Non-Invasive Body Temperature Measurement of Wild Chimpanzees Using Fecal Temperature Decline

RUNNING HEADING: SHORT COMMUNICATIONS

FULL TITLE:

NON-INVASIVE BODY TEMPERATURE MEASUREMENT OF WILD CHIMPANZEES USING FAECAL TEMPERATURE DECLINE

Siv Aina Jensen[1-3], Roger Mundry[1], Charles L. Nunn[1,4], Christophe Boesch[1] and Fabian H. Leendertz[1,2]

[1] *Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany*

[2] *Robert Koch-Institut, Berlin, Germany*

[3] *Norwegian School of Veterinary Science, Oslo, Norway*

[4] *University of California, Berkeley, USA*

CORRESPONDING AUTHOR:

Siv Aina Jensen

Robert Koch-Institut, NG2; Emerging Zoonoses

Nordufer 20

13353 Berlin

Germany

Phone: +49 1888 754 2592

Fax: +49 1888 754 2605

E-mail: JensenS@rki.de

ABSTRACT

New methods are required to increase our understanding of pathological processes in wild mammals. We developed a non-invasive field method to estimate the body temperature of wild living chimpanzees habituated to humans, based on statistically fitting temperature decline of faeces after defecation. The method was established using control measures of human rectal temperature and subsequent changes in faeces temperature over time. The method was then applied to temperature data collected from wild chimpanzee faeces. In humans we found good correspondence between the temperature estimated by the method and the actual rectal temperature that was measured (maximum deviation 0.22°C). The method was successfully applied and the average estimated temperature of the chimpanzees was 37.2°C. This simple-to-use field method reliably estimates the body temperature of wild chimpanzees and probably also other large mammals.

Key-words: health monitoring; wild great apes; wild chimpanzees; body temperature estimation; non-invasive method

Disease plays an important role in the demography of great apes, and health monitoring is a vital part of the conservation of these endangered species (Leendertz et al., 2006). In most cases, diagnosis of disease is restricted to observations of clinical signs and laboratory analysis of samples collected non-invasively. The development of non-invasive methods is therefore essential to improve health monitoring of wild great apes. Body temperature can be measured non-invasively with infrared equipment, but such equipment is expensive. Here we present a simple, inexpensive and reliable field method to estimate the body temperature of wild chimpanzees non-invasively.

The study was conducted in the tropical rain forest of Taï National Park (5°15’-6°07’N, 7°25’-7°54’W) in Côte d’Ivoire, where wild chimpanzees (*Pan troglodytes verus*) have been habituated to human presence. First, the method was established by 29 control measures performed on humans (one male and one female). Thereafter the method was applied to 31 faecal samples collected from visually healthy chimpanzees (17 samples from nine females; 14 samples from seven males).

For the human control measures, the rectal temperature was measured prior to defecation using a commercially available digital thermometer. Thereafter the data were obtained from both humans and chimpanzees in the same way and as follows. The exact time of defecation was recorded and approximately 100 grams of the faeces was collected from the ground as soon as practically possible and held in a gloved hand. Only well formed faeces deposited on the ground were included in the study. The sensor of the thermometer (a digital rectal thermometer or a digital thermometer [Data-Logger thermometer 306]) was placed in the middle of the faeces and held as still as possible during the measurements. The temperature was recorded approximately every 20 seconds or two seconds, with shorter intervals possible using the data-logging thermometer, over a period of at least six minutes. After the measurements were taken the glove was reversed, closed, and weighed with a digital scale. The net weight of the faeces and the environmental temperature were recorded.

Measured temperatures occasionally comprised outliers or unrealistic values, e.g. temperatures rapidly decreasing and later increasing again. Such curves might arise when the sensor opens a hole in the faecal sample, or when the sensor moves outside the sample. To exclude such outliers and unrealistic values from analyses, we used the following operational rule: A measure was excluded if a larger value occurred later in the sequence of measurements (Figure 1).

We used a sigmoidal equation to express temperature decrease as a function of time since defecation. The model we fitted was:

$$T_{(t)} = d + a*(1/(1+e^{(t-b)/c}))$$

where T indicates temperature, t the time since defecation, and a, b, c, and d are coefficients needed to describe the sigmoidal curve. More information on the equation, and a program to implement this method is freely available via the internet (https://diseasegroup.eva.mpg.de/mediawiki-1.6.5/index.php/Defecation) or via email contact with the authors. To evaluate the procedure we compared observed values of rectal temperature with those predicted by the method and related the differences to several covariates. We used standard non-parametric procedures chosen according to the rationales described in Siegel & Castellan (1988) for statistical testing. Tests and curve fits were calculated using SPSS 13.0.1 or a computer program written by R.M. for Spearman's rank correlation. When small samples required their use, we applied exact tests (Mundry & Fischer, 1998; Siegel & Castellan, 1988). Approximate P-values were based on 10,000 permutations for calculating the significance of Spearman's rank correlation coefficients.

Using the sigmoidal model on the human control measures we found a clear relationship between the temperature estimated and the actual rectal temperature that was measured (Spearman's rank correlation: r_S=0.62, N=29, P<0.01; Figure 2). The average (arithmetic mean) absolute deviation between estimates and actual rectal temperatures was 0.22°C (N=29). Fifteen of the estimates differed less than 0.12°C from the actual value, whereas only three differed by more than 0.5°C from the rectal temperature. Estimated temperatures did not obviously over- or underestimate rectal temperatures (Wilcoxon test: T^+= 262, N=29, P=0.35). Temperature estimates were not influenced significantly by sample weight (r_S=0.08, N=26, P=0.68) or environmental temperature (r_S=0.08, N=30, P= 0.70). Absolute deviations of the estimated temperature from the rectal temperature were neither related to sample weight (r_S=-0.13, N=25, P=0.53) nor to environmental temperature (r_S=0.27, N=29, P= 0.16). However, accuracy of temperature estimation in the human samples decreased with increasing interval between defecation and beginning of measurement (r_S=0.46, N=29, P=0.01; Figure 3). The measurements started on average 1.42 minutes (=mean; range 0.17 – 3.17) after defecation. Note that after the thermometer was first placed into the faecal sample, the temperature usually increased for several measurements. We took the point at which the temperature reached its maximum as the beginning of measurement. Accuracy decreased with decreasing number of measures obtained (r_S=-0.37, N=29, P=0.05), whereas total duration of measurement interval did not obviously influence accuracy (r_S=0.06, N=29, P=0.75).

The estimated temperature of the chimpanzees ranged from 34.6 to 39.5°C (excluding one value of 44.3°C, which was clearly outside physiological range). The average temperature of 16 chimpanzees was 37.2°C (figure 4). We found no significant difference in estimated body temperature between males and females (U=22, $N_{females}$=9, N_{males}=7, P=0.35). For the females, the temperature generally increased during the day, whereas this difference was not obvious in the males (Figure 5).

The weight of faecal samples did not differ significantly between chimpanzees (median 97 grams; range: 40 – 172) and humans (median 99 grams; range: 23 – 156) (Mann-Whitney U-test: U=352.5, $N_{chimpanzee\ samples}$=29, $N_{human\ samples}$=26, P=0.68). The temperature measurements of chimpanzee samples started on average 0.58 minutes after defecation (= median; range: 0.18 – 6.00).

In summary, our non-invasive method allows reliable estimation of the body temperature of wild living chimpanzees. The method is easy to perform and requires no expensive equipment, as only a commercially available digital thermometer is needed, in addition to subsequent access to a computer. In the human control measurements half of the body temperatures were estimated with an error of less than 0.12°C. To ensure the most accurate results from this method, it is important to start the measurements as soon as possible after defecation and to continue the measurement until the temperature curve "flattens out." The requirement for fresh faecal samples means, however, that the method is most applicable to human-habituated animals, such as the chimpanzees studied here.

The weight of the faeces did not influence the accuracy of the temperature estimation. Only adult chimpanzees were included in this study, however, as their faeces were most comparable in size to human faeces**.** The method has not yet been evaluated for use in younger chimpanzees with relatively smaller faeces, or in other species. Environmental temperature also did not obviously influence the accuracy of body temperature estimates. Conditions could be somewhat different in other field sites with different climatic conditions and habitats. If so, it would be useful to verify the correct measurement technique by performing human control measurement in local conditions.

Normal human rectal temperature ranges from 34.4 to 37.8°C (Sund-Levander et al., 2002), which shows that even for humans it is impossible to assign a single value as "normal" body temperature. We should therefore expect a similar variation in normal body temperature in wild great apes. Indeed, most of the body temperature estimates of the chimpanzees in this study were within the range of normal human temperature, with an average of 37.2°C. The very low end of the temperature estimate range could be explained by poor measurement techniques, although they are within normal range in humans. Any results could be retested if doubts emerge concerning the measurements. The estimated temperature should be evaluated together with behavioural data, since stress or activities such as hunting or fighting potentially produce a temporary increase in body temperature. It might be useful to know the usual range for an individual when he or she is healthy, so that a comparison can be made when illness occurs. We did not find any difference between the temperature of males and females in this study, but the numbers of samples might have been too low to detect a difference. Our study also showed that, at least for females, body temperature tends to be lower in the morning than later during the day. More data are required to confirm this pattern in wild primates.

When assessing the health status of individuals, veterinarians and field workers in many areas of great ape research could use temperature data to complement behavioural and reproductive data. Body temperature measurements can also be linked to the study of self-medication (Huffman, 2003) – e.g. to help identify the fever-reducing effects of certain plants – and more generally to increase our knowledge about sickness behaviour in primates, as few detailed reports are available (Nunn & Altizer, 2006). Lastly, data on body temperature can help to investigate disease outbreaks and, more generally, will increase our understanding of the effects of disease and fever on wild chimpanzees and other animals.

We thank the Ivorian authorities for long-term support, especially the Ministry of Environment and Forests as well as the Ministry of Research, the directorship of the Taï National Park, L'Office Ivoirienne des Parcs et Réserves, the Max Planck Society, and the Swiss Research Centre in Abidjan. We also thank the field assistants of the Taï Chimpanzee Project.

LITERATURE CITED

HUFFMAN, M. A. 2003. Animal self-medication and ethno-medicine: exploration and exploitation of the medicinal properties of plants. Proceedings of Nutrition Society 62(2):371-81.

LEENDERTZ, F. H., PAULI, G., ELLERBROK, H., MAETZ-RENSING, K., BOARDMAN, W., JENSEN, S. A., JUNGLEN, S., AND C. BOESCH. 2006. Pathogens as drivers of population declines: The importance of systematic monitoring in great apes and other threatened mammals. Biological Conservation 131:325-337.

MUNDRY, R., AND J. FISCHER. 1998. Use of statistical programs for nonparametric tests of small samples often leads to incorrect P-values: Examples from Animal Behaviour. Animal Behaviour 56: 256 - 259.

NUNN, C. L., AND S. ALTIZER. 2006. Infectious Diseases in Primates. Oxford University Press, Oxford, England, 384 pp.

SIEGEL, S., AND N. J. CASTELLAN. 1988. Nonparametric Statistics for the Behavioral Sciences (2nd ed.). McGraw-Hill. New York.

SUND-LEVANDER, M., FORSBERG, C., AND L. K. WAHREN. 2002. Normal oral, rectal, tympanic and axillary body temperature in adult men and women: a systematic literature review. Scandinavian Journal of Caring Science 16: 122-128.

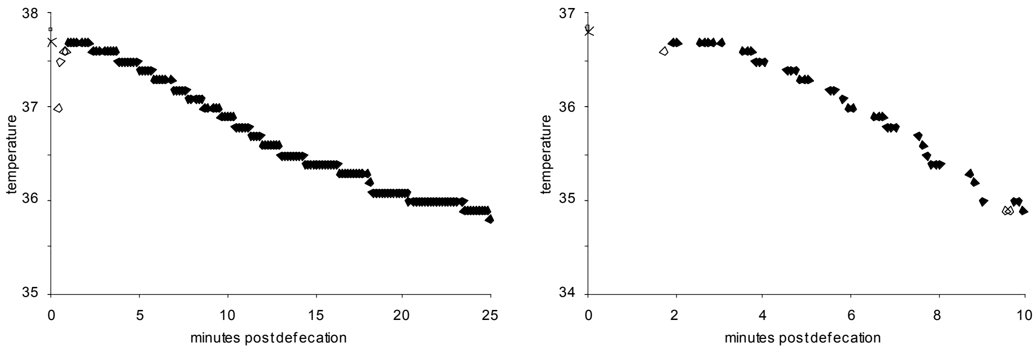

Fig.1. Temperature decrease of human feces samples over time. Indicated are measures (diamonds) of two samples (left and right), rectal temperature (crosses at time zero) and the temperature estimated using sigmoidal curve fitting (unfilled squares on the y-axis). Unfilled diamonds depict measures that were excluded prior to curve fitting since they were later followed by a larger measure (see text).

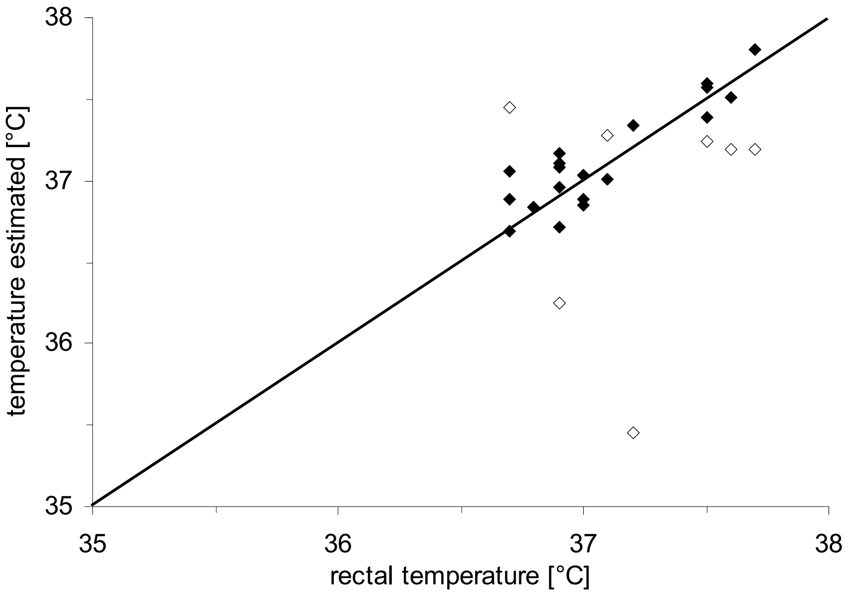

Fig.2. Relation between human rectal temperature and its estimation based on sigmoidal curve fitting. White diamonds denote samples for which measurement began more than two minutes after defecation. The diagonal line indicates the desired result (perfect fit).

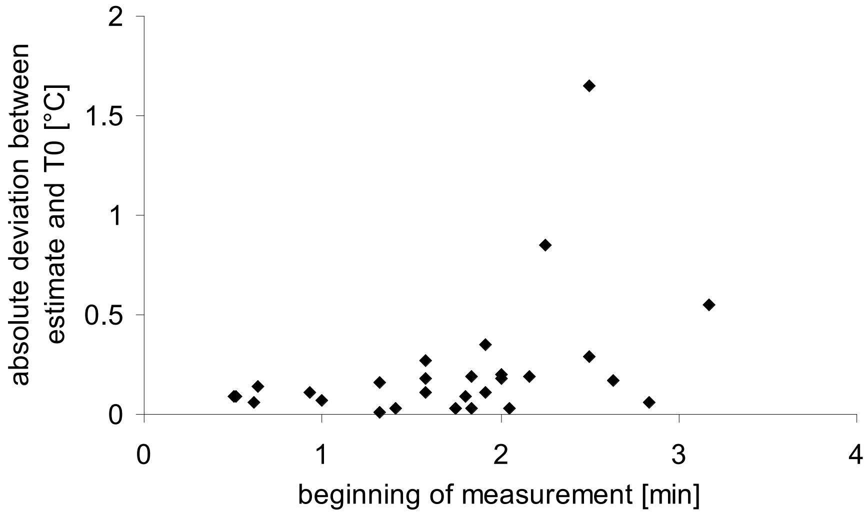

Fig.3. Relation between the absolute deviation of estimated human temperature from measured rectal temperature and the beginning of measurement.

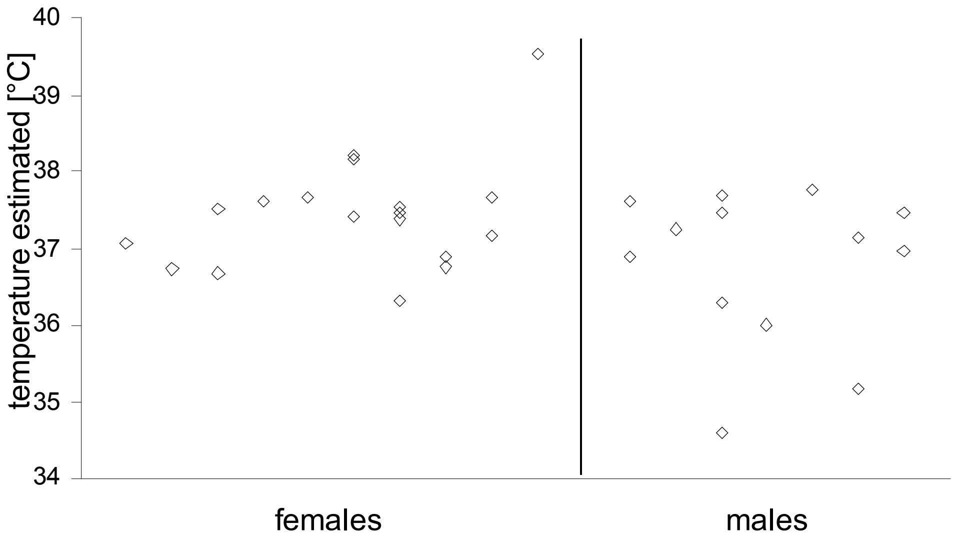

Fig.4. Temperature estimated for 17 chimpanzees. Values above one another are from the same subject.

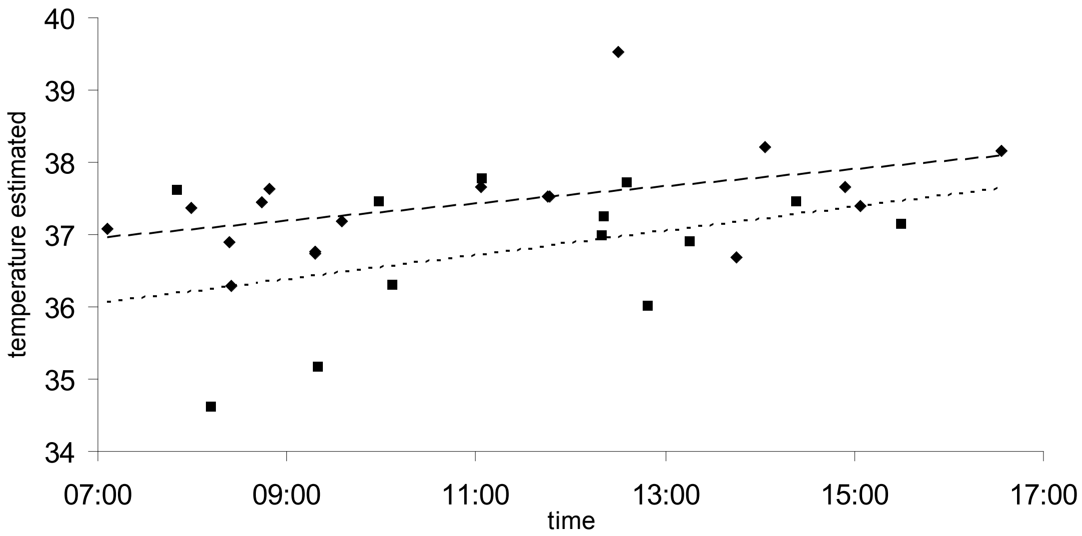

Fig. 5. Temperature of chimpanzees as estimated using the sigmoidal curve fitting approach and their variation with defecation time. Indicated are temperatures for females (diamonds, dashed line) and males (squares, dotted line). Lines were calculated using linear regression. Subjects were pooled. Rank correlation coefficients (with data pooled across subjects): Females: r_S=0.53, N=18, P=0.022; Males: r_S=0.14, N=13, P=0.64.