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The Thermogenic Effect of Reproductive Hormones in Female Bornean Orangutans (*Pongo pygmaeus*) at Bukit Merah Orang Utan Island, Perak

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ABSTRACT

Basal body temperature (BBT) is commonly linked to progesterone and oestrogen concentration, two key reproductive hormones in female humans and non-human primates. Retrospectively, little attention has been given to investigating the association between basal body temperature and reproductive hormones via non-invasive methods among orangutans. Hence, this study was carried out to identify the associations between basal body temperature and reproductive hormones via a non-invasive approach among four female orangutans at Bukit Merah. The basal body temperature of two adult females, Baboon (age 33) and Careena (age 15) and two adolescent female orangutans, April (age 13) and Kate (age 9), was measured using an infrared thermometer gun. A total of 101 faecal samples were gathered and analysed via enzyme-linked immunosorbent assay (EIA). A Spearman's correlation coefficient test revealed a significant moderate positive relationship between progesterone and basal body temperature with r[101]=0.437, p=0.041. Nevertheless, there was no significant relationship between basal body temperature and oestradiol. These findings align with previous research conducted on other mammals, which has shown that progesterone elevation is associated with increased body heat. This result also demonstrated the reliability of using non-invasive techniques, such as infrared thermography and faecal hormone analysis, for tracking reproductive hormone changes in orangutans. This study contributes valuable data to understand the physiological effects of progesterone on thermoregulation in female

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orangutans and offers practical insights for captive breeding programs aimed at enhancing orangutan welfare. Future research could explore the broader implications of progesterone's thermogenic effects on behaviour and reproductive success.

Keywords: Luteal phase, reproductive hormone, resting body temperature, sex steroid hormone

INTRODUCTION

Bornean orangutans (*Pongo pygmaues*) have been listed by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List as one of the critically endangered species (Ancrenaz et al., 2016). They are recognized as the world's largest arboreal mammals and are known for their distinctive behaviour, physiology and reproductive biology (Ancrenaz et al., 2014). Just like humans, female orangutans have complex reproductive cycles that are controlled by multiple hormone fluctuations (Knott, 1999). One of the main hormones is progesterone, which plays a significant role in preparing the body for conception and maintaining pregnancy (Halasz & Szekeres-Bartho, 2013). Estrogen is another key hormone that is responsible for developing female sexual characteristics (Delgado & Lopez-Ojeda, 2023). Despite extensive research on the reproductive physiology of orangutans, limited studies have been conducted on how hormonal changes can affect body temperature regulation in orangutans. Bukit Merah Orang Utan Island serves as an important conservation and research centre for Bornean orangutans, providing a controlled environment to study these physiological processes in detail.

The link between basal body temperature and reproductive hormones has been well-studied in humans since the 1940s (Écochard et al., 2022; Rose & Jones, 1996). Nevertheless, there is still a significant interest in determining the relationship among wildlife, particularly among orangutans. In humans, elevated basal body temperature, in tandem with progesterone concentration, is used to track ovulation or pregnancy (Écochard et al., 2022). This subtle temperature shift is a valuable indicator in assessing hormonal changes and fertility (Écochard et al., 2022). While this association has been well-studied in humans, its role in other primates, particularly orangutans, remains largely unexplored.

The only research that had been done among orangutans was by Asa et al. (1994) 30 years ago. Though the study established a significant relationship between progesterone and basal body temperature, the method used was ethically questionable (Asa et al., 1994). Asa et al. (1994) measured basal body temperature peritoneally by inserting radio telemetry transmitters. The insertion procedure required restraining the animals and sedation, which caused stress for the orangutans (Asa et al., 1994). Stress significantly impacts hormone concentration, thus causing inaccurate results reflected in the biological samples (Foley et al., 2001).

Hence, this study aims to investigate the thermogenic effects of reproductive hormones in orangutans using commercial infrared thermometer guns as a non-invasive approach

to understand their physiology and its implications for future breeding programs. Basal body temperature recording using a thermometer gun is the simplest and easiest approach, without disturbing the animals or causing stress to them (Su et al., 2017). In addition, it is also a safer approach for the researcher as temperature recording requires a distance from the animal. Additionally, this research will contribute to the expansion of knowledge on the relationship between hormones and basal body temperature in primates, offering valuable insights into how these mechanisms have evolved across species.

METHODS

Sampling Site

This study was conducted at Bukit Merah Orang Utan Island, an ex-situ conservation centre that housed 20 orangutans in a 14-acre land area. Bukit Merah is situated approximately 284 kilometres from the centre of Kuala Lumpur, requiring a four-hour drive from the city. The island is surrounded by abundant tropical lowland rainforest trees such as the Bertam palm tree (*Eugeissona tristis*), *asam gelugur* (*Garcinia atroviridis*) and fruit trees (Dharmalingam et al., 2012). *Rambutan* (*Nephelium hamulatum*) and *pulasan* (*Nephelium rambutan-ake*) are examples of fruit trees found on the island (Dharmalingam et al., 2012). The climate and flora of the island are notably comparable to the ecological niche of orangutans in Borneo and Sumatra, Indonesia (Dharmalingam et al., 2012).

Animals, Facilities and Management

The island housed 20 Bornean orangutans in a 19.6 m^3 individual enclosure area during the night. In the morning, orangutans are released into the exhibit areas. Four female orangutans were involved: Baboon (age 33), Careena (age 15), April (age 13) and Kate (age 9) (Figure 1). The selected subjects were divided into two age categories: adults (Baboon and Careena) and adolescents (April and Kate). Orangutans of Bukit Merah are fed with seasonal fresh fruits, approximately 500 g per individual daily during the day and another 500 g during the evening. Additionally, vitamin drinks and fruit juices were also given as daily supplements, with ad libitum water available. Enclosure areas are cleaned and sanitized daily after the animals are released to their respective exhibit areas.

Data Collection

This study was conducted from March 2021 to June 2021, with daily recording of basal body temperature and faecal collection upon availability.

Basal Body Temperature Recording

A Fisherbrand™ Traceable™ Infrared Thermometer Gun was used to record basal body temperature. The thermometer gun can detect temperature within -50 °C to +1000 °C with

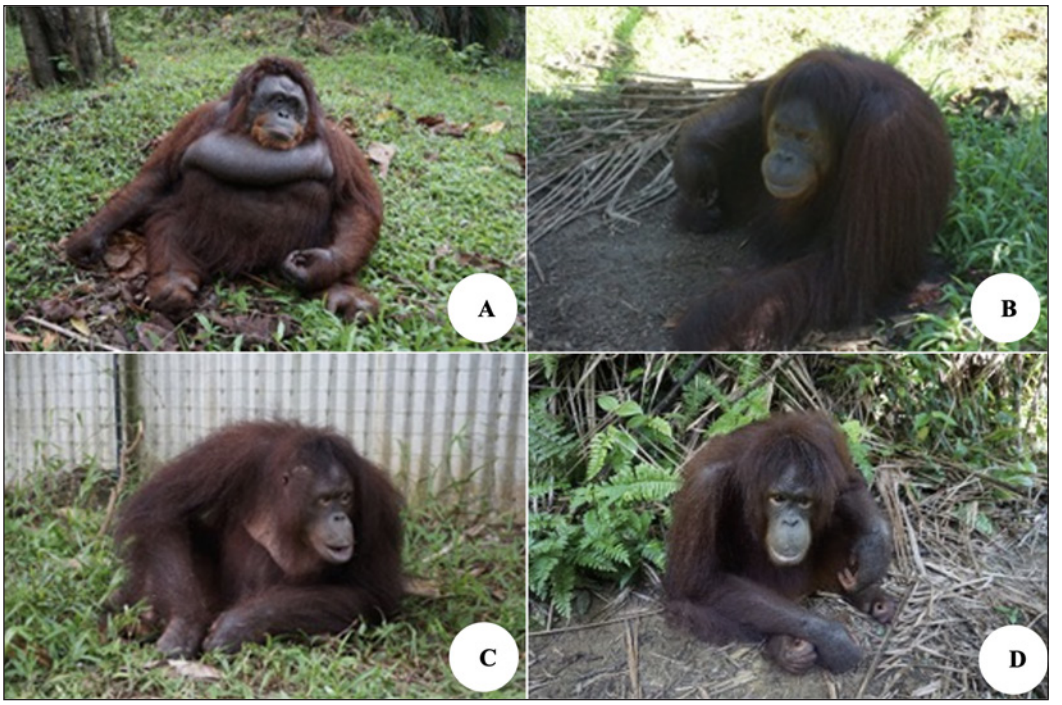

Figure 1. Female orangutans at Bukit Merah Orang Utan Island, Perak. A. Baboon (age 33). B. Careena (age 15). C. April (age 13). Kate (age 9)

resolution at 0.1 °C to 200 °C, 1 °C over 200 °Cand accuracy range at ±1.5% + 2 °C. Basal body temperature was recorded at a similar time in the morning to ensure the accuracy of the results. Three readings were taken and then averaged to get the final temperature. The temperature was recorded by aiming the gun directly at the forehead.

Progesterone Hormone Analysis

Faecal Sampling. Faecal samples were collected based on availability. A total of 101 faecal samples were collected from the orangutans. Enclosures were cleaned daily to minimize faecal contamination and to keep the area hygienic for the animals. Sterile gloves and a mask are mandatory to be worn prior to sample collection to prevent sample contamination. Only fresh samples free from foreign materials were selected and stored in a labelled container. The name of the individual and the date were labelled on the container and placed in a cooling box immediately. The samples were then transferred to a freezer located on the jetty at -20 °C until further analysis. All samples were analysed at Wildlife Forensic Lab, PERHILITAN Headquarters, Cheras, Kuala Lumpur.

Faecal Hormone Extraction

Hormone extraction from the faecal samples started with oven drying at 55 °C. Pestle and mortar were used to powder the dried samples afterward. Next, 0.2 g of the powdered faecal samples was mixed with 2 mL of ACS-graded ethanol in a tube. The tube was then shaken for 30 minutes at room temperature and centrifuged at 5000 rpm for 15 minutes at 4 °C using a Thermo Scientific Heraeus Multifuge X1R centrifuge. Lastly, the supernatants were transferred into a microtube and stored in a freezer at -20 °C. The extraction analysis then proceeded into EIA analysis according to the procedures by Arbor Assays DetectX® Progesterone and Estradiol Enzyme Immunoassay.

Statistical Analysis

This study used IBM SPSS version 23.0 to analyse the data, and significant differences were noted when the p-value was <0.05. Descriptive analysis was used to determine median and interquartile range (IQR) values. Due to the small sample size (n<10), data were analysed non-parametrically. Spearman's correlation test was applied to test the relationship between sex steroid hormones and the basal body temperature of orangutans. The correlation strength follows the guideline from Ratner (2009), which indicates a weak linear relationship for the range between 0 and ±0.3, a moderate linear relationship for the range ±0.3 to ±0.7, and a strong relationship for the range between ±0.7 and 1.0.

RESULTS

Basal Body Temperature-Reproductive Hormone Relationship

Table 1 shows a significant moderate positive relationship between progesterone and basal body temperature with r[101] =0.437, p=0.041 (Table 1). Interestingly, there is no significant relationship between oestradiol and basal body temperature, with a p-value >0.05 (Table 1).

Table 1
The correlation between basal body temperature and progesterone concentration of female orangutans at BMOUI, Perak, using Spearman's correlation coefficient test

	Basal Body Temperature		Strength of correlation
	r	p-value	
Progesterone	0.437	0.041*	Significant moderate positive linear relationship
Estradiol	-0.077	0.445	Non-significant weak negative linear relationship

Note. **P-value is highly significant at p<0.001, *P-value is significant at p<0.05

DISCUSSION

In this study, a higher concentration of progesterone is significantly linked to basal body temperature and vice versa (Table 1). This finding is consistent with the studies among

female orangutans and humans, which found that pregnanediol-3 alpha-glucuronide (PdG) is also positively related to BBT (Asa et al., 1994; Écochard et al., 2022). Additionally, previous research has also confirmed that the increase of progesterone elevates the basal body temperature, confirming ovulation in females (Su et al., 2017).

On the contrary, chimpanzees showed no significant relationship between basal body temperature and progesterone, but it is associated with oestrogen in tandem with the swelling of genital areas (Graham et al., 1977). The swelling of genital areas and a fall in temperature a day after oestrogen peaks, marking the beginning of a fertile phase in chimpanzees (Graham et al., 1977). The swelling of genital areas is non-visible in orangutans and humans, which is a phenomenon called "concealed ovulation" (Durgavich, 2013). This exclusive phenomenon found in only orangutans and humans is a condition where physical cues are absent in determining their fertile phase (Rooker & Gavrilets, 2020). Similarly, Tasmanian bettongs also show a BBT peak during estrous days, followed by a temperature dip in the next two days (Rose & Jones, 1996). On day three, the temperature increased steadily until day 10, together with the rise of progesterone concentration (Rose & Jones, 1996). The temperature dropped two days before oestrus in relation to the decrease of progesterone level and leucocytes observed in vaginal smears (Rose & Jones, 1996). This study demonstrated the adaptability of the BBT method in determining reproductive status across the Mammalia clade, not just in humans and non-human primates.

Basal body temperature is also found to be associated with progesterone among marine mammals such as beluga whales (Katsumata et al., 2006a) and killer whales (Katsumata et al., 2006b). Interestingly, in the studies, the basal body temperature-progesterone relationship was observed among pregnant females and monitored throughout the pregnancy (Katsumata et al., 2006b). It was found that their temperature dropped significantly by 0.3 °C below the mean value five days before parturition and decreased by 0.8 °C a day before parturition (Katsumata et al., 2006b). This finding is valuable in estimating the parturition day for infant delivery preparation for the caregiver or researchers.

Remarkably, the study found that beluga whales demonstrated a similar relationship between basal body temperature and progesterone level, which mimics relationships observed in female orangutans and humans (Katsumata et al., 2006a). In the study, the body temperature of the beluga was low when progesterone concentration declined and increased 11 days after mating took place (Katsumata et al., 2006a). This is evidence that progesterone secreted from corpora lutea is crucial in raising the BBT (Ogino, 1930). It is also worth noting that mating behaviour was observed in beluga whales during low body temperatures (Katsumata et al., 2006a). In summary, this study concluded that the shift of body temperature is linked to the follicular and luteal phases of the estrous cycle in this species. Based on these studies of whales, it is evident that the BBT approach is a flexible and reliable method for determining the reproductive status of marine mammals.

Additionally, similar findings are also found among women taking oral contraceptive pills that contain artificial progesterone (Baker et al., 2001). Body temperature is significantly elevated continuously for 24 hours, suggesting a prolonged effect of synthetic hormone steroids, which is uncommon in the natural menstrual cycle (Baker et al., 2001). This indicates that progestins, a synthetic hormone that is usually combined with oestrogen, have a higher relative binding affinity for the progesterone receptor compared to natural progesterone (Juchem & Pollow, 1990). Additionally, it is also due to the longer metabolic clearance rate compared to natural progesterone (Bergink et al., 1990). Even when the amount of progestins subsides after hormone withdrawal, it could still be active in the brain (Feder & Marrone, 1977) or metabolized into neuroactive steroids (Rogers & Baker, 1997). Due to this effect, women using oral contraceptives had a prolonged thermogenic effect directly or indirectly through progesterone metabolites up to three days after discontinuation (Baker et al., 2001). In menopausal women, progesterone is reported to cause hyperthermia for several days after treatment withdrawal (Piette et al., 1994).

Despite the simplicity and ease of collecting basal body temperature data, interpreting the results can be challenging (Su et al., 2017). This is aligned with the findings from Guermandi et al. (2001) and Hilgers and Bailey (1980), who found that the basal body temperature dip range was too big, from four to eight days prior to ovulation, suggesting that BBT is a poor approach in predicting ovulation in females (Guermandi et al., 2001; Hilgers & Bailey, 1980). In addition, ovulation was determined in only 43% of fertile women and 25% of infertile women, which is insufficient for BBT to be implemented as an ovulation predictor (Lenton et al., 1977). On top of that, scientists have rejected the application of BBT in determining ovulation due to wide day-to-day environmental temperature fluctuation and the influence of illness, medication, diet and changes in sleep patterns in females (McCarthy & Rockette, 1986).

In addition, basal body temperature is also reported to be influenced by environmental parameters, including environmental temperature, rainfall, and duration of daylight (Tatsumi et al., 2020). BBT was also found to be affected by biological factors, including stress, irregular sleep cycles, health issues and drugs (Su et al., 2017). Moreover, the increasing occurrence of aggressive behaviour in female orangutans is also observed in tandem with elevated progesterone levels (Nozmi et al., 2025), possibly due to increases in basal body temperature and air temperature. Aggressive behaviour is a response to uncomfortable conditions, potentially leading to higher stress levels and increasing the risk of injury to both the individual and other animals (Nozmi et al., 2025). In addition, female orangutans exhibited a longer resting duration when the air is hotter and humid, which is another adaptation strategy to negative environmental changes, resulting in lower time spent on activities such as reproduction, feeding, and playing (Nozmi et al., 2023). Hence, these significant negative impact of the external and internal factors on basal body

temperature towards the behaviour of orangutans demonstrates the unreliability of BBT in determining the fertile phase in females.

CONCLUSION

This study implies that the elevation of basal body temperature of orangutans is associated with the rise of progesterone concentration. The safety, ease, and simplicity of using a thermometer gun are useful in monitoring the ovarian cycle, especially during the luteal phase when progesterone levels peak. This information provides information on hormone concentrations linked to the basal body temperature of female orangutans since it is difficult to obtain daily basal body temperature from wild orangutans. Deeper knowledge of orangutans' reproductive physiology and ecology is crucial for effective population management in zoos and to support their survival in the wild. Hence, it would be greatly beneficial to determine other factors that may contribute to the concentration of progesterone from different populations of orangutans, such as in other zoos and conservation centres.

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