Abstract. The aim of the present study was to investigate whether changes in body temperature are related to the ovarian cycle in elephants. Rectal, tongue or fecal temperature was measured for 2 Asian and 5 African elephants using an electric thermometer. Evaluation of ovarian cycles was based on the changes in serum or fecal progestin. The mean ± SD values of the rectal, tongue, and fecal temperatures were 36.3 ± 0.3 (2 Asian), 36.2 ± 0.5 (1 African) and 36.5 ± 0.3 C (4 African), respectively; the fecal temperature was the highest of the 3 temperatures (P<0.01). The longitudinal changes in body temperatures correlated with the ovarian cycle, with higher temperatures occurring during the luteal phase. The fecal temperatures of one acyclic African elephant did not change cyclically. These results suggest that measurement of body temperature can be used to easily evaluate the ovarian cyclicity of an individual animal, although it might not be able to determine the ovarian cycle length.

Key words: Fecal temperature, Ovarian cycle, Progesterone, Rectal temperature, Tongue temperature

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body temperature (basal body temperature) is used to document the menstrual cycle and ovulation time besides being used for health checks. It is well established that basal body temperature changes along with the menstrual or ovulatory cycle in these apes. Measurement of the basal body temperature has been reported to be an effective method of documenting the estrous cycle and to be an indicator of corpus luteum activity in cows. A relationship between the ovarian cycle and body temperature has been also reported for several species of marsupials, such as the Tasmanian bettong (*Bettongia gaimardi*) and common wombats (*Vombatus ursinus*) and marine mammals such as the beluga (*Delphinapterus leucas*). Furthermore, in some mammals, such as sheep, cattle, bottlenose dolphins (*Tursiops truncatus gilli*) and killer whales (*Orcinus orca*), a decrease in body temperature has been observed from several hours to several days before parturition. Therefore, it may be possible to predict the time of parturition. Changes in body temperature at the time of ovulation and parturition are probably related to the fact that secreted progesterone has a thermogenic effect.

The aim of the present study was to investigate whether changes in body temperature are related to the ovarian cycle based on the profiles of serum or fecal progestin in Asian and African elephants.

### Materials and Methods

#### Animals and body temperature measurement

Two Asian and 5 African female elephants were used in this study (Table 1). The temperature of the rectum, feces or tongue was measured at least once a week for 2–3 years. To measure the rectal temperature, an electronic thermometer (direct measurement type, C27; Terumo, Tokyo, Japan) designed for human use was inserted approximately 20–25 cm into the rectum for 3 min at approximately 0830–0900 h. To measure the fecal temperature, a different type of electronic thermometer (calculation type, C202; Terumo) designed for human use was immediately inserted by the animal’s keeper into the center of dung excreted during training or behavioral observation in the afternoon. The tongue temperature was measured at approximately 0850–0900 h with an instant infrared ear electronic thermometer (MC-505; Omron, Kyoto, Japan) designed for human use. The elephant’s keeper directed it to raise its nose and open its mouth, and then the temperature of the surface of its tongue was measured 10 cm from its tip (Fig. 1). The body temperature measurement methods, such as thermometer type and measurement time, could not be standardized among the institutes because the present study utilized data measured and accumulated for health checks at each institute.

#### Determination of ovarian cycle

Blood or feces was collected weekly or biweekly from all the animals for determination of the serum or fecal progestin concentrations (Table 1). Serum samples were separated from the whole blood immediately after collection and were stored at –20 C until assay. A portion (50–100 g) of the feces was collected immediately after defecation in the morning. Fecal samples were placed in Ziploc® bags and stored at –20 C immediately after collection. For the assay of serum progestin, serum samples were extracted twice with ethyl ether. Fecal progestin was extracted using a methanol extraction method. Briefly, frozen fecal samples were lyo-

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Japanese studbook No.</th>
<th>Name</th>
<th>Facility</th>
<th>Birth year</th>
<th>Method of measuring body temperature</th>
<th>Determination of ovarian cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian elephant</td>
<td>133</td>
<td>Mito</td>
<td>KMZ</td>
<td>1971</td>
<td>Rectal temperature</td>
<td>Serum P</td>
</tr>
<tr>
<td></td>
<td>136</td>
<td>Tomo</td>
<td>KMZ</td>
<td>1980</td>
<td>Rectal temperature</td>
<td>Serum P</td>
</tr>
<tr>
<td>African elephant</td>
<td>014</td>
<td>Keny</td>
<td>NHZ</td>
<td>1973</td>
<td>Tongue temperature</td>
<td>Fecal P</td>
</tr>
<tr>
<td></td>
<td>068</td>
<td>Sakuv</td>
<td>GSP</td>
<td>1968</td>
<td>Fecal temperature</td>
<td>Serum P</td>
</tr>
<tr>
<td></td>
<td>092</td>
<td>Nobu</td>
<td>HCP</td>
<td>1981</td>
<td>Fecal temperature</td>
<td>Serum P</td>
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<td>094</td>
<td>Wata</td>
<td>HCP</td>
<td>1982</td>
<td>Fecal temperature</td>
<td>Serum P</td>
</tr>
<tr>
<td></td>
<td>095</td>
<td>Sachi</td>
<td>HCP</td>
<td>1982</td>
<td>Fecal temperature</td>
<td>Serum P</td>
</tr>
</tbody>
</table>

KMZ: Kyoto Municipal Zoo; NHZ: Nagoya Higashiyama Zoo; GSP: Gunma Safari Park; HCP: Himeji Central Park; P: progestin.
philized for approximately 48 h and then pulverized by hand to separate the fecal powder from the fibrous material. A 0.1 g portion of the powder was then extracted with 80% methanol in 5 ml of ultra pure water by vortexing for 30 min. After centrifugation at 2500 rpm for 10 min, an aliquot of the methanol fraction was diluted at a ratio of 1:8 using 0.01 M phosphate buffered saline.

The serum and fecal progestin concentrations were determined by radioimmunoassay for progesterone [19]. The cross-reactivities of the antiserum in the present study were 100% for progesterone, 62.2% for 5α-pregnanedione (5β-Pregnan-3,20-dione), 6.26% for pregnenolone, 3.88% for 11-deoxy-corticosterone, 2.25% for 17α-hydroxyprogesterone, 1.23% for 11α-hydroxyprogesterone and 0.51% for 20α-hydroxyprogesterone. The fecal progestin concentrations are shown as the amount in 1 g dry feces powder.

Data analysis

The temperature data is presented as the mean ± SD. Any abnormal values over 38 C (2 for No. 014 and 1 for No. 092) were excluded for the rectal, tongue and fecal temperatures. Significant differences among the rectal, fecal, and tongue temperatures were analyzed by Fisher’s Least Significant Difference Test. Weekly average values were calculated for the observed tongue or fecal temperature of each animal; weekly average lines are illustrated in the figure graphs. Pearson’s correlation coefficient indicated that there was a relationship between the temperature and progestin concentrations. All data analyses were conducted using Microsoft® Office Excel 2003 and SSRI Excel Statistics 2002. The duration of the ovarian cycle was calculated as the number of days from the first progestin rise to the progestin rise in the following cycle.

Results

The rectal (2 Asian elephants), tongue (1 African elephant) and fecal temperatures from 4 African elephants were 36.3 ± 0.3 C (n=258), 36.2 ± 0.5 C (n=1360), and 36.5 ± 0.3 C (n=1149), respectively (Table 2). The fecal temperature was significantly higher than the rectal and tongue temperatures (0.2–0.3 C, P< 0.01), but not within the same animal.

The lengths of the ovarian cycles of Asian elephants Nos. 133 and 136 based on the changes in their serum progestin concentrations were 14.9 ± 0.7 (n=8) and 16.9 ± 1.3 weeks (n=8), respectively. In both elephants, there was a trend for the rectal temperature to be high during the luteal phase (e.g. Fig. 2), and there was a positive correlation between the rectal temperatures and progestin values (r=0.29, n=230 from 2 females, P<0.01). The length of the ovarian cycle of African elephant No. 014 based on the changes in its fecal progestin concentration was 13.8 ± 1.9 weeks (n=9). There was a visual trend for the tongue temperature to be high during the luteal phase, and there was a positive correlation between the tongue temperatures and progestin values (r=0.20, n=129, P<0.05; Fig. 3). The lengths of the ovarian cycles of African elephants Nos. 092, 094 and 095 based on the changes in their serum progestin concentrations were 14.3 ± 2.0 (n=7), 14.4 ± 1.9 (n=7) and 13.8 ± 2.8 weeks (n=6), respectively. There was a trend for the fecal temperature to be high during the luteal phase (e.g. Fig. 4). In contrast, the serum progestin concentrations of African elephant No. 068 remained at the basal level of 200 pg/ml or less, and no changes in its ovarian cycle were observed throughout the period of study (Fig. 4). The fecal temperature of African elephant No. 068 changed within a narrow range.

Fig. 1. Measurement of the tongue temperature of a female African elephant using an instant electronic infrared ear thermometer
compared with African elephants of Nos. 092, 094 and 095. In these 4 African elephants, there was a positive correlation between the fecal temperatures and progestin values ($r=0.33, n=176$ from 4 females, $P<0.01$).

**Table 2.** Mean values for the rectal, tongue and fecal temperatures of the Asian and African female elephants

<table>
<thead>
<tr>
<th>Animal number</th>
<th>Individual temperature (°C, mean ± SD)</th>
<th>Range (°C)</th>
<th>Total temperature (°C, mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rectal temperature of Asian elephants</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.133</td>
<td>36.2 ± 0.3 (n=130)</td>
<td>35.0–36.9</td>
<td></td>
</tr>
<tr>
<td>No.136</td>
<td>36.3 ± 0.3 (n=128)</td>
<td>35.2–37.4</td>
<td>36.3 ± 0.3 a (n=258)</td>
</tr>
<tr>
<td><strong>Tongue temperature of African elephant</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.014</td>
<td>36.2 ± 0.5 (n=1360)</td>
<td>34.8–37.9</td>
<td>36.2 ± 0.5 a (n=1360)</td>
</tr>
<tr>
<td><strong>Fecal temperature of African elephants</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.068</td>
<td>36.2 ± 0.2 (n=300)</td>
<td>35.7–37.0</td>
<td></td>
</tr>
<tr>
<td>No.092</td>
<td>36.6 ± 0.3 (n=299)</td>
<td>35.4–37.4</td>
<td></td>
</tr>
<tr>
<td>No.094</td>
<td>36.5 ± 0.3 (n=294)</td>
<td>35.9–37.4</td>
<td></td>
</tr>
<tr>
<td>No.095</td>
<td>36.5 ± 0.3 (n=256)</td>
<td>35.6–37.6</td>
<td>36.5 ± 0.3 b (n=1149)</td>
</tr>
</tbody>
</table>

a,b: Fisher’s least significant difference test ($P<0.01$).

**Discussion**

**Rectal, tongue and fecal temperatures**

The temperatures of different parts of an animal’s body are different even if the animal is homeothermal. Body temperature gradually decreases from the deep parts of the body towards the body surface. Skin temperature differs according to the body part and is easily influenced by the temperature of the outside air. In contrast, the temperature of deep parts (core temperature) of the body is almost constant. This is why the rectal temperature is usually used to determine the core temperature [20]. It has been reported that the normal rectal temperature of Asian elephants ranges from 36 to 37 °C [4]. Most of the measurements in our results were within this range. Measurement of
Fig. 3. Changes in the tongue temperatures and fecal progestin concentrations of female African elephant No. 014 during ovarian cycles. The dots and solid line indicate the observed values and weekly average (line) for the fecal temperature, respectively. The arrowhead indicates the day when another female housed with female No. 014 died.

Fig. 4. Changes in the fecal temperatures and serum progestin concentrations of ovarian cycling female African elephant No. 094 and non-cycling female African elephant No. 068. The dots and solid line indicate the observed values and weekly average (line) for the fecal temperature, respectively. The ambient air temperature indicates the maximum air temperature at the facility where female No. 094 was kept.
the rectal temperature is assumed to be the most effective method for determining the body temperature of an elephant. However, measurement of the rectal temperatures requires that the elephant be trained, and it might expose the measurement taker to danger.

Measurement of the fecal temperature is very simple and safe. Benedict [1] confirmed that the fecal temperature consistently reflects the rectal temperature. It has been reported that the mean fecal temperature is 36.5°C (37 times from 24 elephants) [1]. The mean value in our results was close to this value. The fecal temperature was measured immediately after defecation in our study; however, it was slightly higher than the rectal and tongue temperatures. This might be due to production of heat arising from microbial fermentation of the feces. It has been reported that the temperature of the feces of the elephant is 0.7°C higher than that of the urine because of heat of fermentation of the feces [1].

The mean value for tongue temperature, measured using an ear-type thermometer, was almost equal to that of the rectal temperatures. Therefore, measurement of the tongue temperature could be a simple alternative method to measurement of the rectal temperature.

Relationship between body temperature and ovarian cycle

It is known that elephants, unlike many mammals, can alter their body temperature by a few degrees to withstand extreme environmental conditions without much energy loss [21]. Camels are also known to have a similar system of body temperature regulation. The body temperature of the camel rises along with the rise in ambient temperature in order to save body moisture during daytime, and this extra heat is radiated when the ambient temperature decreases at night [22]. The reason for this regulation system is probably adaptation to their extreme living environment. The body temperature of a camel under restricted drinking conditions is easily influenced by the ambient temperature. This has been confirmed by an experiment that compared the rectal temperatures of camels under restricted and unrestricted drinking conditions [22]. The elephants used in our study were kept under constant conditions with the exception of ambient temperature. The ambient air temperature did not greatly influence the elephant’s body temperature (e.g., the maximum ambient temperature during the day is shown in Fig. 4).

The temperature nadir is a more reliable indicator of the time of ovulation in the chimpanzee [6]. The body temperature of cows (vaginal temperature) is lowest just before estrus and is high on the day of estrus, low again at the time of ovulation and high during the luteal phase [8]. Two Asian and 4 African female elephants in the present study exhibited normal ovarian cycles, and their body temperatures tended to be high during the luteal stage. Progesterone has been reported to act on the temperature regulatory center of the hypothalamus and cause thermogenesis [15, 16]. This regulatory mechanism may also occur in the elephant.

A previous study measured the body temperatures of Tasmanian bettong using telemeters implanted in the abdominal cavity in order to assess their reproductive status [9]. Their body temperatures rose in relation to an increase in the plasma progesterone concentration. Monitoring of body temperature might be a useful and simple method for investigating the estrous cycle in zoo and wild mammals. Our results included one reproductive acyclic African elephant. The body temperature of this female did not change cyclically compared with the other ovarian cycling females. Although the daily data for the body temperature of this elephant varied widely and the ovarian cycle length could not be determined based on the temperature data, it was certainly possible to estimate ovarian cyclicity or acyclicity.

In conclusion, the rectal, tongue, and fecal temperatures of Asian and African elephants changed along with the ovarian cycle. In cases where it is not possible to collect blood or where zoos lack the equipment to determine hormone values, longitudinal measurement of body temperature is a simple tool for evaluating the ovarian cyclicity of an elephant, although it might not be able to determine the ovarian cycle length.

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References