



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

The Harvard community has made this article openly available. [Please share](#) how this access benefits you. Your story matters.

Citation	Jensen, Siv Aina, Roger Mundry, Charles Lindsay Nunn, Christophe Boesch, and Fabian H. Leendertz. 2009. Non-invasive body temperature measurement of wild chimpanzees using fecal temperature decline. <i>Journal of Wildlife Diseases</i> 45(2): 542-546.
Published Version	http://www.jwildlifedis.org/
Accessed	May 23, 2018 2:57:41 PM EDT
Citable Link	http://nrs.harvard.edu/urn-3:HUL.InstRepos:4317713
Terms of Use	This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Open Access Policy Articles, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#OAP

(Article begins on next page)

1 **RUNNING HEADING: SHORT COMMUNICATIONS**

2

3 **FULL TITLE:**

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

6

7 Siv Aina Jensen¹⁻³, Roger Mundry¹, Charles L. Nunn^{1,4}, Christophe Boesch¹ and Fabian H.
8 Leendertz^{1,2}

9

10 ¹ *Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany*

11 ² *Robert Koch-Institut, Berlin, Germany*

12 ³ *Norwegian School of Veterinary Science, Oslo, Norway*

13 ⁴ *University of California, Berkeley, USA*

14

15 **CORRESPONDING AUTHOR:**

16 Siv Aina Jensen

17 Robert Koch-Institut, NG2; Emerging Zoonoses

18 Nordufer 20

19 13353 Berlin

20 Germany

21 Phone: +49 1888 754 2592

22 Fax: +49 1888 754 2605

23 E-mail: JensenS@rki.de

24

25

26 **ABSTRACT**

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

38

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

41

42 Disease plays an important role in the demography of great apes, and health
43 monitoring is a vital part of the conservation of these endangered species (Leendertz et al.,
44 2006). In most cases, diagnosis of disease is restricted to observations of clinical signs and
45 laboratory analysis of samples collected non-invasively. The development of non-invasive
46 methods is therefore essential to improve health monitoring of wild great apes. Body
47 temperature can be measured non-invasively with infrared equipment, but such equipment
48 is expensive. Here we present a simple, inexpensive and reliable field method to estimate
49 the body temperature of wild chimpanzees non-invasively.

50 The study was conducted in the tropical rain forest of Taï National Park (5°15'-
51 6°07'N, 7°25'-7°54'W) in Côte d'Ivoire, where wild chimpanzees (*Pan troglodytes verus*)
52 have been habituated to human presence. First, the method was established by 29 control
53 measures performed on humans (one male and one female). Thereafter the method was
54 applied to 31 faecal samples collected from visually healthy chimpanzees (17 samples from
55 nine females; 14 samples from seven males).

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

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

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

77

$$78 \quad T_{(t)} = d + a * (1 / (1 + e^{(t-b)/c}))$$

79

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

92 Using the sigmoidal model on the human control measures we found a clear
93 relationship between the temperature estimated and the actual rectal temperature that was
94 measured (Spearman's rank correlation: $r_s=0.62$, $N=29$, $P<0.01$; Figure 2). The average
95 (arithmetic mean) absolute deviation between estimates and actual rectal temperatures was
96 0.22°C ($N=29$). Fifteen of the estimates differed less than 0.12°C from the actual value,
97 whereas only three differed by more than 0.5°C from the rectal temperature. Estimated
98 temperatures did not obviously over- or underestimate rectal temperatures (Wilcoxon test:
99 $T^+ = 262$, $N=29$, $P=0.35$). Temperature estimates were not influenced significantly by

100 sample weight ($r_s=0.08$, $N=26$, $P=0.68$) or environmental temperature ($r_s=0.08$, $N=30$, $P=$
101 0.70). Absolute deviations of the estimated temperature from the rectal temperature were
102 neither related to sample weight ($r_s=-0.13$, $N=25$, $P=0.53$) nor to environmental
103 temperature ($r_s=0.27$, $N=29$, $P=0.16$). However, accuracy of temperature estimation in the
104 human samples decreased with increasing interval between defecation and beginning of
105 measurement ($r_s=0.46$, $N=29$, $P=0.01$; Figure 3). The measurements started on average
106 1.42 minutes (=mean; range 0.17 – 3.17) after defecation. Note that after the thermometer
107 was first placed into the faecal sample, the temperature usually increased for several
108 measurements. We took the point at which the temperature reached its maximum as the
109 beginning of measurement. Accuracy decreased with decreasing number of measures
110 obtained ($r_s=-0.37$, $N=29$, $P=0.05$), whereas total duration of measurement interval did not
111 obviously influence accuracy ($r_s=0.06$, $N=29$, $P=0.75$).

112 The estimated temperature of the chimpanzees ranged from 34.6 to 39.5°C
113 (excluding one value of 44.3°C, which was clearly outside physiological range). The
114 average temperature of 16 chimpanzees was 37.2°C (figure 4). We found no significant
115 difference in estimated body temperature between males and females ($U=22$, $N_{\text{females}}=9$,
116 $N_{\text{males}}=7$, $P=0.35$). For the females, the temperature generally increased during the day,
117 whereas this difference was not obvious in the males (Figure 5).

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

123 In summary, our non-invasive method allows reliable estimation of the body
124 temperature of wild living chimpanzees. The method is easy to perform and requires no

125 expensive equipment, as only a commercially available digital thermometer is needed, in
126 addition to subsequent access to a computer. In the human control measurements half of the
127 body temperatures were estimated with an error of less than 0.12°C. To ensure the most
128 accurate results from this method, it is important to start the measurements as soon as
129 possible after defecation and to continue the measurement until the temperature curve
130 “flattens out.” The requirement for fresh faecal samples means, however, that the method
131 is most applicable to human-habituated animals, such as the chimpanzees studied here.

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

140 Normal human rectal temperature ranges from 34.4 to 37.8°C (Sund-Levander et al.,
141 2002), which shows that even for humans it is impossible to assign a single value as
142 “normal” body temperature. We should therefore expect a similar variation in normal body
143 temperature in wild great apes. Indeed, most of the body temperature estimates of the
144 chimpanzees in this study were within the range of normal human temperature, with an
145 average of 37.2°C. The very low end of the temperature estimate range could be explained
146 by poor measurement techniques, although they are within normal range in humans. Any
147 results could be retested if doubts emerge concerning the measurements. The estimated
148 temperature should be evaluated together with behavioural data, since stress or activities
149 such as hunting or fighting potentially produce a temporary increase in body temperature. It

150 might be useful to know the usual range for an individual when he or she is healthy, so that
151 a comparison can be made when illness occurs. We did not find any difference between the
152 temperature of males and females in this study, but the numbers of samples might have
153 been too low to detect a difference. Our study also showed that, at least for females, body
154 temperature tends to be lower in the morning than later during the day. More data are
155 required to confirm this pattern in wild primates.

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

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

170

171 **LITERATURE CITED**

172 HUFFMAN, M. A. 2003. Animal self-medication and ethno-medicine: exploration and
173 exploitation of the medicinal properties of plants. *Proceedings of Nutrition Society*
174 62(2):371-81.

175

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

180

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

184

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

187

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

190

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

194

195

196

197

198

199

200

201

202

203

204

205

206

207

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

213

214

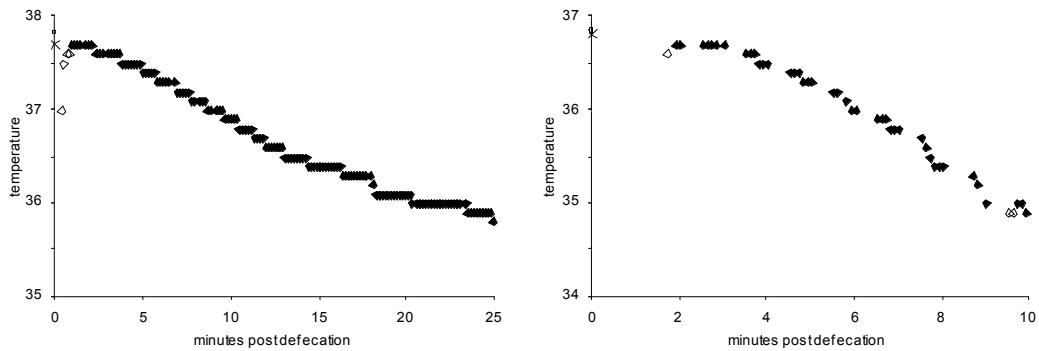
215

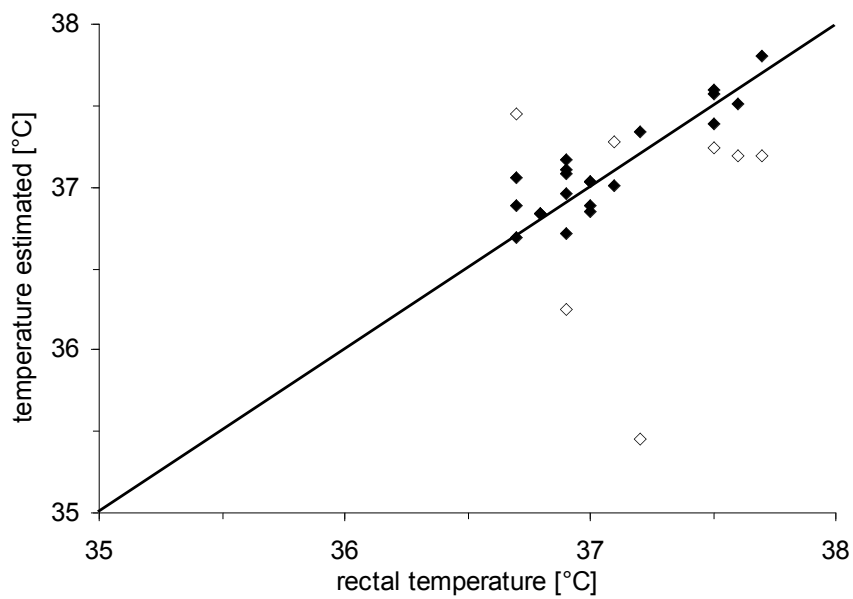
216

217

218

219





220

221

222

223

224 Fig.2. Relation between human rectal temperature and its estimation based on sigmoidal

225 curve fitting. White diamonds denote samples for which measurement began more than two

226 minutes after defecation. The diagonal line indicates the desired result (perfect fit).

227

228

229

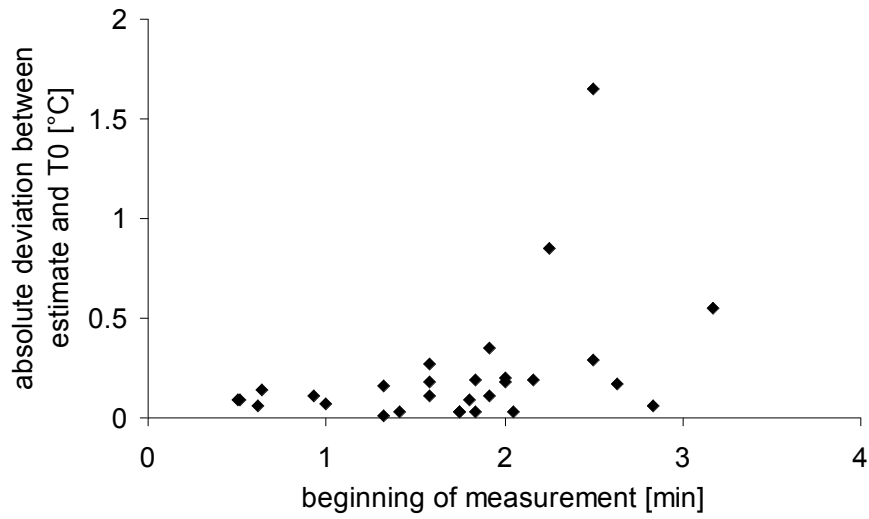
230

231

232

233

234



235

236

237

238

239 Fig.3. Relation between the absolute deviation of estimated human temperature from

240 measured rectal temperature and the beginning of measurement.

241

241
 242
 243
 244
 245
 246
 247
 248
 249
 250
 251
 252
 253
 254
 255
 256
 257
 258

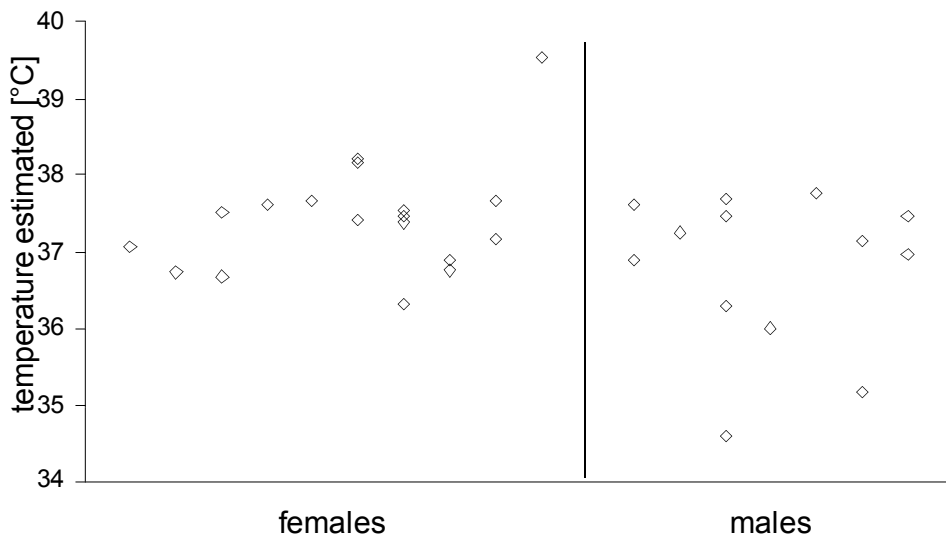
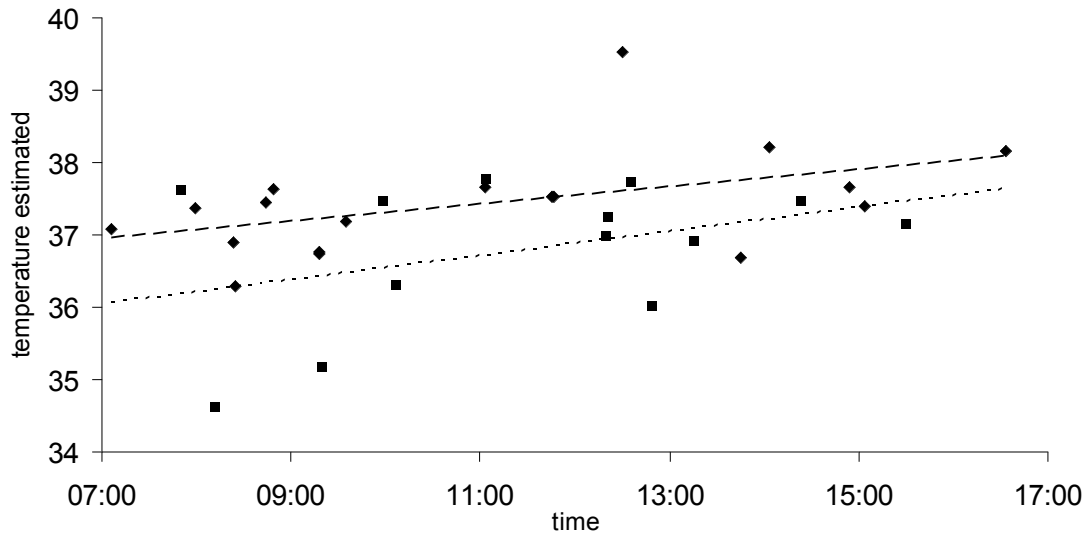


Fig.4. Temperature estimated for 17 chimpanzees. Values above one another are from the same subject.



259

260

261

262

263 Fig. 5. Temperature of chimpanzees as estimated using the sigmoidal curve fitting approach

264 and their variation with defecation time. Indicated are temperatures for females (diamonds,

265 dashed line) and males (squares, dotted line). Lines were calculated using linear regression.

266 Subjects were pooled. Rank correlation coefficients (with data pooled across subjects):

267 Females: $r_s=0.53$, $N=18$, $P=0.022$; Males: $r_s=0.14$, $N=13$, $P=0.64$.