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Lise J. King-Dooley • Melissa E. Thompson

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Females of catarrhine primates during the mid-ovarian cycle exhibit exaggerated swellings of the perineal skin. The significance of their function is still debated. Sexual swelling during early pregnancy is common, thus allowing estrus females to increase their social status within the community and gain benefits. Swelling increases a pregnant female's attractivity, which leads to copulation with males of recent sexual history. Swellings act as a passport for safe intergroup transfer for nonpregnant and pregnant females. Thirty-two sexual swellings of wild chimpanzee (*Pan troglodytes schweinfurthii*) females from Kibale, Uganda, were studied. A photo scale-2 digital caliper was used to capture sexual swellings and conduct measurements with ImageJ of the two-laser points, height, width, and best-fit area using an ellipse. Used the Pearson correlation to test if age 1 and 2 predict the swelling size; also used a one-way ANOVA to test if sexual swelling height and area changes between a female's reproductive state. Our findings resulted in the correlation test not having a statistically significant difference between the two age groups and their height and area. However, there was a statistically significant difference in the height and area between reproductive states for pregnant, nulliparous, and parous females.

Key words: sexual swelling, sexual behavior, menstrual cycle, mating behavior, social bonds, false estrus, chimpanzees

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Introduction

Evolution and Function of Sexual Swellings

Among females of some catarrhine species evince exaggerated sexual swellings atop the perineum concerning the female menstrual cycle; with the proposal that sexual swellings possibly evolved multiple times (Dixson 1983; Nunn 1999). No found records of sexual swellings in New World Monkeys or Strepsirrhine, but not to say that it might not evolve years from now if species do not get annihilated. Swellings are water balloon size, prominent, and brightly colored during the follicular phase (Dixson 1983; Nunn 1999). Exaggerated sexual swellings are observed in a polygynandrous (or promiscuous) breeding society, meaning females are mating with many males through her time of oestrus, and changes to male behavior is off the roof with male-male competition. It is suggested that the exaggerated swellings increase male competition, and the sizeable the swelling, the more arousal (Domb & Pagel, 2001). The specific functions of exaggerated swellings remain controversial.

Numerous studies are narrowing down why sexual swellings evolved, and some theories suggest the swellings evolved for the benefit of females which makes since because of natural selection. Females possibly benefit by mating with more than one male because male competition will allow the female to notice the winner as the "best male hypothesis" and recognize his fitness as the so-called best gene to pass onto her offspring (Clutton-Brock & Harvey, 1976; Hrdy & Whitten 1987). The "many males hypothesis according to Hrdy, empowers females to mate with multiple males as possible during the menstrual cycle. With this strategy of mating with multiple males across the menstrual cycle, females might be increasing paternal uncertainty (Boesch & Boesch-Achermann, 2000). Males are genetically uncertain about the infant belonging to the female they mated with is an infant he sired, but this outcome is handy due to parental care increasing for the infant and reducing any possibility of infanticide suffering to female's offspring (Hrdy, 1979). Furthermore, a study on male captive black-and-white ruffed lemurs (*Varecia variegata*) revealed that infants they sired were less likely to experience infanticide, backing up Hrdy's theory. The graded-signals hypothesis proposed first-hand by Nunn in 1999, proposes that exaggerated sexual swellings signal female fertility period and that at peak swelling only, dominant males are inclined to stay by the female a long while after mating, therefore granting females to mate with subordinate males pass peak swelling (Nunn 1999). Ovulation possibly occurs when the female sexual swelling is enormous ergo suggesting the phase of being most fertile (Nunn & Schaik & Zinner, 2001).

On the other hand, female exaggerated swellings are proposed to be costly by many; first, the instant attraction to males can lead to increased injuries by the downfall of male-male competition (Goodall 1986; Zinner et al., 1994). Second, the swellings are exposed to blood-sucking insects to feast upon (F. White, personal communication), which is significantly costly, especially with the swellings being in an awkward position that can be tough to effectively keep the insects off. Third, the extra body weight is costly on traveling on the ground and climbing on trees (Schmidt-Nielson, 1984). Finally, the visibly bright-colored swellings might be vulnerable to other predators around the community (Dixson, 1998).

Female Sexual Behavior

Estrus being a distinct period around ovulation is characterized by three related changes (Beach, 1976). The female sexuality is comprised of *attractivity*, *proceptivity*, and *receptivity*. An increase in *attractivity,* in terms of females' value as a stimulus to males. Attractivity is measured by the likelihood of being approached and the attempts to mount. With an increase in *proceptivity* behaviors, females engage in activities in the presence and behavior of males. Proceptive behaviors generally include affiliation behaviors like approaching to sit near the male and behave that solicit sexual contact directly, for example, showcasing the hindquarters to the male. An increase in *receptivity* behaviors, actions are designed to facilitate copulation itself, an estrogen-dependent mating posture that is long-lasting to allow ejaculation (Hrdy, 1987). Lordosis reflex is a classic example of receptivity and species must have true "estrus" to mate at ovulation which will lead to conception.

The reproductive cycles in great apes, humans, and many monkeys differ from traditional estrous cycles in two ways: first, menstruation is included in the cycles, a cyclical sloughing of the uterine lining; second, the timing is significantly flexible of proceptive and receptive behaviors and estrus duration is longer. Sexual receptivity throughout all or much of the cycle in some species is frequently exhibited under natural conditions (e.g., humans, bonobos, common marmosets: Thompson-handler, Malenky, and Badrian 1984; Hearn, 1978; Hrdy 1987), prolonged receptivity is detected in other species due to captivity conditions (common chimpanzees: Lemmon and Allen 1978). This distinctive flexible receptivity indeed makes these species, and many other monkeys and great apes stand out from other mammals. All primates maintain the habit of centralizing mating at midcycle. Manifested among savanna baboons (Hausfater 1974) and gorillas (Graham 1981), tamarins at a small degree (Brand and Martin 1983), or humans (Adams, Gold, and Burt 1978). Due to the capacity of flexible receptivity in catarrhine primates, estrus does not suggest the specific physiological conditions surrounding ovulation, even though estrus and ovulation coexist in gorillas (Mitchell et al., 1982).

Primatologists are redefining estrous as an actively lustful behavior by females who allow copulations despite being or not being near ovulation (Wolfe 1984). With hormone levels and ovulation being hard to confirm under field conditions (unless the pregnancy is detected subsequently), it is practical to have a behavioral definition of estrus when measuring proceptivity and receptivity behaviors done by females (Hrdy, 1987).

The Menstrual Cycle

The chimpanzee menstrual cycle from menstruation and fluctuations in the size of sexual swelling breaks down into six phases (Yerkes & Elder, 1936; Clark & Birch, 1948, Graham, 1973. The *menstrual phase* is where undeveloped sexual swellings occur and uterine bleeding. The *postmenstrual phase* is where sexual swelling remains dormant, yet uterine bleeding is not present. During the *tumescent phase*, the sexual swelling balloon up but is not quite fully developed. The *maximal tumescence* period lasting from beginning to end is where sexual swellings are large and maximal size remains steady. Sexual swellings enter the revert period, which is the *detumescent phase*; detumescence is when follicular estrogen levels decrease, but luteal progesterone levels increase (Graham, 1977). The sexual skin is minimal in size for several days during the *post-tumescent phase*. Finally, menstruation appears again (Young & Yerkes, 1943, Graham, 1973).

The menstrual cycle of great apes and Old-World monkeys varies from 25 to 35 days. From laboratory studies done on a small number of species, the endocrine events occurring in these cycles bear a resemblance to human cycle patterns, with minor variations of course (Hrdy 1987) (great apes--Graham 1981, rhesus macaques—Hess and Resko 1973). The first cycle stage from the end of menstruation till ovulation is called the follicular phase in humans. Throughout this phase, the follicle carrying an egg develops in an ovary. While the ovarian follicle develops, levels of estrogenic hormones (estradiol) slowly rise, roughly around 15 days of cycle peaking occurs. The pituitary produces a surge of the luteinizing hormone due to the high level of estrogens, the instant stimulus for ovulation. Peaking of testosterone hormones occurs midcycle (Hrdy 1987). As the egg releases, the ovarian follicle transforms into a solid body which is the corpus luteum, producing progesterone during the cycle of this luteal phase. Stimulated by progesterone, the uterus or endometrium is lined up to get ready to receive the fertilized egg. In the event that fertilization does not transpire, progesterone levels drop, uterus lining disintegrates, and menstruation comes after. Bleeding is frequently noticeable amongst humans, apes, and Old-World monkeys from the 1-to-8-day period.

Mating Behavior

Studies done on chimpanzees report that their mating system is promiscuous. During the oestrous period, there might be patterns that are noticeable among all adults of both sexes. The first pattern is *opportunistic*, non-competitive mating, receptive females are mated by every adult male in the group. Second, *possessiveness* is a short-term relationship formed between an adult male and receptive female which blocks lower-ranking males from copulating with that female. Third, *consortships* occur when a single adult male distances the female from the group allowing full access to copulate with her, and both actively commit to keeping away from other chimpanzees. This mating pattern is significant because of sexual selection occurring only under these restrictive patterns, through female choice, male-male competition, and possibly both; some males are increasing their reproductive success at a cost to other males (Tutin, 1979).

In the early tumescence stage, many females are ignored by adult males, yet mated by infants, juveniles, and early adolescents, a win-win opportunity for these males who will not have the chance to continue to mate with the female when she is surrounded by larger males but a chance of conceiving for them is quite little. When the full swelling size is achieved and during the fertile cycle, the female is the center of attention and followed by many or all the community males. At first mating becomes promiscuous (or opportunistic) and most of her sexual party consist of all the males, but with a fairly high exception of any adult son or occasionally maternal adult sibling. Around the second half of her maximum tumescence, the pattern of *possessiveness* occurs; one adult male accompanies her, frequently grooming her, along with himself copulating with her and discouraging other males from copulation—(occurring only when the males are lower ranking than him). Moreover, if this behavior is done by the top-ranking male in the party, he certainly can *monopolize* the female by discouraging or aggressively discouraging males seeking copulation with her. During a stage in her cycle and anestrous period, an adult male may strive to pull the female away from the other males to a quiet location, and if he succeeds, a consortship is formed among the pair (McGinnis, 1973; Tutin, 1979) and may stay up to three months together. Ultimately, the female either wanders or is taken in by males of another neighboring community and mates with her. She might stay within this community as an immigrant or go back to her natal group pregnant (occasionally) (Goodall, 1986; Tutin, 1979).

Social Bonds/Male Dominance and Reproductive Success in Male Chimpanzees

Studies have shown that males form stronger bonds with other males than females do to other females. These bonds are beneficial for the males when the mating season approaches because high-ranking males are the first to all resources and most importantly increasing their reproductive success by copulating first with as many females at the expense of his competitors. If an alpha male is not demoted by a charging rivalry, his success rate of having the possibility of siring an infant is higher compared to lower-ranking males. Similarly, females are attracted and mate with big strong males to pass down his genes to her offspring. Males that form strong bonds with high-ranking males are brilliant to a degree that these bonds might not mean what we think it means, rather it is a devious route for a lower-ranking male to take and get the trust of the prominent member of the group to gain access to females by avoiding male-male competition with the higher-ranking or possibly other lower-ranking males.

However, some males develop successful strategic skills in consort and sire infants without competing with the high-raked rivals in the group. This allows them to pass down their genes to the next generation when opted out from a struggle with an adult male. The connection between male dominance and reproductive success is almost unnecessary because it is energetically costly to fight to be alpha male, and most times, the competition is ferocious by males leaving the fight with severe wounds. Lower-ranking males have strong skills to copulate with females and be successful at times when an alpha male is (not always) present during the female's estrus peak (not always the case with a prolonged swelling period) and if a low-ranking male copulates with her during that time frame undisturbed, he is most likely to take advantage of this situation now and future occasions. Courtship behavior of branch shaking is a signal which orders the female to approach the male, along with another step of secretly copulating with the female behind an object which leads her away from the group and follows her admirer to his secret locations. Males that succeed in this behavior, are most definitely increasing their reproductive success at the expense of the high-ranking male and lower-ranking males (Goodall, 1986).

With all that said, the question that engross us is why do female chimpanzees exhibit sexual swellings with no intentions of conceiving? The definite hormonal mechanism involved in anogenital swellings is still a bit unclear among females. Three hypotheses were put forward and proposing the possible advantages for anogenital swelling in female chimpanzee pregnancy (Wallis, 1982).

a. Sexual swelling during menstrual cycles increases social status in the community, leading to the benefits of the group security, increased social grooming, and acquisition of shared food. Any benefits gained by cycling female may as well be enjoyed by pregnant females exhibiting sexual swelling.
b. Sexual swelling increases a pregnant female's attractivity, thus allowing the establishment of a recent sexual history with males of the community. This may serve to decrease the likelihood of male-perpetrated infanticide and increase male tolerance and protection toward the female and her offspring
c. Sexual swelling acts as a passport for safe intergroup transfer, thus permitting an increase in genetic diversity by allowing free movement between natal and neighboring communities for both nonpregnant and pregnant females.

Larger groups allows females to have access to more meat, shared by males and other cycling females, which increases the benefits of social grooming and group security. It is further to suppose that the benefits estrous females receive will also be enjoyable by pregnant females exhibiting sexual swelling. There is an increase in attractivity among pregnant females exhibiting sexual swelling and possibly decrease any chances of infanticide and instead females gaining extra care and protection from nonpaternal males. A pregnant female that enters a community with a "false estrus," will be more welcomed by the males than if she entered the community utterly detumescent. Essentially anogenital swelling serve as a "passport" for safely transferring between groups (Wallis, 1982). With the attacks that some females face, it is not clear the length of time a female must be away until she is viewed as a stranger (Goodall, 1977). Known females are reported to have fewer common attacks. Pregnant females exhibiting sexual swellings are more likely to escape death from aggressive males and instead males are attracted to the females, which leads to that additional care the female receives for herself and her offspring (Wallis, 1982)

The overall aim of this study is to analyze measurements of the photogrammetric images taken among the females and compare how the size of the swellings has changed from six years (2013-2018). We explore our main questions based on our data: why do females exhibit sexual swellings with no possibility of conceiving after conception has already happened? As females age does that predict their sexual swelling size? Does sexual swelling height and area change between reproductive state? Using the Pearson Correlation to test if height and area are changing as the two age groups increase by the help of a scatter plot, and a One-Way ANOVA to test whether the sexual swelling height and area changes between reproductive state by the help of a box & whisker. We are hoping to find a significance for the height and area between the reproductive state in relation to the *P-value* and what that percentage means.

Materials and methods

Subjects and data collection

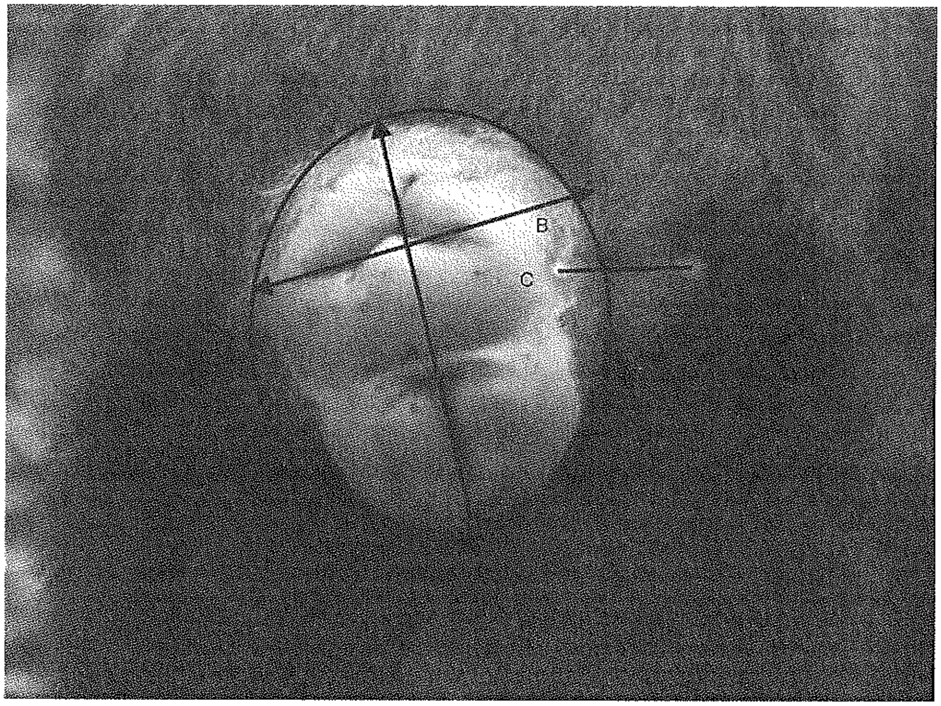
A total of 28,221 Photographs taken of chimpanzee females from the Kibale Chimpanzee Project by graduate students from 11 January 2013 through 25 March 2014, 21 October 2015 through 10 February 2016, and 15 November 2017 through 22 January 2018, were analyzed for a proximate period of 4 hours every Monday. Photogrammetric images were stored in Adobe Lightroom and images were flagged to use later, used of ImageJ to conduct calibration and measurements (acquired pixel counts for reference parallel lasers versus length/area of the whole swelling). Out of a total of 424 photos of evident swellings, 32 final images were collected and recoded on Microsoft Excel. These females picked for the study had swellings that were clear to measure compared to other females that were missing one of the two laser points, bad sunlight, or could only measure one angle of the swelling. The images comprises 12 individuals— (PO, OU, RD, QT, WL, UM, TS, ML, LN, GG, DL, JU) with the age of . (Table 1) provides information regarding the date, chimp ID, laser clarity, chimp focus, margin clarity, angle, orientation, priority, fullness of the swelling, and series of repeated swellings. A score of 1-3 was given, as so, for laser clarity (1= ideal, 2= good, 3= poor), chimp focus (1= excellent, 2= good, 3= poor), angle (1= perfect, 2= good, 3= poor, and identify the orientation of the chimp (quad, back, tree), priority (high, medium, low).

TABLE 1. Information regarding the subjects from 2013-2018

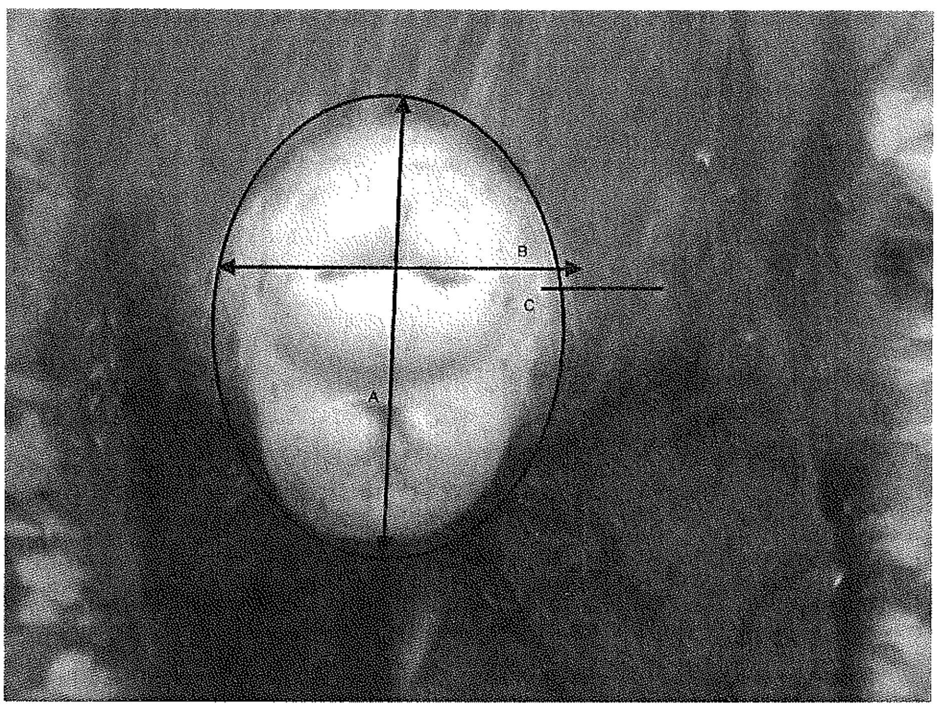
Date	ChimpID	Laser Clarit	Chimp Foc	Margin Clarity	Angle	Orientat	Priority	Full	Series
15-Nov-17	GG	1	1	2	2	TREE	MEDIUM	Semi-full	KCP_2017-11-15_Body Size_102.jpg
15-Nov-17	GG	1	1	2	2	TREE	MEDIUM	Semi-full	KCP_2017-11-15_Body Size_102.jpg
5-Dec-17	DL	1	1	1	1	QUAD	HIGH	Semi-full	KCP_2017-12-05_Body Size_57.jpg
6-Dec-17	DL	2	1	1	1	QUAD	HIGH	Semi-full	KCP_2017-12-06_Body Size_122.jpg
6-Dec-17	DL	1	1	1	1	QUAD	HIGH	Semi-full	KCP_2017-12-06_Body Size_122.jpg
8-Dec-17	JU	1	1	1	1	Quad	HIGH	Full	KCP_2017-12-08_Body Size_121.jpg
20-Dec-17	PO	3	1	1	1	QUAD	High	Full	KCP_2017-12-20_Body Size_42.jpg
20-Dec-17	PO	3	1	1	1	QUAD	High	Full	KCP_2017-12-20_Body Size_42.jpg
21-Dec-17	PO	2	1	1	1	QUAD	High	Full	KCP_2017-12-21_Body Size_55.jpg
21-Dec-17	PO	2	1	1	1	QUAD	High	Full	
22-Dec-17	PO	1	1	1	1	BACK	High	Full	
9-Jan-18	DL	1	1	1	1	QUAD	High	Full	
9-Jan-18	DL	1	1	1	1	QUAD	High	Full	
22-Jan-18	JU	2	1	2	2	TREE	High	Full	KCP_2018-01-10_Body Size_88.jpg
22-Jan-18	JU	2	1	2	2	TREE	High	Full	
1-Nov-13	OU or PO	1	1	1	1	QUAD	High	Semi-full??	None
1-Nov-13	OU or PO	1	1	2	2	QUAD	Medium	Semi-full??	None
1-Nov-13	OU or PO	1	1	2	2	QUAD	Medium	Semi-full	None
1-Nov-13	OU or PO	3	2	2	2	QUAD	Low	Semi-full	None
30-Apr-14	RD	1	1	1	1	QUAD	High	Full	None
2-May-14	RD	1	1	1	1	QUAD	High	Full	None
5-May-14	PO	2	1	1	1	QUAD	High	Full	None
5-May-14	PO	1	1	1	1	QUAD	High	Full	None
21-May-14	QT	1	1	2	2	QUAD	Medium	Full	None
21-May-14	QT	2	1	1	1	QUAD	Medium	Full	None
25-Mar-14	WL or QT	2	2	2	2	QUAD	Low	Full	None
21-Oct-15	UM	1	2	1	1	QUAD	High	Full	None
21-Oct-15	UM	1	1	2	2	QUAD	High	Full	None
22-Oct-15	TS	1	2	1	1	QUAD	Medium	Full	None
22-Oct-15	TS	1	2	1	1	QUAD	Medium	Full	None
2-Dec-15	TS	1	1	1	1	TREE	High	Full	None
10-Feb-16	ML or LN??	1	2	1	1	QUAD	High	Full	None

Photographic methods

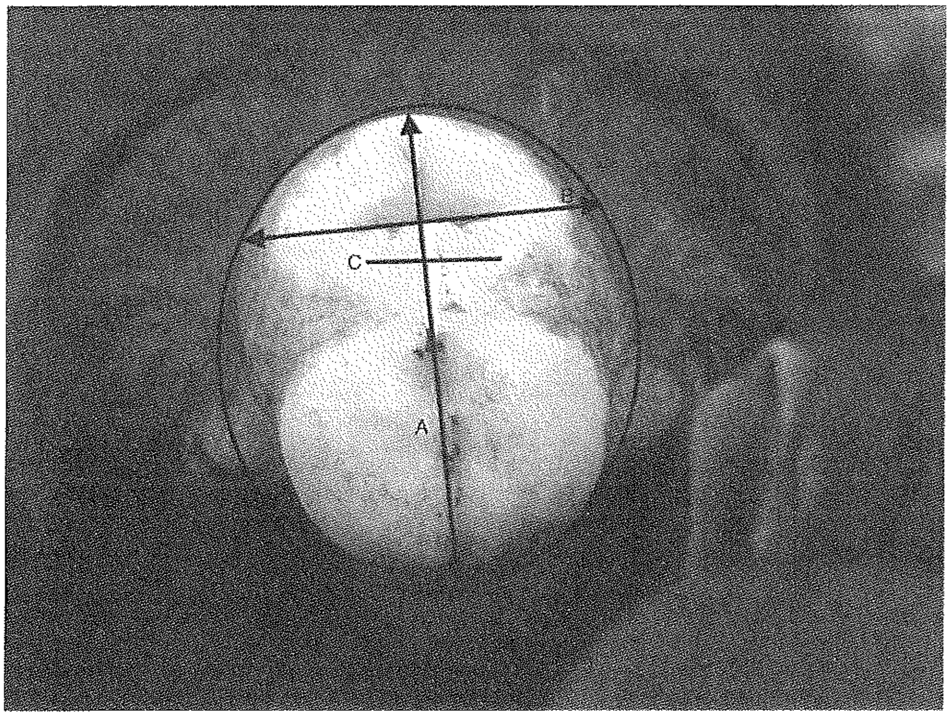
Measures of complete size of swelling were acquired courtesy of the Photoscale-2 digital caliper (Jacobson 1991). This method is the idea of parallel lasers will project light at equal distances despite of the distance from the origin. Two parallel lasers attached to a digital camera and the laser beams project to that object. A photograph is captured, and the image gives a scale bar in which can be used to measure sizing in the image of physical traits (Rothman, Chapman, Twinomugisha, Wasserman, Lambert, Goldberg, 2008). The photographs collected were of fully swollen females from the rear to measure the full height, labial width, and using ellipse for the best fit of the swelling (Emery & Whitten 2003). Figure 1 shows three (2013, 2015, 2018) perfectly focused and oriented photographs of how the three measurements were taken. Looking at the rear view only, the height of the swelling was best measured from the highest point above the anus where the swelling has begun all the way down of the labial swelling. Swelling width taken straight across the anus and stopped at the edge of rump. Additionally, the area was roughly calculated two times by using the best-fit ellipse around the swelling.



2013



2015



2018

Fig. 1 Measurements of sexual swelling size from the rear view. *(A)* full height, *(B)* anal width, *(C)* laser length. *(Black circle)* illustrates whole area using an ellipse for the best fit.

Results

Observed 28,221 photos, flagged swellings that were accurate to measure and calculate. That resulted with a total of 424 flagged swelling images, then a final total of 32 sexual swellings from 12 females were collected for measurements and calculations. Photogrammetric images were collected by graduate students from 2013-2018. More perfectly captured sexual swellings from 2017-2018 compared to the other years owing to alignment of camera.

M*easurements*

From Table 4, laser measurements were accumulated by measuring the two parallel lasers on the chimpanzee's rear view and measuring the distance for all 32 females. Height measurements of the highest point above the anus all the way down of the labial swelling, width measurements from straight across the anus and stop near the edge of the rump (see figure 1). Area composed of two measurements, the ellipse had to be angled to find the best fit and it took two tries to accurately get the whole swelling (see figure 1-black circle). The remaining four columns used the simple ratio calculation: laser width in pixels / laser width in cm = swellings measure in pixels / swelling measure in cm. The laser calibration width from (2013-2014 and 2015-2016) was 4.6 cm, and for (2017-2018) 4.53 cm, these two-laser width were calculated to convert the measurements of the swellings. Height (cm)—(height measurement / laser measurement)*4.6 for 2013-2014 and 2015-2016, height (cm)—(height measurement / laser measurements)*4.53 for 2017-2018. Width (cm)—(width measurement / laser measurement)*4.6 for 2013-2014 and 2015-2016, width (cm)—(width measurement / laser measurement)*4.53 for 2017-2018. Area 1 (cm2)—(area measurement 1 / (laser measurements / 4.6)^2 for 2013-2014 and 2015-2016, area 1 (cm2)—(area measurement 2 / (laser measurement / 4.53)^2 for 2017-2018.

TABLE 4. Information Concerning all Measurements of Subjects From 2013-2018

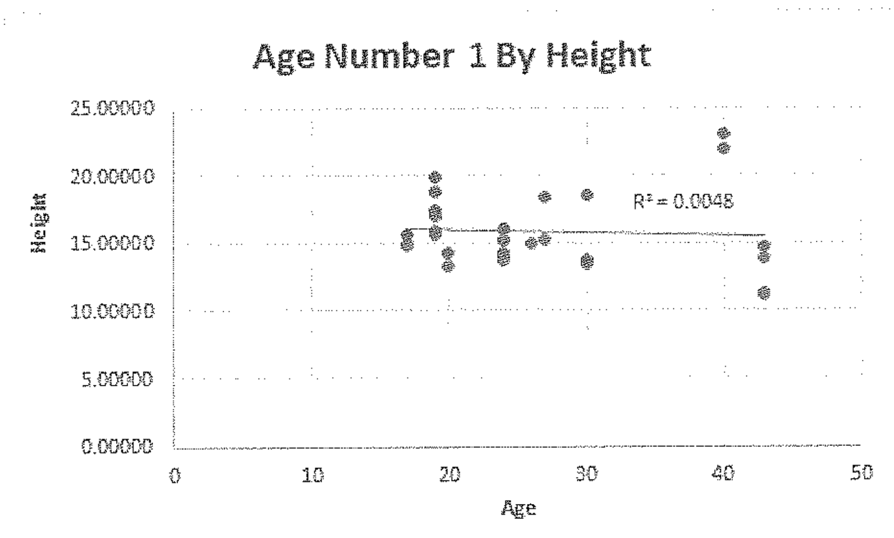
Date	ChimpID	Age	Meas_Lasers	Meas_Height	Meas_Width	Meas_Area1	Meas_Area2	Height_CM	Width_CM	Area1_CM2	Area1_CM2	Reproductive state
15-Nov-17	GG	20	273	805	504	431466	423853	13.35769	8.363076923	118.8003413	116.7041692	not fully swollen
15-Nov-17	GG	20	266	842	534	417686	416078	14.33932	9.09406015	121.1387393	120.6723816	not fully swollen
5-Dec-17	DL	19	336	1161	774	882836	900332	15.65277	10.43517857	160.4714894	163.6517055	not fully swollen
6-Dec-17	DL	19	372	1294	915	1272161	1199528	15.75758	11.14233871	188.6481722	177.8774579	not fully swollen
6-Dec-17	DL	19	370	1395	938	1166824	1222879	17.07932	11.48416216	174.9034231	183.3058997	not fully swollen
8-Dec-17	JU	19	195	684	442	334200	329994	15.88985	10.26800	180.3572592	178.0874129	nulliparous/cycling
20-Dec-17	PO	24	412	1281	812	1141220	1119386	14.08478	8.928058252	137.965769	135.3261863	parous/cycling
20-Dec-17	PO	24	426	1297	961	1263548	1166820	13.79204	10.21908451	142.8791805	131.9413947	parous/cycling
21-Dec-17	PO	24	304	1026	763	724979	740539	15.28875	11.36970	160.9810159	164.4361016	parous/cycling
21-Dec-17	PO	24	304	1026	763	724979	740539	15.28875	11.36970	160.9810159	164.4361016	same picture as above???
22-Dec-17	PO	24	266	836	690	559619	545432	14.23714	11.75075188	162.3026392	158.1880763	parous/cycling
9-Jan-18	DL	19	268	1109	808	762516	731432	18.74541	13.65761194	217.859136	208.9780983	pregnant
9-Jan-18	DL	19	254	1114	786	832004	851992	19.86780	14.0180315	264.639328	270.9970028	pregnant
22-Jan-18	JU	19	248	958	609	662538	665095	17.49895	11.12407258	221.0567775	221.9099243	nulliparous/cycling
22-Jan-18	JU	19	253	958	573	651606	649576	17.15312	10.25964427	208.9009603	208.2501545	nulliparous/cycling
1-Nov-13	OU or PO	43 or 24	205	657	432	278028	288713	14.74244	9.693658537	139.989827	145.3698294	OU is pregnant, PO is nulliparous/cycling
1-Nov-13	OU or PO	44 or 24	216	654	412	271488	277190	13.92778	8.774074074	123.1285597	125.7146005	OU is pregnant, PO is nulliparous/cycling
1-Nov-13	OU or PO	45 or 24	157	385	243	103603	106814	11.28025	7.119745223	88.93827255	91.69476409	OU is pregnant, PO is nulliparous/cycling
1-Nov-13	OU or PO	46 or 24	163	396	232	106139	104143	11.17546	6.547239264	84.53089089	82.9412428	OU is pregnant, PO is nulliparous/cycling
30-Apr-14	RD	27	249	828	614	532957	514054	15.29639	11.34297189	181.8901327	175.4388258	pregnant
2-May-14	RD	27	136	542	291	163058	168094	18.33235	9.842647059	186.5434299	192.3047708	pregnant
5-May-14	PO	24	351	1229	837	1086414	1087444	16.10655	10.96923077	186.5936173	186.7705217	pregnant
5-May-14	PO	24	354	1235	899	1121774	1100144	16.04802	11.6819209	189.4150614	185.762768	pregnant
21-May-14	QT	30	201	589	450	333267	336875	13.47960	10.29850746	174.5483953	176.4380832	pregnant
21-May-14	QT	30	234	696	482	394910	393574	13.68205	9.475213675	152.6096793	152.0933932	pregnant
25-Mar-14	WL or QT	30 or 30	51	206	128	28928	29475	18.58039	11.54509804	235.3389004	239.7869273	QT is pregnant, WL parous/cycling
21-Oct-15	UM	40	132	663	380	289918	297810	23.10454545	13.24242424	352.0813177	361.6654959	pregnant
21-Oct-15	UM	40	133	635	392	286432	286500	21.96240602	13.55789474	342.6367302	342.7180734	pregnant
22-Oct-15	TS	17	163	532	410	205478	205574	15.01349693	11.57055215	163.646147	163.722603	nulliparous/cycling
22-Oct-15	TS	17	153	523	403	188492	187880	15.72418301	12.11633987	170.3827895	169.8295869	nulliparous/cycling
2-Dec-15	TS	17	212	686	520	332990	333722	14.88490566	11.28301887	156.7743948	157.1190263	nulliparous/cycling
10-Feb-16	ML or LN??	26 or 27	337	1102	808	868392	869342	15.0421365	11.02908012	161.7974511	161.9744536	ML is pregnant, LN parous/cycling

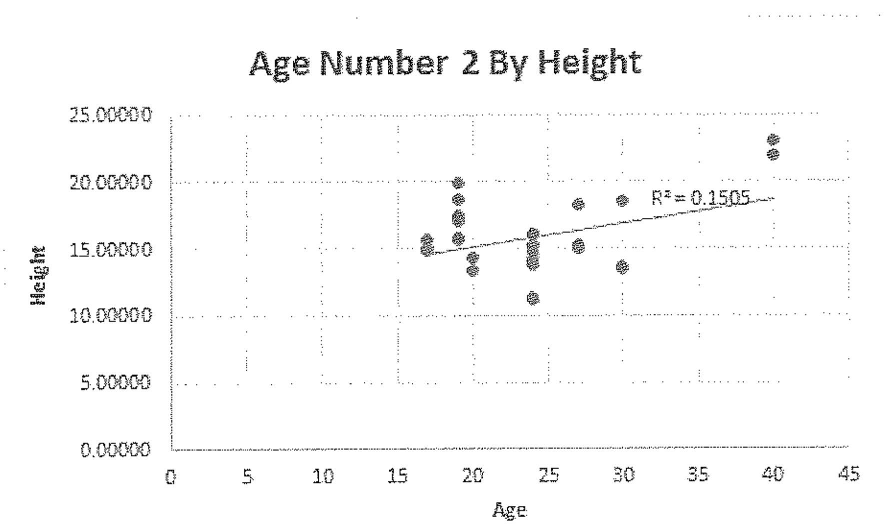
Ages and Swellings Height and Area

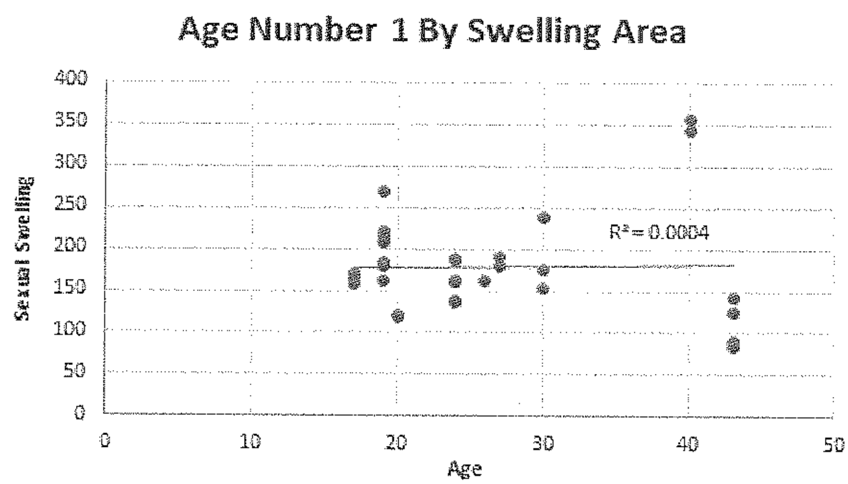
A correlation test was done to see if age predicts sexual swelling size among females. We did two ages groups because there were three instances where it was unclear which female was in the photo, so we included both females in the study instead of removing one.

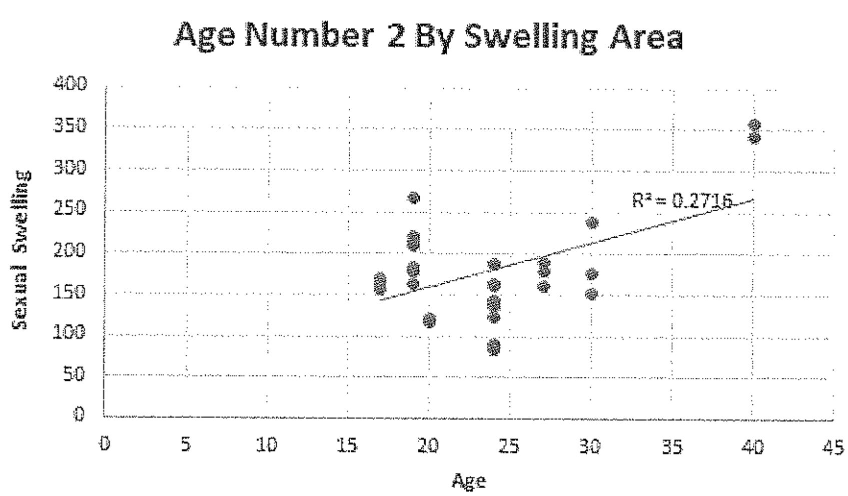
Figure 2 shows age number 1 by height with $R^2 = 0.0048$ and had a *P-value* of 0.979199. The results were not significant at P < .05. Age number 2 by height with $R^2 = 0.1505$ and had a *P-value* of 0.410973. The result were not significant at P < .05. Age number 1 by area with $R^2 = 0.0004$ and had a *P-value* of 0.998266. The result were not significant at P < .05. Age number 2 by area with $R^2 = 0.2716$ and had a *P-value* of 0.132658. The results were also not significant at P < .05. We learned from the correlation test that as these female chimpanzees age, it does not predict their sexual swelling size.

Fig. 2. The correlation test between the two age groups of females sexual swelling height and area.









Changing Rate of Swelling Height and Area Between Reproductive State

A one-way analysis of variance was used for the three groups, pregnant, nulliparous, and parous, to test if sexual swelling height and area changes between the females' reproductive state. We did two reproductive states, similar to the two age groups in the correlation test. Table 1 shows the significant results we found for height changing between reproductive states two only, with a P-value of 0.01, meaning there is only a 1% chance that we found a difference between the pregnant, nulliparous, and parous females. That is only 0.5 in 50 chances of these being a random fluke by just the data we selected. Figure 3 shows pregnant females' sexual swelling height had a significant result during the reproductive state compared to the nulliparous and parous females but not a massive difference. Therefore, we rejected the null hypothesis of the ANOVA and concluded there is a statistically significant difference between the means of the three groups.

Table 2 shows the significant results for area changing between reproductive state two, with the p-value being 0.002, suggesting there is only a 0.2% chance that we found a difference between the three groups, with only 0.1 in 50 chances for this being a random fluke as well. Figure 4 shows the difference between the groups; and we rejected the null hypothesis of the ANOVA and concluded there is a statistically significant difference between the means of the three groups.

Table 1. The analysis of variance for sexual swelling height between the three groups

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Pregnant	11	195.206	17.75	9.93
Nulliparous	15	223.477	14.90	3.59
Parous	6	87.734	14.62	0.44

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	62.147	2	31.073	5.94	0.01	3.33
Within Groups	151.706	29	5.231			
Total	213.853	31				

Fig. 3. Comparison of the height and reproductive state among the three groups

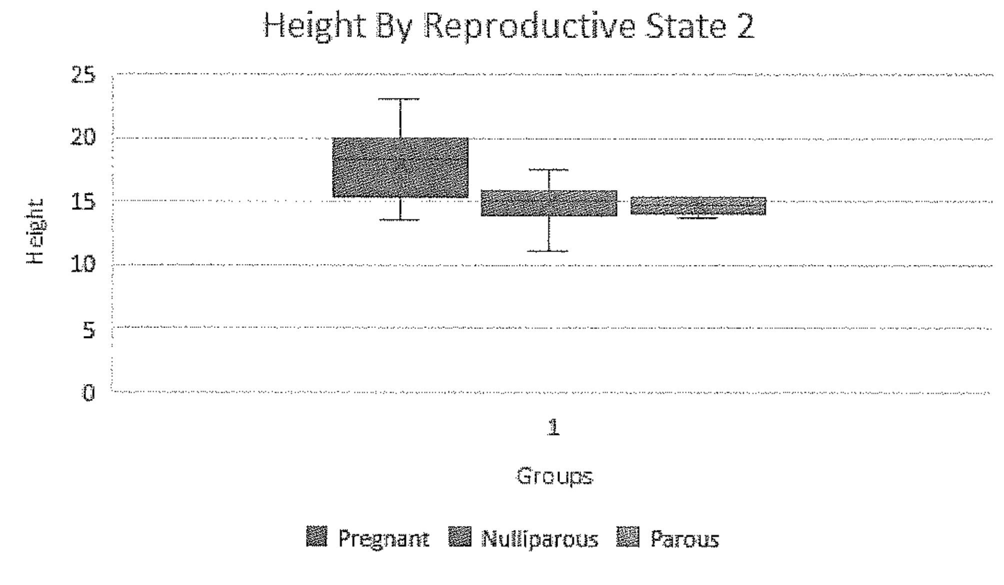
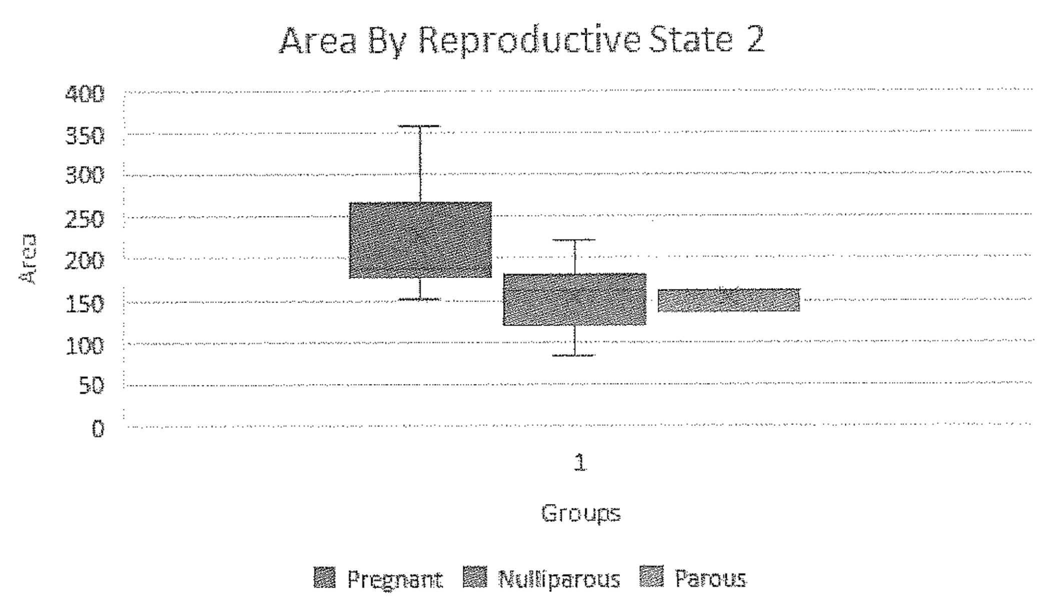


Table 2. The analysis of variance for sexual swelling area between the three groups

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Pregnant	11	2488.56	226.23	4735.64		
Nulliparous	15	2304.26	153.62	1606.05		
Parous	6	921.60	153.60	165.66		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	38069.03	2	19034.51	7.81	0.002	3.33
Within Groups	70669.39	29	2436.88			
Total	108738.42	31				

Fig. 4. Comparison of the area and reproductive state among the three groups



Discussion

This study revealed that age does not seem to predict sexual swelling size among the 32 females we observed for this small-scale study. Height and area of age 1 and 2 results were not significant at $p < .05$. We fail to reject the null hypothesis and conclude there was no sufficient evidence that suggests a statistically significant difference between the means of the groups. However, if more females were observed for this study, our results could have turned out differently, and we might have found a significant difference in age predicting swelling sizes.

Among the three groups, sexual swelling height changes between reproductive state two only, more so for pregnant females with the average being 17.75. The same noticeable results for the area changing between reproductive state two only with an average of 226.23 for pregnant females. However, the results we got is fairly small, and random chance that we happened to find a significance among the height and area between the reproductive state. Three possible advantages explored of why females exhibit sexual swellings with no possibility of conceiving after conception has already happened. 1. During the menstrual cycle, females with sexual swellings increase their social status in their community. The benefits cycling females receive will also be enjoyed by pregnant females. Therefore, pregnant females can blend in with the cycling females and get as much attention from the males. 2. Pregnant female attractivity increases. This leads to mating with a familiar male in the community resulting in a decrease in male-perpetrated infanticide and increasing male protection towards the female and her offspring. 3. As humans use passports to travel to different countries, sexual swellings are a females passports for intergroup transfer; the passport allows nonpregnant and pregnant chimpanzee females to increase their chances of free movement between natal and neighboring communities (Wallis, 1982). It is possible that females might not want males disturbing them as they are already pregnant yet will tolerate males following and touching their swellings because it is saving them from a brutal attack that could lead to her and her offspring's death.

The limitation noticed in our study is that only 32 females were chosen with the best viewed sexual swelling to measure height, width, and area. The females in our data had swelling sizes that were way better for measuring compared to all the other females not measured. Furthermore, a few females with massive swellings were excluded from the study because their swelling size was either taken at a side angle, only one laser point showed in the picture, or the sunlight made it difficult to measure. It is possible our p-values for the correlation test could have been significant and maybe answer our question of whether age predicts sexual swellings. Furthermore, if our study included about 100 or more females, the p-value might have had greater significance on height and area changing between reproductive states.

Future Directions for Research

Additional research on female chimpanzee's age predicting sexual swelling size is needed, and if the reproductive state plays a role in increasing a female's sexual swelling.

Also, why would a previously pregnant female exhibit sexual swellings bigger than nonparent cycling females? Which seems should be reversed. More research on pregnant females' sexual swelling serves as a passport, observing if this is the cause for all communities or if pregnant females still get attacked even with a sexual swelling (Wallis, 1982). Furthermore, can males detect if females exhibiting sexual swellings are pregnant, and is that why they are so driven to mate with that female because they figured it out that she can reproduce? More research on if infanticide can still occur if the male is familiar with the female he previously mated with? Do male-perpetrate infanticide on an offspring they sired and have no recollection of mating with that female? As well as, do males provide support towards the female's offspring they did not sire, because they want to be the first to mate with the mother or do they care about protecting the infant?

Since bonobos are the subspecies of the chimpanzees, when did the shift occur where females became the dominant group? If this study was done again, a fascinating route would be to compare, if feasible, both female bonobos and chimpanzee's sexual swelling and see the height and area and what our p-values can tell us. Furthermore, testing to see how long chimpanzees exhibit their swellings compared to female bonobos and do pregnant female bonobos exhibit sexual swelling with no intention of conceiving after conception transpired?

Conclusions

In conclusion, age does not predict the swelling size for both age groups. However, pregnant females have a significantly larger swelling size compared to nulliparous and parous females only for the reproductive state two. Another specific future research can be on the sexual swelling size of chimpanzees and bonobos and what the results can say with a dominant female bonobo group versus and non-dominant female chimpanzee group. And if pregnant female bonobos exhibiting swellings receive the same attention as pregnant females chimpanzees do in their community.

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