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Individually Coded Telemetry: a Tool for Studying Heart Rate and Behaviour in Reindeer Calves

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Eloranta E, Norberg H, Nilsson A, Pudas T, Säkkinen H: Individually coded telemetry: a tool for studying heart rate and behaviour in reindeer calves: Acta vet scand. 2002, 43, 135-144. – The aim of the study was to test the performance of a silver wire modified version of the coded telemetric heart rate monitor Polar Vantage NV^{TM} (PVNV) and to measure heart rate (HR) in a group of captive reindeer calves during different behaviour. The technical performance of PVNV HR monitors was tested in cold conditions (-30 °C) using a pulse generator and the correlation between generated pulse and PVNV values was high (r=0.9957). The accuracy was tested by comparing the HR obtained with the PVNV monitor with the standard ECG, and the correlation was significant (r=0.9965). Both circadian HR and HR related to behavioural pattern were recorded. A circadian rhythm was observed in the HR in reindeer with a minimum during night and early morning hours and maximum at noon and during the afternoon, the average HR of the reindeer calves studied being 42.5 beats/min in February. The behaviour was recorded by focal individual observations and the data was synchronized with the output of the HR monitors. Running differed from all other behavioural categories in HR. Inter-individual differences were seen expressing individual responses to external and internal stimuli. The silver wire modified Polar Vantage NV^{TM} provides a suitable and reliable tool for measuring heart rate in reindeer, also in natural conditions.

heart rate; measuring technique; method; individual coding; reindeer; behaviour; circadian.

Introduction

Changes in the environment, caused by nature or man, stress wild animals and threaten their well-being causing anything from discomfort to death. The reindeer (*Rangifer tarandus tarandus* L.) is a semi-domesticated free-ranging ruminant living under harsh environmental conditions and it is subject to a wide variety of thermal and nutritional stressors during the natural seasonal cycle. In northern Finland, Sweden and Norway reindeer husbandry is an important livelihood with approx. 500 000 productive animals. Reindeer management practices, such as herding, handling, restraint, transport and slaughtering induce additional stress responses and may adversely affect the animals' welfare. Due to the rapid development in management practices it has become important to study the behavioural and physiological changes associated with stress in these animals to be able to assess their welfare.

Heart rate (HR) changes in relation to behaviour and the environment have earlier been monitored e.g. in sheep (*MacArthur et al.* 1979), white-tailed deer (*Moen* 1978, *Mautz & Fai*r 1980), mule deer (*Kautz et al.* 1981), and red deer (*Price et al.* 1993). The HR of the reindeer has been measured earlier from anaesthetised animals during heart catheterizations (*Timisjärvi* 1978), and by using subcutaneous electrodes connected to a graphic recorder (*Timisjärvi et al.* 1979, *Nilssen et al.* 1984). *Mesteig et al.* (2000) applied silver wire modified non-coded Polar® Sport Testers (PST) to measure HR telemetrically from 2 reindeer. However, there is still a lack of knowledge relating to the HR variation and associated behavioural patterns of reindeer.

When studying the normal HR on a daily basis, it is important to keep the environmental factors, such as the group structure, as constant as possible and to minimize human activities to prevent disturbing stimuli. To be able to evaluate the stress and welfare of the animals with HR, it has become evident that the changes in HR over the 24-h period and also during normal behaviour have to be monitored.

The aim of this study was to test the performance of a silver wire modified version of a coded telemetric HR monitor Polar® Vantage NV™ (PVNV; Polar Electro Oy, Kempele, Finland) and its applicability in behavioural studies. We also describe the daily rhythms of HR in unrestrained captive reindeer calves.

Materials and methods

Animals and experimental design

The study was carried out during March 1997 and February 1998 at the Zoological Gardens of the Department of Biology, University of Oulu (65°04'N, 25°30'E), Finland. Reindeer calves, aged 6 to 7 months, were brought from natural pastures and allowed at least 2 months habituation in the Zoological Gardens prior to the experiments. The calves were kept outdoors in about 650 m^2 pens and they were offered a mixture of lichen (*Cladina* spp.), mixed with leaves (*Salix* spp.) and shrubs *(Vaccinum myrtillus) ad lib.* Feeding took place twice a day: one-third of the ration in the morning and the rest at noon. Fresh water was available *ad lib.* The health status of the reindeer was checked by the Oulu university veterinary.

In 1997, 8 calves, weight on average 43.6 kg (range 39.9-45.9 kg), were kept in 2 equal groups to enable simultaneous individual observations. Prior to the study the reindeer had taken part in an experiment involving behavioural studies, weighing and blood sampling (*Nilsson et al.* 2000). The calves were maintained in their original groups (control and restricted diet) of the previous study, thus the social hierarchy of the groups was established. The HR and behaviour were monitored on 4 occasions altogether ca. 5 h including 1) a 20-min period after installation of the HR monitors, 2) a 30-min undisturbed period, 3) a 60-min period starting 15 min before feeding and 4) a 60-min period starting 15 min before a 15-

Table 1. Definitions of different behaviour categories recorded via focal observations in the study.

Behaviour	Definition
Lying	Lying passively
Standing	Standing passively
Locomotion	Moving, walking or running
Running	Constant running under human harassment
Eating	Animal inside the feeding area ingesting feed or water from the grip or chewing and masticating feed close to the feeding area
Ruminating	Ruminating lying; refining a regurgitated food bolus

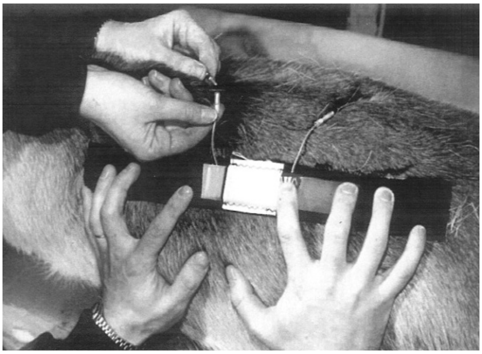

Figure 1. The electrodes were inserted under the skin and the transmitter was attached to 'rip-strip' tape, which was placed parallel to the vertebral column. The other side of the tape was glued to the hair. There was a joint in the middle of the wire to protect the skin. Photo by Harri Nurminen.

Figure 2. The wrist monitor was attached to the collar and the transmitter to the fur. An elastic band was used to secure the attachment of the transmitter. Photo by Harri Nurminen.

min running period and continuing 30 min after. Running was provoked by human harassment. The behaviour of each animal in the group was recorded by focal observations at one-minute intervals using the categories defined in Table 1. The HR and the behaviour were connected by synchronizing the focal observation data with the output of the HR monitors. In addition to the experiments with the calves one 1.5-year-old female reindeer was used to test the accuracy of the PVNV in October 1997.

In 1998 the circadian HR data of 6 calves (weight on average 38.9 kg (range 35.8-42.1 kg)) was recorded using the PVNV. Prior to this study these animals were treated as the control group in an experiment conducted by *Åhman et al.* (in press). HR was recorded continuously at one-min intervals for 72-74 h and 50 consecutive hours of the data were extracted for presentation. The mean and mode were calculated over one 24-h period. Circadian HR is presented as 15-min averages for 6 calves.

During trials in March 1997 the outdoor temperature was, on average, -3,2ºC (-10.8 - +3,6ºC). For 1998 the outdoor temperature is presented in Fig. 5.

The heart rate monitoring device

The transmitter belts and the wrist receiver monitors Polar® Vantage NV™ with individual coding were installed on the reindeer calves. The animals were restricted on the treatment bench by hand, and no sedatives were used. Silver needle electrodes connected to the transmitter were used in order to make contact with the skin. The electrodes were inserted subcutaneously using local anaesthetic (Xylocain 20 mg/ml) and an 18-G needle leading the electrode through a fold of the skin. The first electrode was placed behind the scapula and the second about 30 cm posterior to the first. The pelage was cut down to 1 cm hair length on a 3 cm × 30 cm area parallel to the vertebral column and one half of a 'rip-strip' tape was glued on. The transmitter was attached to the other half of the tape. There was a joint in the middle of the electrode lead to protect the skin in case of external tension in the lead (Fig 1).

In the PVNV the HR signal is telemetrically transmitted within a range of 50 cm to the wrist monitor, which in the present study was attached to the collar (Fig. 2). The receiver monitor calculates the HR, based either on the beat-to-beat interval or a beat-to-beat time-averaging algorithm, at 5-, 15- or 60-s intervals. According to the manufacturer's information the memory capacity of the wrist monitor is 134 h with averaging at 60-s intervals. However, in this study the maximal recording capacity acquired with PVNV monitors at 60-s intervals was only 99 h and 59 min. The HR data was transferred to a computer by Polar Precision Performance Software™ for Windows® (Polar Electro Oy, Kempele, Finland) for further analysis.

Accuracy tests for heart rate measurement

Electrocardiogram (ECG) and HR measured with PVNV were compared in one 1.5-year-old female reindeer. The electrocardiogram was recorded with a three channel direct-writing recorder (Mingograph Minor 3, Siemens-Elema, Stockholm). The standard limb leads I, II and III and the augmented unipolar limb leads aVR, aVL, and aVF were recorded with subcutaneous needle electrodes. The reindeer was sedated with Zalopine (Orion, Finland, 10 mg/ml; 50 µg/kg BW) and the pulse rate during anaesthesia was increased with adrenalin i.v. (10 mg/ml; 50 μg/kg BW). Antisedan (Orion, Finland, 5 mg/ml; 200 μg/kg BW) was used as the antidote for the anaesthetic and ECG recording was continued until the animal recovered. Simultaneously with ECG recording the PVNV transmitter and the wrist monitor were used to record the HR data at 5-s intervals to compare this data with the ECG. To investigate whether the variations in PVNV values reflect the variability in beat-to-beat variation, a period of 80 successive beat-to-beat intervals was extracted from the ECG data and the intervals were compared.

To test the accuracy of the PVNV in cold temperatures, the technical performance of 8 PVNV receiver monitors was tested according to the method described by Hopster and Blokhuis (1994). Each monitor was exposed to a temperature of -30 °C in a freezer, and to room temperature (20 °C). The transmitter was connected to a pulse generator, which generated an electrical pulse with an amplitude of 2 mV and duration of 70 ms. The frequency of the pulse could be varied manually from 0 to 500 beats per minute (bpm). Each monitor computed the average HR values at 5-s intervals. The frequency of the simulated heartbeat was adjusted stepwise according to Fig. 3.

Statistical analysis

Relationships between monitor performances at different temperatures and between the ECG and PVNV equipment were described using Pearson's correlation coefficient. Differences in HR between behaviour categories were compared by calculating behaviour-specific means for each animal, and after log-transformation, running one-way ANOVA followed by Tukey test *post hoc*. HR values 20 min after installation were excluded from the behaviour-specific analysis, because the installation interfered with the behaviour and increased the HR of the study animals. Statistical testing was carried out using SPSS statistical software.

Results

Accuracy

Data from ECG recording was processed using the QRS complex, which represents ventricular activity, and measuring the consecutive RR-intervals in milliseconds. The RR-interval measured by ECG correlated significantly (r= 0.9965) with the values measured by PVNV. The generated pulse rate values and respective PVNV values during the cold trial were also

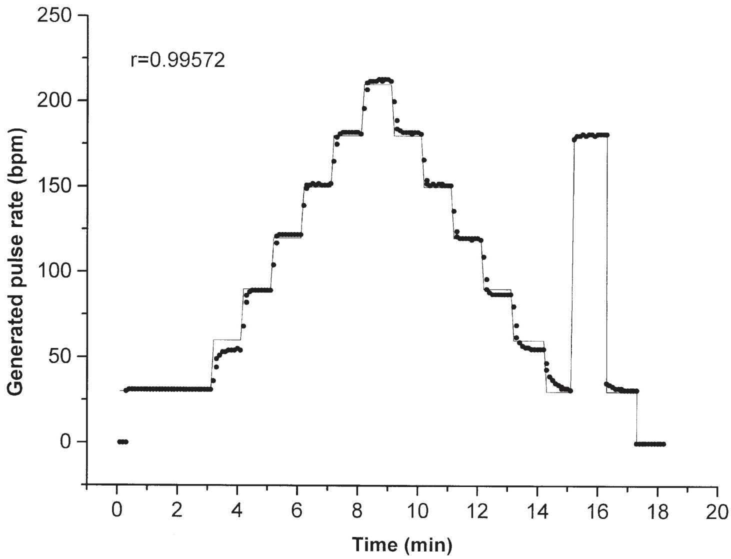

Figure 3. Generated pulse rate (solid line) and respective pulse rates measured using PVNV (dotted line) in the cold (-30°C). PVNV (n=8) followed stepwise changes of the generated pulse rate with a small lag, but with high association as measured by the correlation coefficient.

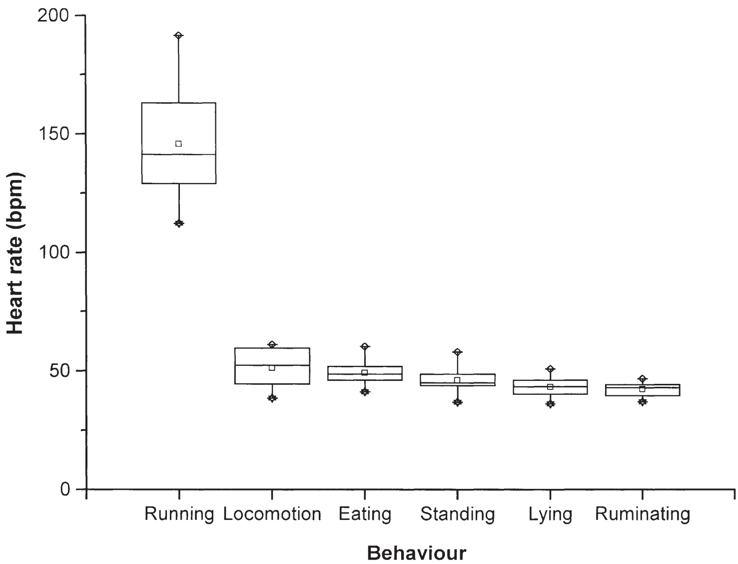

Figure 4. The heart rates of 8 reindeer calves in relation to different behaviour categories. Data for each behaviour category has been calculated as an average of individual mean values. The box-plot presentation shows the standard median, and 10, 25, 75 and 90 percentiles. The square plot presents the average and the outermost plots 1 and 99 percentiles, and minimum and maximum values, respectively.

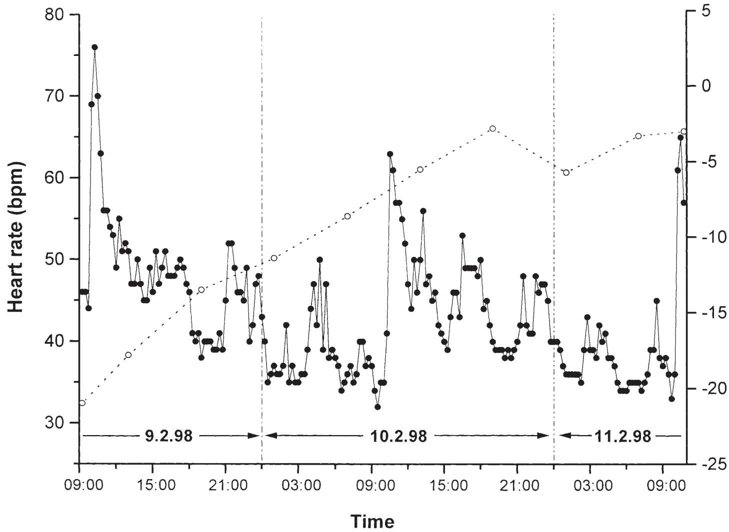

Figure 5. The average heart rate of 6 female reindeer calves measured with the PVNV. The dots are represented at 15-min intervals as an average of 15 measurements per animal. The original heart rate data was collected at one-min intervals. Heart rates were recorded during the weekend of 9-11 February 1998 at the Zoological Gardens of the University of Oulu. The total time span is 50 h. The ambient temperature during the study is presented with a dotted line.

highly correlated (r=0.9957; Fig. 3). The equipment coded the pulse rate with the same accuracy both in the cold (-30 °C) and at room temperature (r=0.9999).

Behavioural studies

The average HR in running was 146 bpm, in locomotion 52 bpm and in other behaviour categories between 42-49 bpm. HR in running was significantly ($p<0.001$) higher compared to HR in all other behaviour categories (Fig. 4). The mean HR and the standard deviation of HR associated with ruminating were lowest of all the studied behaviour categories. Individual variation in HR was observed throughout the study. The recovery time of HR after the provoked running varied individually between 2-12 min.

Circadian heart rate variation

The peaks in circadian HR, i.e. in 24-hour rhythm, were observed around noon, whereas HR was lowest in the early morning hours (Fig. 5). HR fluctuation reflected the level of activity, with the peaks being related especially to feeding times. The circadian HR recorded from six calves during one day on February 10th 1998 was on average 42.5 beats min^{-1}. The mode of those 8640 HR values (one value/animal/min) recorded was 35 beats min^{-1}. This means that the frequency distribution of circadian HR-values was skewed, low values being dominant.

Discussion

Only a few techniques are available for monitoring the HR of free-ranging animals and the literature about the reliability of HR meters under field conditions is scarce. In this study the

PVNV was tested at +20 and –30 °C and no difference in accuracy was observed due to the temperature. A clear time lag was observed between the generated pulse rate and the PVNV values, indicating a gradual adaptation to changes in generated pulse rate. PVNV adjusts to changes in the pulse rate in about 5 s but the lag varies with the pulse rate. The correlation was 0.9957, which was slightly higher than the correlation measured by Hopster and Blokhuis (1994).

PVNV HR monitors operate on the recognition of the QRS complexes of the ECG. Earlier studies have shown that telemetric HR meters provide valid readings on both precision and accuracy in children and adults in a wide variety of exercise, and also that the system is not significantly affected by electrical noise artefacts or muscle contraction (*Karvonen et al.* 1984, *Treiber et al.* 1989, *Seaward et al.* 1990). In this study, values from the tested PVNV monitors correlated significantly with the HR measured from the standard ECG in the reindeer. The suitability of a modified version of the Polar® Sport Tester (PST) with stainless steel plate electrodes has been tested successfully in the horse (*Ewans & Rose* 1986, *Sloet van Oldruitenborgh-Oosterbaan et al.* 1988) and dairy cows (*Hopster & Blokhuis* 1994). PST with plate electrodes has been applied on the reindeer as well (Nilsson unpubl.). In these studies some problems with proper skin contact in moving animals have been reported. Recently a silver wire modified PST was used in reindeer (*Mesteig et al.* 2000). To our knowledge the use of a coded PVNV monitor has not been published before in fur coated animals.

The correlation between ECG and PST monitor has been shown to decrease in exercise which, according to *Hopster & Blokhuis* (1994), is due to movements of the plate electrodes on the skin. When using plate electrodes, up to 30% of the data has been lost due to poor skin-electrode contact (*Baldock et al.* 1987, *Price et al.* 1993). The use of plate electrodes demands contact on the bare skin and wetting of the electrodes or electrode gel is required. This method exposes the skin to frostbite in a cold environment. The advantage of subcutaneous electrodes was demonstrated in this study since only 2% of the data was missing either due to poor skin-electrode contact or problems in transmitting the signal. In addition no frostbite was observed and minor skin damage was found only in one study animal. Right after the installation of the HR monitors reindeer were seen to shake themselves and try to lick the transmitter, but no further disturbance due to the equipment was observed. The silver needle electrodes used in this study proved to be a practical solution taking into account both the contact performance and function in the cold environment.

Great care should be exercised when preparing and installing the wires for silver electrodes. In nine cases of all individual observation periods (28%) the data was lost due to equipment related problems. Typically the wires were broken due to the non-elastic material, which did not tolerate continuous back-and-forth movement. Alternatively, the reindeer were seen to lick and chew the wires. These problems were reduced by switching the wires to silicon-coated material, which was more flexible and easier to hide in the fur. The method has been further improved by developing a harness including both the transmitter and the receiver with the wires inside.

Earlier studies on cows have shown that monitors located at 0º and 180º angles to the transmitter do not receive the signal properly, but do at other angles (*Hopster & Blockhuis* 1994). In the present study the monitors were attached to the collar close to the 0º angle in relation to the transmitter, but there were only occasional problems in receiving the signal. The individual coding of the monitor was also lost a few times.

HR as a study parameter was successfully related to different behaviour patterns in the present study. In addition to behaviour-associated changes in HR, inter-individual differences in animals' responses were also seen. Individual variations in HR levels and recovery times were pronounced during and after human disturbance, but were substantially reduced during ruminating. Respective results have earlier been presented by *MacArthur et al.* (1979) in bighorn sheep *(Ovis canadensis)*. Both low inter-individual and within-individual variation in HR levels related to ruminating probably resulted from low sympathetic and increased parasympathetic activity during this behaviour. In the present study the environmental stress was minimized because of the animals' adaptation to the daily routines of the Zoological Gardens. Also, the social hierarchy of the groups was well-established prior to the study.

The present results show that there is a circadian rhythm in the HR of reindeer with a minimum occurring during the night and early morning and maximum at noon and during the afternoon. This pattern supports the idea that the reindeer is a diurnal species. According to *Collins & Smith* (1989) reindeer in the Seward Peninsula, Alaska, allocated more time for resting during the night than during the day in February-March. Also *Erkinaro et al.* (1983) observed a similar pattern in the activity of semi-domestic reindeer in Finnish Lapland. These results on circadian activity budgets are in good accordance with HR data presented in this study where the average HR was lower during night hours. The clear increase in HR by noon in the present study was associated with enthusiasm and locomotion activity at the feeding places during feeding at fixed times. This presumably does not reflect the actual activity level in nature at these times. However, the cyclic rhythmicity recorded in HR corresponds to the 24-h activity observations obtained from natural grazing conditions (*Erkinaro et al.* 1983, *Collins & Smith* 1989).

Except for the elevated HR due to feeding activity, increased HR subsequent to feeding may also reflect increased blood flow to the gastrointestinal system (*von Engelhardt & Hales* 1977). *Mesteig et al.* (2000) have shown that there is a positive correlation in long term voluntary food intake and HR in the reindeer. Our results of circadian HR recorded in February correspond with winter values presented in earlier studies (*Nilssen et. al.* 1984, *Fancy & White* 1986). In this study no association was observed between HR and changing outdoor temperature (Fig. 5). This is in agreement with *Baldock et al.* (1988) who found that in sheep the correlation of HR was better with photoperiod than with temperature. However, climatic conditions have been shown to affect behaviour patterns in growing cattle (*Redbo et al.* 1996), which may lead to different HR levels. In addition to the circadian and circannual rhythms environmental factors must also be considered when interpreting HR measurements in reindeer.

The present results indicate that the telemetric Polar® Vantage NV™ HR monitor, which has been developed to record HR in humans doing sport or exercise, is also suitable for HR measurements in the reindeer in field conditions. The advantage that the present method offers is the possibility to study animal behaviour and HR variation with minimal human disturbance. Furthermore, the individual coding provides a new tool for monitoring individual HR in groups of animals simultaneously. This equipment provides a useful tool for monitoring the animals' responses to different environmental stimuli and e.g. energy expenditure in natural conditions. However, when employing HR as a measurement, great care should be emphasised in interpreting the results, since a wide variety of factors, both internal and external, affect the HR.

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Sammanfattning

Individrelaterad telemetri: ett verktyg vid studier av hjärtfrekvens och beteende hos renkalvar

Syftet med studien var att testa en silvertrådsmodifierad version av en kodad telemetrisk hjärtfrekvensmätare Polar Vantage NV™ (PVNV), och att mäta hjärtfrekvens vid olika beteende hos en grupp hägnade renar. Den tekniska prestanda av PVNV mätare testades i kyla (-30 °C) med en pulsgenerator och korrelationen mellan genererad puls och PVNV värden var hög (r=0.9957). Exaktheten hos PVNV mätare testades genom att jämföra uppmätt hjärtfrekvens med standard EKG och korrelationen var signifikant (r=0.9965). Såväl mönster i hjärtfrekvens som hjärtfrekvens relaterad till olika beteende studerades. Ett återkommande mönster i hjärtfrekvens observerades hos renar med minimum under natten och tidiga morgon timmar och maximum mitt på dagen och eftermiddagen, genomsnittet var 42.5 slag per minut för de studerade renkalvarna i februari. Djurens beteende studerades genom individuella fokal observationer och resultaten synkroniserades med värden från PVNV mätarna. Hjärtfrekvens när djuren sprang skilde sig från övriga beteende kategorier. Inomindividuella skillnader observerades och sågs som uttryck för olika individers respons på externa och interna stimuli. Den silvertrådsmodifierade versionen av Polar Vantage NV™ är en lämplig och tillförlitlig metod för att mäta hjärtfrekvens hos renar, även under naturliga förhållande.

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