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The Relationship between Reproductive Hormones with General Behaviour of Captive Female Bornean Orangutans at Bukit Merah Orang Utan Island, Perak

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ABSTRACT

Managing critically endangered species in captivity, like the orangutans (*Pongo pygmies*), requires deep knowledge of their physiology and behavior to provide the best husbandry under human care. Progesterone and estrogen, the main hormones in the reproductive cycle, play an essential role in controlling behavior in female mammals. However, the influence of hormones on behavior in non-human primates, such as orangutans, is still very limited. This study investigates the impact of progesterone and estrogen in captive female orangutans at Bukit Merah Orang Utan Island, a conservation center in Perak, Malaysia. The research explores the relationship between progesterone and estradiol levels with aggressive behavior and daily activities. Fecal sampling and behavioral observation were conducted in 93 days from March 2021 until June 2021. A total of 101 fecal samples were collected from four female orangutans named Baboon (age 33), Careena (age 15), April (age 13), and Kate (age 9) for enzyme-linked immunosorbent assay (EIA) via commercial kits. Behavioral observation was conducted for 337 hours via focal and scan sampling. Aggression and four daily activities were observed, which included playing, moving, resting, and feeding. Overall, the results indicate that progesterone significantly correlates with resting, playing, and aggression behaviors, while estradiol shows no significant relationship with any behaviors. A Spearman's correlation coefficient showed a significant but moderate positive relationship between progesterone concentration and resting behavior, r[101]=0.462, p=0.006, and with playing behavior with a moderate negative relationship, r[101]=-0.439, p=0.015. A Spearman's correlation coefficient revealed a significant moderate negative relationship between aggression and the level of progesterone, r[101]=-0.440, p=0.009. There was no correlation between estradiol and any behaviors with p>0.05. The findings of this study will enhance the knowledge of orangutan physiology and support conservation efforts by providing data that can be used to optimize the reproductive health and well-being of captive orangutans. This research is a step towards ensuring the survival of this critically endangered species by improving the conditions under which they are kept and managed in captivity.

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INTRODUCTION

Progesterone, a key steroid hormone, regulates female mammals' reproductive physiology and behavior, including primates (Motta-Mena et al., 2017). In non-human primates, particularly great apes like orangutans, progesterone is integral to the menstrual cycle, pregnancy maintenance, and various behavioral patterns (Durgavich et al., 2022). Despite extensive research on the hormonal influences in human and non-human primates, the specific impacts of progesterone on the behavior of orangutans remain underexplored.

On the other hand, estrogen is also known as the primary sex hormone in women, besides progesterone (Blackburn et al., 1999). Estrogen is crucial in the menstrual cycle, including regulating tissue thickness and menstrual bleeding (van Iten, 2016). There are three types of estrogen: estrone (E1), estradiol (E2), and estriol (E3). Estradiol (E2) plays a vital role during the menstrual cycle (van Iten, 2016), while estriol (E3) is found in abundance during pregnancy (Dorland's Illustrated Medical Dictionary, 2011). When a woman enters menopause, estrone (E1) is higher, causing menstrual bleeding and the cycle to stop (Dorland's Illustrated Medical Dictionary, 2011). As a result, this study focuses on estradiol because it involves non-pregnant female orangutans.

The Bornean orangutan (*Pongo pygmaeus*), an endangered species, is particularly interested in conservation biology due to its unique reproductive biology and complex social behaviors (Knott, 1999). Understanding the relationship between hormonal fluctuations and behavior in female orangutans is critical for effective management and conservation efforts, especially in captive settings where breeding programs are implemented to ensure species survival.

This study investigates the behavioral effects of progesterone in captive female Bornean orangutans at Bukit Merah Orang Utan Island, Perak. By monitoring progesterone levels and corresponding behaviors, this research aims to determine how hormonal changes influence aggressive behavior and daily activities such as resting, feeding, moving, and playing. The findings of this study will contribute to a deeper understanding of the physiological and behavioral adaptations in orangutans, with potential implications for improving captive breeding programs and enhancing the overall welfare of these primates in managed care environments.

EXPERIMENTAL

Study Location

Bukit Merah Orang Utan Island is an ex-situ conservation center for Bornean orangutans in the northwestern part of Perak. The island covers about 14 acres of land, filled with tropical lowland rainforest trees. As a conservation center, it caters to several programs, which include conservation, breeding, rehabilitation, research, and promotion of educational activities. The weather and vegetation on the island are similar to the original habitat of orangutans in Borneo and Sumatra (Dharmalingam et al., 2012).

Animal Profiles

Four sexually developed female orangutans were included in this study: Baboon (age 33), Careena (age 15, April (age 13), and Kate (age 9) (Figure 1). Baboon and Careena are adults, whereas April and Kate are adolescents. Baboon is the only multiparous animal, with the rest being nulliparous. All animals weighed within the normal range of captive female orangutans, ranging from 40 to 81 kg (Loomis, 2003), except for April, who is underweight with only 36 kg.

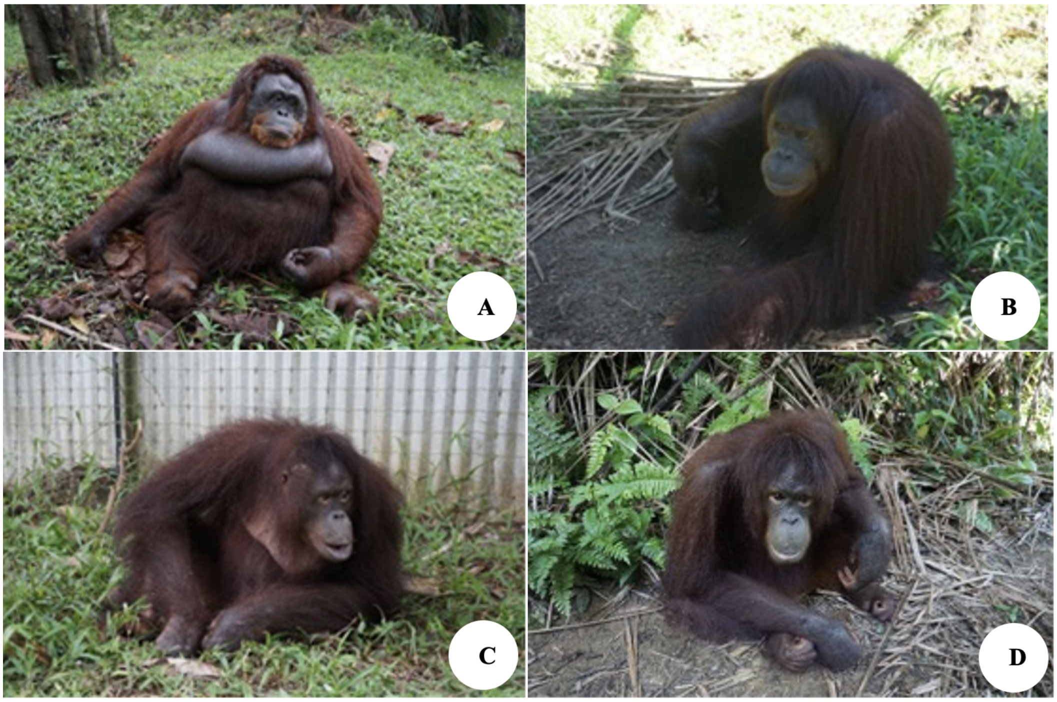

Fig. 1. Female orangutans at Bukit Merah Orang Utan Island, Perak. A. Baboon, age 33. B. Careena, age 15. C. April, age 13. Kate, age 9.

Animal Husbandry

Orangutans at BMOUI are released in the exhibit areas during the day, from 9 a.m. until 5 p.m. From 5 p.m. onwards, they are individually kept indoors in a 19.6 m^3 enclosure area. Baboon and her son Mannu were the only ones who shared the same enclosure. Orangutans consume 500ml of vitamin drink and four slices of bread before their release in the morning. Throughout the day, they were fed 500g of fruits individually, including coconut, star fruit, mango, papaya, pineapple, jackfruit, and sugarcane. Another 600ml of milk and 500g of fruits were given in the evening. Water was available as an ad libitum during the day.

Progesterone Hormone Analysis

Faecal Sample Collection

Fecal samples were collected daily based on availability in the morning. One hundred fecal samples were collected from Baboon, Careena, April, and Kate. Only fresh samples were collected and must be free from foreign materials such as urine and food waste. Samples were labeled with name and date of collection before being placed in a cooling box. The samples were then transported to the jetty and stored in a freezer at -20°C until further analysis.

Fecal Hormone Extraction

Fecal samples were dried using an oven at 55°C before being powdered via pestle and mortar. An amount of 0.2 g was transferred into a tube, and 2 ml of ACS-graded ethanol was added. The tube was placed into a shaker for 30 minutes at room temperature before being centrifuged at 5000 rpm for 15 minutes at 4°C using Thermo Scientific Heraeus Multifuge X1R Centrifuge. The supernatants were collected and stored in a microtube at -20°C. Further EIA analysis was conducted using the Arbor Assays DetectX® Progesterone and Estradiol Enzyme Immunoassay procedure.

Behavioral Observation

Focal-animal sampling method was used to observe the daily behavior of female orangutans. This study followed the standardized focal-animal protocol established by Morrogh-Bernard and colleagues (2002). Behavioral observation was conducted twice daily at 09:00 and 12:00 for 30 minutes. The ethogram of daily activity budget followed Kamaluddin and colleagues (2021) and Morrogh-Bernard (2009) [Table 1 and Figure 2). Behavior with a duration of less than 0.7% was omitted, which included urinating, defecating, grooming, and nesting.

The scan sampling adapted from Martin and Bateson (1993) quantified aggressive behavior. Scan sampling was conducted hourly, from 9:30 a.m. to 2.30 p.m., with six daily scans for each animal. The ethogram of aggressive behavior followed the definition developed by Aureli and de Waal (2001) (Table 1).

Table 1. Ethogram of daily activity behavior and aggression of orangutans

Categories	Definition
Daily Activities	
Resting	The animal is immobile while in a sitting or lying position.
Feeding	The animal is engaged in searching, reaching, obtaining, handling, chewing, swallowing food, and drinking, including brief movement around the feeding behavior.
Playing	The animal is in solitary and/or social engagement, including following, making hand contact, fighting, dragging, pushing, and grooming.
Moving	The animal is engaged in traveling on the ground or in trees. Locomotion patterns include brachiating, hanging, clinging, and walking quadrupedally. The animal is considered to rest when it remains immobile for more than one minute between moving activities.
Aggression	Purposeful action by an individual (aggressor) toward another group member (victim), resulting in physical harm or indicating an intention to cause harm (Aureli & de Waal (2000).

Statistical Analysis

Data was analyzed via IBM SPSS 23.0. Descriptive analysis determined median and interquartile range (IQR) values. Data was analyzed non-parametrically due to the small sample size (n<10). P-value is significant at <0.05 and highly significant at <0.001. Spearman's correlation coefficient test was used to test the association between reproductive hormone concentration and the behavior of orangutans. The strength of correlation followed the guideline from Ratner (2009), with 0 to ±0.3 indicating a weak linear relationship, ±0.3 to ±0.7 indicating a moderate linear relationship, and ±0.7 to 1.0 indicating a strong relationship.

Fig. 2. The daily activity of orangutans. A. Lying. B. Feeding. C. Playing. D. Moving.

RESULTS AND DISCUSSION

Hormone Profiles of Female Orangutans of BMOUI

Figures 3, 4, 5, and 6 illustrate the hormone profiles of Baboon, Careena, April, and Kate. Overall, fecal progesterone concentrations ranged as low as 0.031 µg/ml (Careena, age 15) [Figure 4] to the highest P4 recorded of 7.371 µg/ml (Kate, 9) [Figure 6]. The median concentration of P4 recorded among four females ranged from a low 0.203 µg/ml (Baboon, age 33) to as high as 1.141 µg/ml (Kate, age 9). Fecal estradiol concentrations ranged from 0.003 µg/ml (Careena, age 15) [Figure 4] to the highest E2 level recorded of 0.110 µg/ml (Baboon, age 33) [Figure 3]. The median concentration of E2 recorded was as low as 0.016 µg/ml (Kate, age 9) to as high as 0.031 µg/ml (April, age 13).

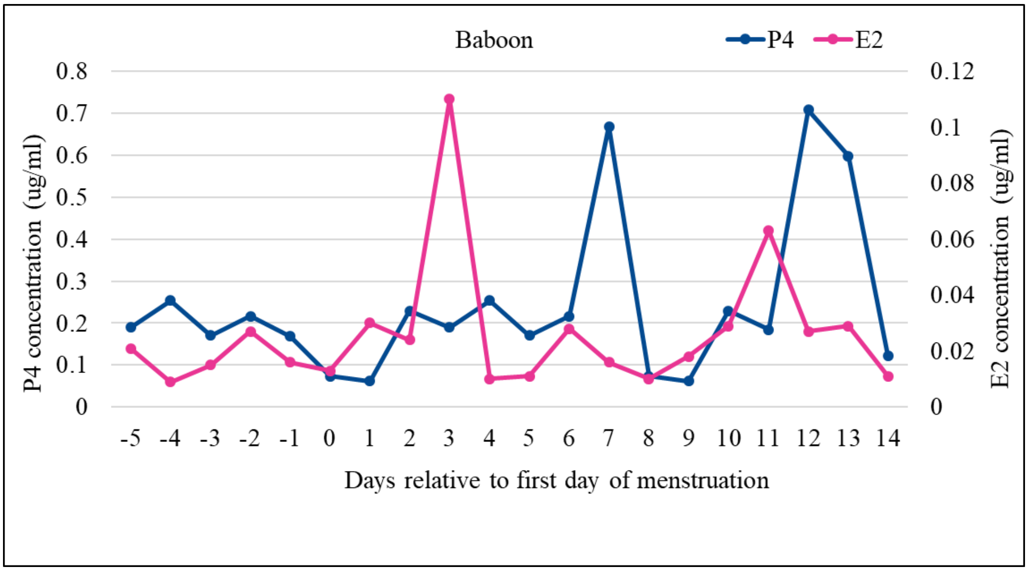

Fig. 3. Menstrual cycle profile of Baboon (age 33) illustrating estrogen (estradiol [E2]) levels in pink bullets and progesterone [P4] levels in blue bullets

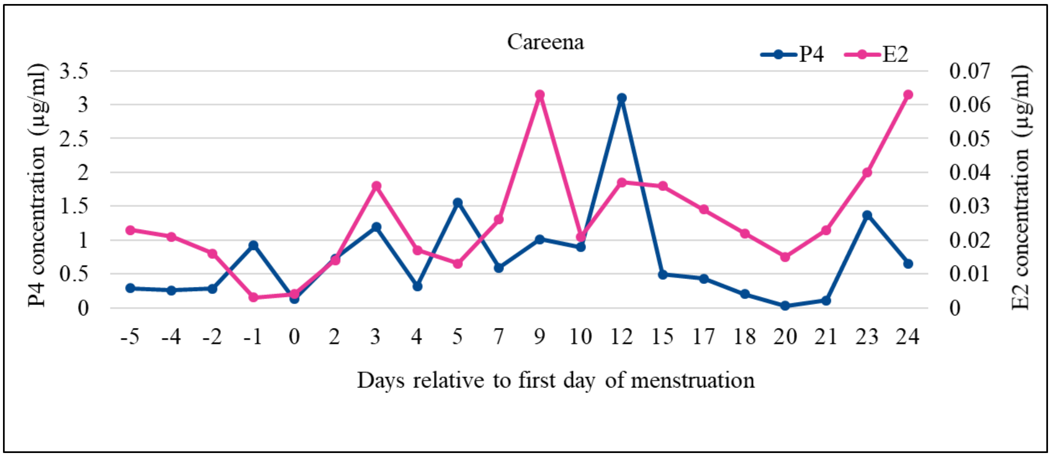

Fig. 4. Menstrual cycle profile of Careena (age 15) illustrating estrogen (estradiol [E2]) levels in pink bullets and progesterone [P4] levels in blue bullets

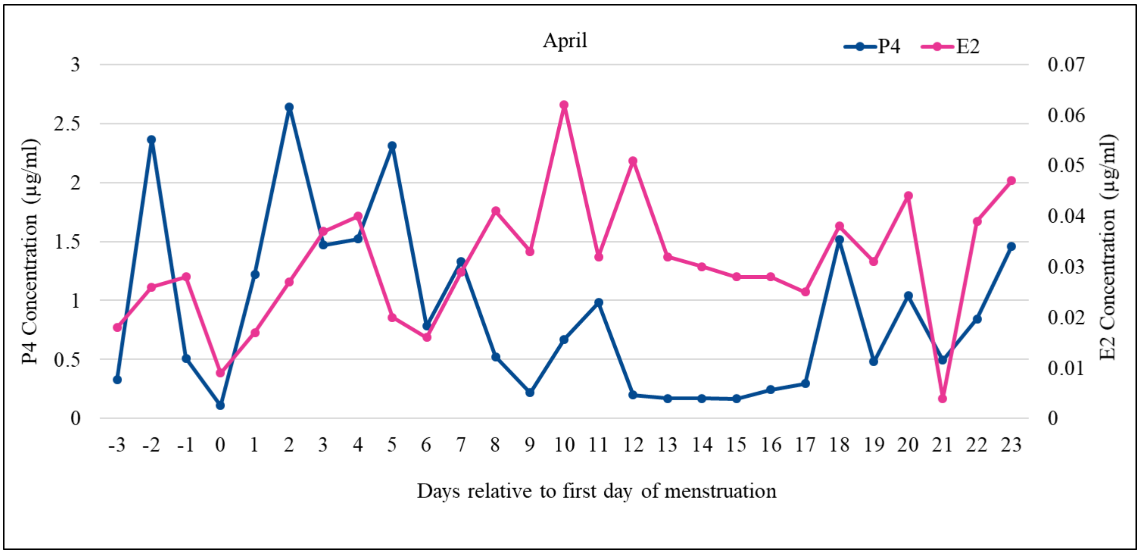

Fig. 5. Menstrual cycle profile of April (age 13) illustrating estrogen (estradiol [E2]) levels in pink bullets and progesterone [P4] levels in blue bullets

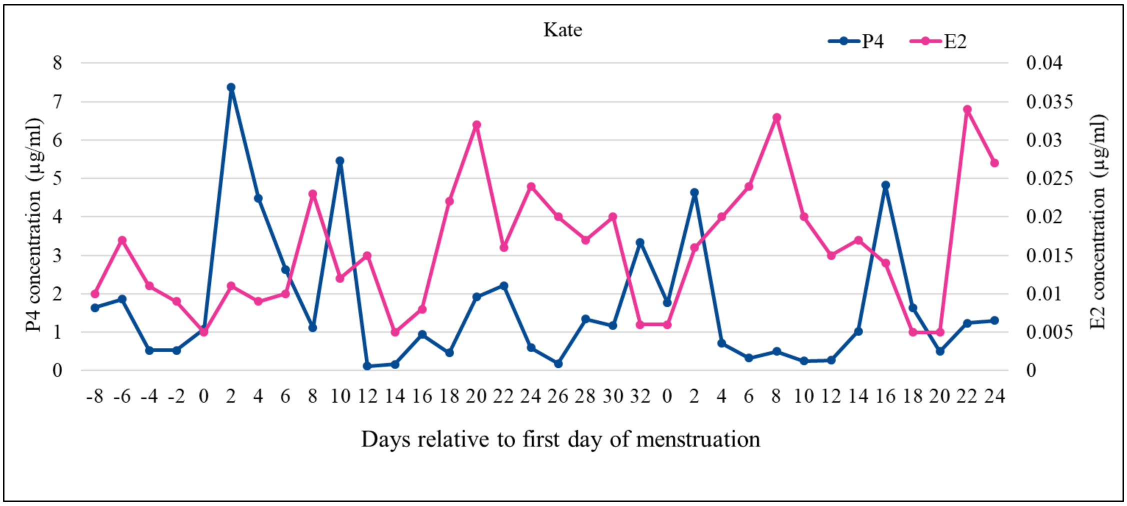

Fig. 6. Menstrual cycle profile of Kate (age 9) illustrating estrogen (estradiol [E2]) levels in pink bullets and progesterone [P4] levels in blue bullets

Progesterone-Behaviour Relationship

A Spearman's correlation coefficient reveals a significant but moderately positive relationship between resting behavior and the level of progesterone, r[101]=0.462, p=0.006 (Table 2). The test also shows a significant but moderate negative relationship between playing behavior and progesterone concentrations, r[101]=-0.439, p=0.015 (Table 2). A Spearman's correlation coefficient reveals a significant moderate negative relationship between aggression and the level of progesterone, r[101]=-0.440, p=0.009 (Figure 2).

Table 2. Correlation (r) between progesterone concentration with daily activities and aggressive behavior of female Bornean orangutans via Spearman's correlation coefficient test

Daily Activities	Progesterone	
	r	p-value
Resting	0.462	**0.006***
Playing	-0.439	**0.015***
Moving	-0.183	0.299
Feeding	-0.224	0.204
Aggression	-0.440	**0.009***

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

Progesterone and daily activity behavior

In this study, higher progesterone concentration is linked to higher resting periods, lower playing behavior, and lower aggression encounters, and vice versa (Table 2). Previous studies revealed contradicting findings in the literature regarding the association of progesterone with body activities, which reported that high progesterone in the luteal phase is associated with higher cardiovascular function, muscle fatigue, and insulin resistance (Moran et al., 2000; Carmichael et al., 2021; Maya Gault & Smith, 2023).

Moran and colleagues reported a lower resting heart rate and systolic blood pressure during the follicular phase with a higher progesterone level, which signals good cardiovascular functioning. The heightened progesterone level in the luteal phase causes lower resting systolic blood pressure due to vasodilation and suppression of vasoconstrictor reflexes (Moran et al., 2000). Hence, it is suggested that women incorporate targeted exercise in this phase due to low heart rate, low systolic pressure, and faster recovery (Moran et al., 2000). A better understanding of the impact of hormones in different menstrual cycles associated with cardiovascular functioning helps promote appropriate exercise among women. However, this information is only applied to sedentary women. Women athletes and highly trained women do not condition to the menstrual cycle-hormone-related fluctuation in their performance.

In contrast to Moran and colleagues' (2000) finding, a more recent study reported higher muscle fatigue during heightened progesterone levels in the luteal phase (Maya Gault & Smith, 2023). During this phase, higher basal temperatures disrupt the normal ventilation pattern, resulting in increased exhaustion (Hackney et al., 2019). Additionally, progesterone is also linked to the rise of metabolic rate, causing higher oxygen debt post-exercise and lowering the recovery rate (Webb, 1986). As a result of these findings, females adapt to the condition by resting more and playing less during the luteal phase. This behavioral modification of female orangutans showcased in this study supports the notion by Maya Gault and Smith (2023).

Increasing progesterone is also associated with insulin resistance (Carmichael et al., 2021). Hence, during the luteal phase, it is recommended to consume more carbohydrates, preferably complex carbohydrates, to stabilize blood sugar (Maya Gault & Smith, 2023). Rice potatoes, potatoes, and corn are good carbohydrate options for orangutans during this phase (McLay et al., 2017).

Progesterone and aggression

The results of this study regarding the correlation between aggression and reproductive hormones greatly advance our knowledge of orangutan ovarian activity. This study emphasizes the association between progesterone concentration and aggression among captive female orangutans at Bukit Merah

Orang Utan Island, Perak. Ideally, progesterone would rise in the luteal phase after ovulation occurs in a normal menstrual cycle (Graham, 1981). During this phase, it has been reported that there is also an increase in fear and a faster reaction to stimuli (Conway et al., 2007). Hence, the heightened sensitivity of fear during the luteal phase may affect the behavior of orangutans, causing less aggressive encounters with others. This behavior adaptation observed is a strategy to reduce the risk of injury to the mother and fetus during the early pregnancy phase (Conway et al., 2007). It is also reported as an adaptation of the body to prepare for the next stage of pregnancy (Conway et a., 2007).

In contrast to this discovery, increased progesterone concentration is linked to female emotional changes, potentially leading to aggressive behavior (Sundström-Poromaa, 2018). During this phase, most women indicated symptoms such as depression, irritability, and emotional instability (Epperson et al., 2012; Yonkers, O'Brien, & Eriksson, 2008). Negative mood impact was also reported among women prescribed artificial progesterone as a birth control method (Lundin et al., 2017; Gingnell et al., 2013). Progesterone impacts emotional regulation in women because it is highly lipophilic and easily permeable through the blood-brain barrier (Sundstrom Poromaa, 2018). This causes progesterone to accumulate in the brain, particularly in the amygdala, which controls emotion processing, increasing amygdala reactivity in women (van Wingen et al. 2008). It has been reported that increasing amygdala reactivity is likely to lead to fear and anxiety (Ressler, 2010).

Additionally, genetic factors also play a crucial role in influencing sex hormones for emotional processing (Hamstra et al., 2017). However, the relationship between progesterone and emotions in women is rather complicated, with mixed findings found among studies (Sundström-Poromaa, 2018). It is hypothesized that perhaps the mixed findings of progesterone hormone towards emotion regulation depend on the current reproductive status of the women at the time, i.e., pregnant or non-pregnant, postpartum. For example, allopregnanolone has protective and mood-stabilizing effects during pregnancy and postpartum, allowing females to optimize cognitive function during critical phases (Osborne et al., 2017). This finding is contradicted by the previous study by Lundin and colleagues (2017), where artificial progesterone causes a negative mood impact among non-pregnant women.

Although the results of this study show that changes in progesterone levels are associated with aggressive behavior in female orangutans, it is unclear whether this is also associated with stress levels in orangutans. Future studies are recommended to bring attention to this issue, as cortisol measurement is an important aspect that should be investigated in ensuring the welfare of orangutans in captivity.

Estradiol-Behaviour Relationship

Spearman's correlation coefficient tests show no significant relationship between estradiol and behavior ($p>0.05$ (Table 3). In contrast to the mixed findings of progesterone-behavior interaction, estrogen reported more consistent findings in previous studies. Estrogen, known as the "happy hormones," is associated with positive mood and cognition (Kaunitz & Mansion, 2015). Estrogen is the key hormone in regulating the central system because it controls neurotransmitters in the amygdala, hippocampus, and prefrontal lobes, which play a vital role in emotional cognition (Chen et al., 2011). It also affects the hypothalamus-pituitary-adrenal (HPA) axis, which changes the emotional behavior of a woman (Chen et al., 2011). Interestingly, estrogen influences emotional processing through its ability to detect changes in other people's facial expressions and intensity of feelings (Chen et al., 2011). Due to this ability, women might have higher sensitivity towards their own emotions and others, causing negative mood impacts during the high estrogen phase.

Table 3. Correlation (r) between estradiol concentration with daily activities and aggressive the behavior of female Bornean orangutans via Spearman's correlation coefficient test

Daily Activities	Estradiol	
	r	p-value
Resting	-0.283	0.105
Playing	0.268	0.125
Moving	0.079	0.658
Feeding	-0.207	0.240
Aggression	0.055	0.543

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

This finding in women is consistent with animal studies, which found that injecting estradiol into the amygdala reduced depressive behavior in rats (Frey et al., 2008). This data confirms that the amygdala is strongly linked to mood regulation due to its high sensitivity of estradiol-sensitive neural structure, which is an important site for the regulation of anxiety and depression (Wharton et al., 2012). Estrogen is also linked to aggressive behavior in electric fish and birds (Zubizarreta et al., 2023). This is due to the influence of neuroestrogens in regulating social behaviors, including aggression (Heimovics et al., 2018) and reproduction (Cornil & Court., 2022).

However, these findings in women, fish, and mammals contradict the findings of this study on orangutans. However, additional studies with a larger sample size of female orangutans should be conducted to provide a more comprehensive and in-depth data analysis. Combining multiple parameters, including psychological, neuroscience, and endocrine data, to determine emotional fluctuations in female orangutans is also recommended.

CONCLUSION

In summary, female orangutans have unique needs based on their reproductive hormone concentration, particularly progesterone, throughout the menstrual cycle. This study demonstrates significant associations between progesterone and the behavior of female orangutans. Hence, understanding the effect of fluctuating hormone concentration on female orangutans' behavior can help optimize their fertility in captivity. The BMOUI management team's adaptation strategy can help provide better care for captive orangutans to improve their fertility, increasing the likelihood of conception and successful pregnancies. However, the result from this study is derived from a small sample size of Bukit Merah and does not represent the general population of orangutans. Hence, further studies should include more female orangutans in the wild and captivity to better understand orangutans' ovarian activities and behavioral changes in the menstrual cycle. There might be variations among individual orangutans and populations as a complex correlation of hormonal, environmental, and social factors influences them.

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AUTHOR'S CONTRIBUTION

Noramira Nozmi carried out the research and wrote the article. Nur Nadiah Md Yusof contributed to designing and implementing the research and reviewing the article. Farida Zuraina anchored the review and revisions and approved the article submission. Hartini Ithnin verified the reproducibility of ELISA analysis and consulted the software application to analyze ELISA outputs. Muhammad Fahmi Ramli helped with the data collection investigation process.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted without any self-benefits or commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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