared to ECG data to assess for systematic differences between the methods. Three different methods for handling missing IBI data were used. Criterion validities were calculated by intraclass correlation coefficients (ICCs) and corresponding 95% confidence intervals (CIs). Relative reliabilities and levels of agreement were calculated by ICCs and the Bland and Altman analysis for repeated measurements per subject.
Results: Correlation coefficients between IBI data from ECG and Polar® RS800CX varied between 0.73 and 0.84 depending on how missing values were handled. Polar® was over- and underestimating IBI data compared to ECG. The mean difference in log transformed (base10) IBI data was 0.8%, and 93.2% of the values were within the limits of agreement. Internally excluding three subjects presenting IBI series containing more than 5% erroneous IBIs resulted in ICCs between 0.97 and 0.99. Bland and Altman analysis ($n = 8$) showed mean difference was 1.8 ms, and 98.5% of the IBI values were plotted inside limits of agreement.
Conclusion: This study showed that Polar® systematically biased recorded IBI series and that it was fundamental to detect measurement errors. For Polar® RS800CX heart rate monitor to be used interchangeably to ECG, by showing excellent criterion validity and reliable IBI measures in group and individual samples, only less than 5% of artifacts could be accepted.

1. Introduction

Heart rate variability (HRV) is defined as the variability of time intervals in consecutive heart beats. Fluctuations between heart beats are caused by autonomic cardiac modulations, mainly via increased sympathetic or reduced vagal activity in efferent nerves, to the sinoatrial node of the heart. By analyzing fluctuations in series of inter-beat intervals

* Corresponding author at: Evidensia Djurkliniken Gefle, Norra gatan 1, SE - 803 21 Gävle, Sweden. Tel.: +46 70 6927562; fax: +46 26 10 63 18.
E-mail address: ann.essner@gmail.com (A. Essner).

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(IBIs), various parameters are indicating modulations and activity in the autonomic nervous system [1,2].

Heart rate variability analysis has been used as a quantitative marker of autonomic activity in behavioral, clinical and experimental research in humans [3,4] and different animal species [5–7]. The interplay between the sympathetic and the parasympathetic nervous systems is complex and HRV analysis allows detailed information about modulations in the autonomic nervous system [2].

Performing HRV analysis requires a series of normal-to-normal IBIs. One IBI is the time in milliseconds (ms) between two consecutive R-peaks, in an electrocardiogram (ECG) or in a heart rate monitor, such as a Polar® RS800CX. The equipment of choice depends on the purpose of the examination, if the subject is at rest or ambulatory, or whether the recording is supposed to be short-term or long-term (24 h). In order to standardize studies on short-term HRV analysis, IBI series of 5 min has been recommended [1,2].

The cost and complexity of ECG have made HRV analysis difficult outside laboratory environment. Although, in the last two decades a number of studies have used different Polar® heart rate monitors to record cardiac activity in dogs [8–12], horses [13,14] and sheep [7,15] during physical exercise, to evaluate the level of stress and under the influence of pain.

As changes in cardiac activity are influenced by psychological and emotional states there are potential clinical applications for short-term HRV parameters as outcome measures for the relief of pain and/or stress in humans [16,17] and animals [18]. Within the field of canine behavioral science, a growing number of professionals and scientists are including physiological outcome measures such as heart rate and short-term HRV analysis to report autonomic responses [6,19–23]. The relationship between short-term HRV parameters and the level of stress [12,24], responses to human–dog contact [19,21] and physical as well as mental activities [23] have been studied in dogs of various breeds and of differing ages.

In addition, HRV has been used as an outcome measure in various physical interventions and exercise regimens for the possible effect on the autonomic nervous system in humans [25–27] and in dogs [28].

Different Polar® heart rate monitors have been tested for validities and reliabilities, against ECG, for recording short-term HRV data in humans [29–32], dogs [33,34] and horses [35,36]. Results are conflicting and researchers have raised concerns whether Polar® heart rate monitors should be used interchangeably with ECG [35,37,38]. The time- and frequency-based parameters in HRV analysis may easily be biased by measurement errors in IBIs. It is recommended to assess the accuracy of IBI measurements from a device designed to record IBI series by comparing to a gold standard method (i.e. ECG) [1]. Preferably only segments of IBIs that are completely free from error and/or non-sinus beats should be included in an HRV analysis. Marchant-Forde et al. [37] presented that even a small amount of errors in IBI data may bias the outcome of time- and frequency-based parameters of an HRV analysis in five pigs. The Polar® RS800C heart rate monitor has also been shown to present errors in IBI data in dogs [33]. Some of the errors may be explained as artifacts originating from interruption of the transmission of the cardiac signal or distortions from a burst of physical activity. Yet, there are errors described that are unexplainable and therefore the criterion validity of Polar® heart rate monitors has been questioned [33,37]. The error detection process is fundamental as a small amount of errors may seriously affect HRV analysis parameters. Von Borell et al. [2] suggest that IBI series containing more than 5% errors, should not be included in HRV analysis.

Recently two studies have shown that Polar® RS800CX heart rate monitor is valid and reliable for measuring heart rate, defined as heart beats per minute, in dogs [33,34]. Jonckheer-Sheehy et al. [33] identified a number of errors in Polar® data from a homogeneous group of ten Beagle dogs, and showed there were no significant differences between either time- or frequency-domain data collected from Polar® RS800CX and ECG. However, to the authors' knowledge, there is a lack of research on the validity and reliability of Polar® RS800CX for measuring IBIs in dogs. The data accumulated to date, suggest there is more to assess before Polar® RS800CX may be used interchangeably with ECG for recording IBI data and performing HRV analysis in dogs. If the Polar® RS800CX heart rate monitor is valid and reliable in measuring IBIs in dogs there are obvious potential benefits in using the Polar® device instead of ECG. The Polar® RS800CX is easily accepted by dogs and is less expensive than ECG, and thereby potentially useful for collection of IBI data for further analysis of HRV parameters in clinical settings such as canine physiotherapy units or in veterinary facilities. The accuracy of the Polar® RS800CX remains to be determined before considering any further clinical application of HRV analysis.

The objectives of the present study were to assess the criterion validity, relative reliability and level of agreement of Polar® RS800CX heart rate monitor measuring IBIs, compared to simultaneously recorded ECG, in dogs during stationary standing position.

2. Methods and materials

2.1. Study design

This study was an observational study with a methodologically standardized approach [39]. One group of dogs, on a consecutive sample, was studied with the objective to compare simultaneously recorded IBI data from two measurement devices. A priori power analysis, conducted before data acquisition to the present and a previously published article [34], showed that eight to ten dogs were required to detect true differences and avoid the occurrence of type II errors, when implementing the study.

2.2. Study group

Data from eleven (six female and five male) dogs from various breeds, with mean ± standard deviation (SD) age of 3.8 ± 1.3 years and mean ± SD weight of 29.9 ± 7.2 kg were included in the study. None of the dogs had a history or current evidence of cardiovascular or systemic diseases, as assessed by a veterinarian. None of the dogs seemed to react with aggression or fear during the study. As the dogs were privately owned, the owners were informed as to the procedures and objectives of the study and informed owner consent was obtained. The study was approved by the Local Ethical Committee in Uppsala, Sweden (C81/12).

2.3. Data acquisition

Two IBI recording devices were applied to the dogs. Polar® RS800CX (Polar® Electro Oy), consisted of electrode belt and transmitter W.I.N.D. and heart rate monitor RS800CX. The electrode belt and transmitter supported recording and processing of IBIs at a frequency of 1000 Hz and 2.4 GHz transfer between the belt and heart rate monitor. The coat was clipped at all electrode sites and the skin was cleaned with alcohol and air-dried. Cefar® electrode transmission gel (Cefar-Compex Scandinavia AB) was applied liberally to promote conductivity. The electrode belt was strapped around the chest of the dogs with the transmitter placed ventrally and the electrodes on each side of the sternum. Cardiostore digital ECG (Vetronic Services Ltd.) was attached by three adhesive ECG electrodes (Kruuse Svenska AB). Electrodes were placed: 1) on the right side of the thorax, slightly caudal and dorsal to the point of the elbow and caudal to Polar® electrode belt, 2) on the left side of the thorax in level with the xiphoid process of sternum and at the lowest point on the side of the dog without being ventral and, 3) at the dorsal side of the neck (Fig. 1) [40]. The ECG recorded cardiac activity at a frequency of 600 Hz.

One person was responsible for all measurements. The dogs came from their routine activities and were fed not less than 2 h before the