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New insights in Cercopithecinae spermatozoa.

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Keywords:	ART, Non-human primates, Sperm morphology, Sperm morphometry, Sperm parameters
Abstract:	<p>Sperm morphometric and morphologic data have been shown to represent useful tools for monitoring fertility, improving assisted reproduction techniques and conservation of genetic material as well as detecting inbreeding of endangered primates. We provide here for the first time sperm morphologic and morphometric data from <i>Cercopithecus neglectus</i>, <i>Cercopithecus cephus</i>, <i>Papio papio</i> and critically endangered <i>Cercopithecus roloway</i>, as well as comparative data from other Cercopithecinae species, i.e. <i>Allochrocebus lhoesti</i>, <i>Mandrillus sphinx</i> and <i>Papio anubis</i>. Following collection from epididymis, spermatozoa were measured for each species for the following parameters: head length, head width, head perimeter, head area, midpiece length and total flagellum length, and we then calculated head volume, ellipticity, elongation, roughness and regularity. Our data are consistent with both the general morphology and the morphometric proportions of Cercopithecinae sperm. Some specificities were observed, with <i>C. cephus</i> displaying a narrow head (width = $2.76 \pm 0.26 \mu\text{M}$) and <i>C. roloway</i> displaying a short midpiece ($6.65 \pm 0.61 \mu\text{M}$). This data set represents an</p>

	<p>important contribution, especially for <i>Cercopithecus roloway</i>, one of the most endangered monkeys in the world, and further data on additional specimens coupled to data on mating systems and reproductive ecology should allow to better understand the mechanisms underlying these morphological differences across primate species.</p>

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TITLE

New insights in *Cercopithecinae* spermatozoa.

RUNNING TITLE

Morphologic analyses of *Cercopithecinae* sperm

AUTHORS

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ABSTRACT

Sperm morphometric and morphologic data have been shown to represent useful tools for monitoring fertility, improving assisted reproduction techniques and conservation of genetic material as well as detecting inbreeding of endangered primates. We provide here for the first time sperm morphologic and morphometric data from *Cercopithecus neglectus*, *Cercopithecus cephus*, *Papio papio* and critically endangered *Cercopithecus roloway*, as well as comparative data from other *Cercopithecinae* species, i.e. *Allochrocebus lhoesti*, *Mandrillus sphinx* and *Papio anubis*. Following collection from epididymis, spermatozoa were measured for each species for the following parameters: head length, head width, head perimeter, head area, midpiece length and total flagellum length, and we then calculated head volume, ellipticity, elongation, roughness and regularity. Our data are consistent with both the general morphology and the morphometric proportions of *Cercopithecinae* sperm. Some specificities were observed, with *C. cephus* displaying a narrow head (width = 2.76 ± 0.26 μM) and *C. roloway* displaying a short midpiece (6.65 ± 0.61 μM). This data set represents an important contribution, especially for *Cercopithecus roloway*, one of the most endangered monkeys in the world, and further data on additional specimens coupled to data on mating systems

and reproductive ecology should allow to better understand the mechanisms underlying these morphological differences across primate species.

KEYWORDS:

ART; Non-human primates; Sperm morphology; Sperm morphometry; Sperm parameters

MAIN TEXT:

1. Introduction

Primates, like other mammals, are subject to selection pressures (e.g. sperm competition, cryptic post-copulatory female choice, sexual coercion, climatological factors; see review in Martinez et al., 2020) resulting in inter-specific and intra-specific variability in sperm shapes. Analyzing this variability with morphological sperm measurements is becoming increasingly relevant, especially in the context of animal health and fertility monitoring (Oliveira et al., 2016; Garcia-Vasquez et al., 2016; Piña-Aguilar et al., 2016). Indeed, the worldwide decline of many primate populations (Estrada et al., 2017) could lead to an increase in the use of medically assisted reproduction techniques (ART) to conserve the genetic material, detect inbreeding and potentially address primate fertility issues (Andrabi et al., 2007) in the framework of *ex-situ* conservation. For instance, evaluation of sperm morphology makes it possible to determine an individual sperm quality when standards exist as morphology is closely linked to successful fertilization (Garcia-Vasquez et al., 2016). Although most studies on primate semen parameters are primarily conducted on laboratory model species (Devilliers et al., 2018), there is a growing literature for endangered and critically endangered species (Martin et al., 1975; Thomson et al., 1992; Robson et al., 1997; Steinberg et al., 2009; Nakazato et al., 2015; Sampaio et al., 2017; Leao et al., 2020).

Here, we provide for the first time sperm morphometric and morphologic data from De Brazza's monkey (*Cercopithecus neglectus*), moustached monkey (*Cercopithecus cephus*), Guinea baboon (*Papio papio*), and critically endangered Roloway monkey (*Cercopithecus roloway*), as well as supplementary data for L'Hoest's monkey (*Allochrocebus lhoesti*), mandrill (*Mandrillus sphinx*) and olive baboon (*Papio anubis*). These data are highly valuable, especially for the Roloway monkey, which is listed as one of the 25 most endangered primate species in the world (Koné et al., 2019).

2. Materials and Methods

Animals

All samples were obtained from French zoos, EAZA (European Association of Zoos and Aquaria) members, assuring the best veterinary care practices for the animals. Testes from *A. lhoesti*, *C. roloway*, *C. cephus* and *C. neglectus* were collected from adult males of proven fertility (registered offspring) who died from accident or disease not affecting spermatogenesis. Testes from *M. sphinx*, *P. anubis* and *P. papio* were collected from sexually mature males at the time of castration. Testicles were sent to the laboratory for sperm cryoconservation and creation of a primate sperm biobank. Morphological analyses were carried out as part of the sperm evaluation before freezing.

Sperm collection and preparation

Testis were kept at 4°C and processed within 48 h after castration or death discovery. Sperm extraction was carried out by dissecting the tail of the epididymis using needles in a petri dish with 2 mL Sperm Preparation Medium (SPM, Origio). Spermatozoa were allowed to swim 10 minutes at 37°C, washed twice in SPM (by centrifugation at 500g, 5 min), displayed over a slide, dried at room temperature, and then fixed in Ethanol

70° for Harris-Schorr staining. Simple and easy to perform, this staining gives good results in routine human sperm evaluation (WHO, 2010).

Sperm morphometric analysis

All cells measurements were realized on a Nikon Eclipse 80i microscope equipped with a Nikon DS-Ri1 camera with NIS-Elements D (version 3.1.) software. At least 100 cells were measured for each individual. Measured parameters were head length (L), head width (W), head perimeter (P), head area (A), midpiece length (MP) and total flagellum length (Flag). Calculated parameters were head volume ($V = 4/3\pi(L/2)^2(W/2)$), head ellipticity ($\xi = L/W$), head elongation ($\Sigma = (L-W)/(L+W)$), head roughness ($Ro = 4\pi(A/P^2)$) and head regularity ($Re = \pi((L*W)/(4*A)$). Given the small sample size within each species (only one individual), we were unable to statistically investigate differences in morphometric measurements between species.

Sperm morphologic analysis

Morphology was assessed by a trained biologist (GM) with a counting of at least 400 spermatozoa per slide using a magnification of 1000×. Analysis were performed according to WHO recommendations for human sperm analysis based on a modified Kruger classification (Cooper et al., 2010).

3. Results

Morphometry

Our morphometric data are presented in Table 1 and alongside the literature in Table 2 with means (\pm SD) calculated for each genus. All individuals displayed an oval-shaped sperm head, with *C. cephus* displaying the most elongated and narrowest head within all known spermatozoa species (head width 2.76 ± 0.26 , ellipticity 1.98 and

elongation 0.32). Regarding total sperm length, *P. papio*, *P. anubis*, *M. sphinx* and *A. lhoesti* were measured at around 70 μM whereas *C. neglectus*, *C. cephus* and *C. roloway* were around ~ 50 μM (see Table 2 for further details). Moreover, *C. roloway* spermatozoa were characterized by a notable morphological particularity, i.e. the shortest intermediate piece among *Cercopithecinae* (6.65 ± 0.61 μM).

Morphology

Our morphologic data are presented in Table 3 and alongside the literature in Table 4. The proportion of morphologically normal spermatozoa in the ejaculate is homogeneous for the seven species examined (mean \pm SD of $69.18 \pm 5.77\%$, range 62.00-78.07%) and across the literature ($72.19 \pm 12.17\%$, range 50-96.95%). On the other hand, the localization of the morphological abnormalities is heterogeneous from one species to another and mainly concentrated on the tail ($15.70 \pm 6.52\%$, range 7-29.32%) or head ($10.53 \pm 9.83\%$, range 0.4-26.13%) but few on the midpiece ($1.78 \pm 2.80\%$, range 0-8%). At the species level, the anomalies are mostly present on the tail, with the exception of *A. lhoesti*, *C. cephus* and *C. roloway* which mostly present head anomalies (26.00, 26.13 and 23.00% respectively). The presence of cytoplasmic droplets should be noted for *P. anubis* and *C. neglectus* but in very low proportion (2.00 and 0.08%, respectively).

4. Discussion

This study contributes to increase our knowledge of primate sperm morphometry and morphology by providing original data for four primate species scarcely studied and supplementary data for three other species. Our data are consistent with the general morphometric and morphologic proportions reported in the literature for primates (Table 2 and 4).

All the species we measured here have an oval-shaped sperm head, like most primates, the only exceptions being *Lorisidae* and *Lemuroidea* taxa (Gould et al., 1978). It should be noted that *C. cephus* displays a specific head pattern with a narrow head. Some species of the *Cercopithecus* genus tend to have shorter spermatozoa with an average length of $58.20 \pm 13.99 \mu\text{M}$ (*Macaca*: 75.85 ± 9.41 ; *Papio*: 69.89 ± 0.33), with *C. neglectus*, *C. cephus* and *C. roloway* being the shortest representatives of all *Cercopithecinae*. Yet, due to the small sample sizes inherent in such studies, we report only suggestive trends which may illuminate further studies with more individuals in order to determine if our current findings can be generalized to these different species. Therefore, these morphometric differences between species deserve more attention and future studies combining sperm morphometrics on additional specimens with data on mating systems and reproductive ecology are needed.

This study brings to 48 the number of primate species for which we have sperm morphological data. Our normal-form sperm rates (mean 69.18%, range 62.00-78.07%) are consistent with those observed in the literature for *Cercopithecinae* (mean 73.44%, range 49.50-96.95%). Although preliminary, these data could help to assess the reproductive potential of individuals, as an abnormal decrease in the number of normal-form sperm is often associated with infertility (Gould et al., 1993; Piña-aguilar et al., 2016) when it occurs during a reproductive period (Seier et al., 1993; Hernandez-lopez et al., 2002).

Interestingly, the distribution of morphological abnormalities appears heterogeneous, with some species mainly presenting head anomalies (*A. lhoesti*, *C. cephus*, *C. roloway*) and others flagellum anomalies (*C. neglectus*, *M. sphinx*, *P. anubis*, *P. papio*) with sometimes strong ratios (3.7 times more head abnormalities than flagellum

for *A. lhoesti* and 3 times more flagellum than head abnormalities for *M. sphinx*). The causes of this differential positioning are not known and non-human primate spermocytograms in the literature are rarely detailed, making further analysis impossible without additional data collection.

Sperm morphological abnormalities increasing with the inbreeding degree (Gomendio et al., 2000), the data on sperm parameters presented here can also be of major importance for ART as valuable indicators of inbreeding depression. The increase in matings between genetically related individuals due to shrinking habitats and declining populations in the wild or space and management constraints in captivity can lead to a reduction in genetic diversity. The negative impact of inbreeding on reproductive fitness is also well known and the avoidance of inbreeding is one of the priorities in the conservation and captive breeding of endangered species (Hedrick et al., 2000). Thereby, assisted breeding techniques may be useful in the future to ensure assisted selective genetic propagation, avoid inbreeding and thus prevent the decline of the general reproductive ability of the captive species (Pukazhenthil et al., 2005).

5. Conclusion

All data on primate reproduction are critical in the current context of global population declines, especially for endangered species. Beyond the improvement of our general knowledge on primate sperm, we provide here essential data for potential future implementation of ex-situ conservation actions and monitoring of animal health and fertility.

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Not applicable

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The authors have declared that no competing interests exist.

AUTHOR CONTRIBUTIONS:

Study design: G.M., C.A., R.L.; Sample collection and processing: G.M., C.F-B., S.L., A.L., A.L., B.M., T.P., B.Q., S.B., C.A., C.C.; Data analysis and interpretation: G.M., C.G., R.L.; Manuscript drafting: G.M., C.G., R.L. All authors read, critically revised and approved the final manuscript.

REFERENCES:

Ackerman, D. R., & Roussel, J. D. (1968). Fructose, lactic acid and citric acid content of the semen of eleven subhuman primate species and of man. *Reproduction*. 17(3), 563-566. [HTTPS://DOI.ORG/10.1530/jrf.0.0170563](https://doi.org/10.1530/jrf.0.0170563)

Anderson, M. J., Nyholt, J., & Dixson, A. F. (2005). Sperm competition and the evolution of sperm midpiece volume in mammals. *J. Zool.* 267(2), 135-142. [HTTPS://DOI.ORG/10.1017/S0952836905007284](https://doi.org/10.1017/S0952836905007284)

Andrabi, S. M. H., & Maxwell, W. M. C. (2007). A review on reproductive biotechnologies for conservation of endangered mammalian species. *Anim Reprod Sci.* 99(3-4), 223-243. [HTTPS://DOI.ORG/10.1016/j.anireprosci.2006.07.002](https://doi.org/10.1016/j.anireprosci.2006.07.002)

Bedford, J. M. (1967). Observations on the fine structure of spermatozoa of the bush baby (*Galago senegalensis*), the African green monkey (*Cercopithecus aethiops*) and man. *Am. J. Anat.* 121(3), 443-459. [HTTPS://DOI.ORG/10.1002/aja.1001210303](https://doi.org/10.1002/aja.1001210303)

Bedford, J. M., & Hoskins, D. D. (1990). The mammalian spermatozoon: morphology, biochemistry and physiology. *Marshall's physiology of reproduction.* 2, 379-568.

Carrick, F. N., & Hughes, R. L. (1982). Aspects of the structure and development of monotreme spermatozoa and their relevance to the evolution of mammalian sperm morphology. *Cell. Tiss. Res.* 222(1), 127-141. [HTTPS://DOI.ORG/10.1007/BF00218293](https://doi.org/10.1007/BF00218293)

Chan, P., Cseh, S., Corselli, J., & Bailey, L. (1999). Sperm characteristics after sequential semen collection and pentoxifylline treatment in the baboon (*Papio anubis*). *Theriogenology.* 51(1), 340. [HTTPS://DOI.ORG/10.1016/S0093-691X\(99\)91899-X](https://doi.org/10.1016/S0093-691X(99)91899-X)

Chrétien, F. C., Dubouch, P., & Francois, N. (1977). Scanning electron microscopy of ejaculated baboon (*Papio anubis*) spermatozoon. *Cell. Tiss. Org.* 97(3), 339-346. [HTTPS://DOI.ORG/10.1159/000144751](https://doi.org/10.1159/000144751)

Cooper, T. G., Noonan, E., Von Eckardstein, S., Auger, J., Baker, H. W., Behre, H. M., ... & Vogelsong, K. M. (2010). World Health Organization reference values for human semen characteristics. *Hum. Reprod. Update.* 16(3), 231-245. [HTTPS://DOI.ORG/10.1093/humupd/dmp048](https://doi.org/10.1093/humupd/dmp048)

Cranfield, M. R., Kempeske, S. E., & Schaffer, N. (1988). The use of in vitro fertilisation and embryo transfer techniques for the enhancement of genetic diversity in the captive population of the Lion-tailed macaque *Macaca silenus*. *International Zoo Yearbook.* 27(1), 149-159. [HTTPS://DOI.ORG/10.1111/j.1748-1090.1988.tb03208.x](https://doi.org/10.1111/j.1748-1090.1988.tb03208.x)

Cseh, S., Chan, P. J., Corselli, J., & Bailey, L. L. (2000). Electroejaculated baboon (*Papio anubis*) sperm requires a higher dosage of pentoxifylline to enhance motility. *J. Assist. Reprod. Genet.* 17(8), 449-453. [HTTPS://DOI.ORG/10.1023/A:100946931959](https://doi.org/10.1023/A:100946931959)

Cummins, J. M., & Woodall, P. F. (1985). On mammalian sperm dimensions. *Reproduction.* 75(1), 153-175. [HTTPS://DOI.ORG/10.1530/jrf.0.0750153](https://doi.org/10.1530/jrf.0.0750153)

de Villiers, C. (2018). A comparison between the semen and sperm parameters from the captive-bred Vervet monkey (*Chlorocebus aethiops*) and Rhesus monkey (*Macaca mulatta*). *J. Med. Primatol.* 47(4), 211-216. [HTTPS://DOI.ORG/10.1111/jmp.12349](https://doi.org/10.1111/jmp.12349)

Dixon, A. F. (2018). Copulatory and Postcopulatory sexual selection in Primates. *Fol Primatol.* 89(3-4), 258-286. [HTTPS://DOI.ORG/10.1159/000488105](https://doi.org/10.1159/000488105)

Estrada, A., Garber, P. A., Rylands, A. B., Roos, C., Fernandez-Duque, E., Di Fiore, A., ... & Rovero, F. (2017). Impending extinction crisis of the world's primates: Why primates matter. *Sci. Adv.* 3(1), e1600946. [HTTPS://DOI.ORG/10.1126/sciadv.1600946](https://doi.org/10.1126/sciadv.1600946)

Flechon, J. E., & Hafez, E. S. (1975). Spermiation and epididymal maturation of spermatozoa in the bonnet macaque (*Macaca radiata*) as viewed by scanning electron microscopy. *Fertil. Steril.* 26(12), 1219-1227. [HTTPS://DOI.ORG/10.1016/s0015-0282\(16\)41538-4](https://doi.org/10.1016/s0015-0282(16)41538-4)

Flechon, J. E., Kraemer, D. C., & Hafez, E. S. E. (1976). Scanning electron microscopy of baboon spermatozoa. *Fol. Primatol.* 26(1), 24-35. [HTTPS://DOI.ORG/10.1159/000155727](https://doi.org/10.1159/000155727)

Gadea, J., Toledano-Díaz, A., Navarro-Serna, S., Jiménez-Movilla, M., Soriano, P., Matás, C., & Santiago-Moreno, J. (2019). Assessment and preservation of liquid and frozen-thawed Black crested mangabey (*Lophocebus aterrimus*) spermatozoa obtained by transrectal ultrasonic-guided massage of the accessory sex glands and electroejaculation. *Anim. Reprod Sci.* 210, 106176. [HTTPS://DOI.ORG/10.1016/j.anireprosci.2019.106176](https://doi.org/10.1016/j.anireprosci.2019.106176)

Gage, M. J. (1998). Mammalian sperm morphometry. *Proc. R. Soc. Lond. B. Biol. Sci.* 265(1391), 97-103. [HTTPS://DOI.ORG/10.1098/rspb.1998.0269](https://doi.org/10.1098/rspb.1998.0269)

Gago, C., Perez-Sanchez, F., Yeung, C. H., Tablado, L., Cooper, T. G., & Soler, C. (1998). Standardization of sampling and staining methods for the morphometric evaluation of sperm heads in the *Cynomolgus* monkey (*Macaca fascicularis*) using computer-assisted image analysis. *Int. J. Androl.* 21(3), 169-176. [HTTPS://DOI.ORG/10.1046/j.1365-2605.1998.00113.x](https://doi.org/10.1046/j.1365-2605.1998.00113.x)

Gago, C., Pérez-Sánchez, F., Yeung, C. H., Tablado, L., Cooper, T. G., & Soler, C. (1999). Morphological characterization of ejaculated *cynomolgus* monkey (*Macaca fascicularis*) sperm. *Am. J. Primatol.* 47(2), 105-115. [HTTPS://DOI.ORG/10.1002/\(SICI\)1098-2345\(1999\)47:2<105::AID-AJP2>3.0.CO;2-L](https://doi.org/10.1002/(SICI)1098-2345(1999)47:2<105::AID-AJP2>3.0.CO;2-L)

García-Vázquez, F. A., Gadea, J., Matás, C., & Holt, W. V. (2016). Importance of sperm morphology during sperm transport and fertilization in mammals. *Asian. J. Androl.* 18(6), 844. [HTTPS://DOI.ORG/10.4103/1008-682X.186880](https://doi.org/10.4103/1008-682X.186880)

Gomendio, M., Cassinello, J., & Roldan, E. R. S. (2000). A comparative study of ejaculate traits in three endangered ungulates with different levels of inbreeding: fluctuating asymmetry as an indicator of reproductive and genetic stress. *Proc. R. Soc. Lond. B. Biol. Sci.* 267(1446), 875-882. [HTTPS://DOI.ORG/10.1098/rspb.2000.1084](https://doi.org/10.1098/rspb.2000.1084)

Gould, K. G., & Martin, D. E. (1978). Comparative morphology of primate spermatozoa using scanning electron microscopy. II. Families Cercopithecidae,

Lorisidae, Lemuridae. *J. Hum. Evol.* 7(7), 637-642. [HTTPS://DOI.ORG/10.1016/S0047-2484\(78\)80048-7](https://doi.org/10.1016/S0047-2484(78)80048-7)

Gould, K. G., Young, L. G., Smithwick, E. B., & Phythyon, S. R. (1993). Semen characteristics of the adult male chimpanzee (*Pan troglodytes*). *Am. J Primatol.* 29(3), 221-232. [HTTPS://DOI.ORG/10.1002/ajp.1350290307](https://doi.org/10.1002/ajp.1350290307)

Hedrick, P. W., & Kalinowski, S. T. (2000). Inbreeding depression in conservation biology. *Annu. Rev. Ecol. Syst.* 31(1), 139-162. [HTTPS://DOI.ORG/10.1146/annurev.ecolsys.31.1.139](https://doi.org/10.1146/annurev.ecolsys.31.1.139)

Hernández-López, L., Parra, G. C., Cerda-Molina, A. L., Pérez-Bolaños, S. C., Sánchez, V. D., & Mondragón-Ceballos, R. (2002). Sperm quality differences between the rainy and dry seasons in captive black-handed spider monkeys (*Ateles geoffroyi*). *Am. J. Primatol.* 57(1), 35-41. [HTTPS://DOI.ORG/10.1002/ajp.1086](https://doi.org/10.1002/ajp.1086)

Kholkute, S. D., Gopalkrishnan, K., & Puri, C. P. (2000). Variations in seminal parameters over a 12-month period in captive bonnet monkeys. *Primates.* 41(4), 393-405. [HTTPS://DOI.ORG/10.1007/BF02557650](https://doi.org/10.1007/BF02557650)

Koné, I., Oates, J. F., Dempsey, A., Gonedelé, Bi. S., McGraw, S., Wiafe, E. (2019). *Cercopithecus roloway*. The IUCN Red List of Threatened Species 2019: e.T4232A92384429. [HTTPS://DOI.ORG/10.2305/IUCN.UK.2019-](https://doi.org/10.2305/IUCN.UK.2019-)

Kyaligonza, J. K. (1998). Semen analysis and induction of acrosome reaction in spermatozoa of *Tana mangabey* (*Cercocebusgaleritus*) and de brazza's (*Cercopithecus* monkeys (Doctoral dissertation, University of Nairobi).

Leão, D. L., Sampaio, W. V., Sousa, P. C., Moura, A. A., Oskam, I. C., Santos, R. R., & Domingues, S. F. (2020). Micromorphological and ultrastructural description of spermatozoa from squirrel monkeys (*Saimiri collinsi* Osgood, 1916). *Zygote*, 28(3), 203-207. [HTTPS://DOI.ORG/10.1017/S0967199419000868](https://doi.org/10.1017/S0967199419000868)

Maree, L. (2011). Sperm mitochondria: Species specificity and relationships to sperm morphometric features and sperm function in selected mammalian species. Thesis.

Martin, D. E., Gould, K. G., & Warner, H. (1975). Comparative morphology of primate spermatozoa using scanning electron microscopy. I. Families Hominidae, Pongidae, Cercopithecidae and Cebidae. *J. Hum. Evol.* 4(4), 287-292. [HTTPS://DOI.ORG/10.1016/0047-2484\(75\)90067-6](https://doi.org/10.1016/0047-2484(75)90067-6)

Martinez, G., & Garcia, C. (2020). Sexual selection and sperm diversity in primates. *Mol. Cell. Endocrinol.* 110974. [HTTPS://DOI.ORG/10.1016/j.mce.2020.110974](https://doi.org/10.1016/j.mce.2020.110974)

Mastroianni Jr, L., & Manson Jr, W. A. (1963). Collection of monkey semen by electroejaculation. *Proc. Soc. Exp. Biol. Med.* 112(4), 1025-1027. [HTTPS://DOI.ORG/10.3181/00379727-112-28242](https://doi.org/10.3181/00379727-112-28242)

Mdhului, M. C., Seier, J. V., & van der Horst, G. (2004). The male vervet monkey: sperm characteristics and use in reproductive research. *Gynecol Obstet Invest.* 57, 17-18. PMID:14971416

Muller, M. N., Thompson, M. E., Kahlenberg, S. M., & Wrangham, R. W. (2011). Sexual coercion by male chimpanzees shows that female choice may be more apparent than real. *Behav Ecol.* 65(5), 921-933. [HTTPS://DOI.ORG/10.1007/s00265-010-1093-y](https://doi.org/10.1007/s00265-010-1093-y)

Nakazato, C., Yoshizawa, M., Isobe, K., Kusakabe, K. T., Kuraishi, T., Hattori, S., ... & Kai, C. (2015). Morphological characterization of spermatozoa of the night monkey. *Journal of Mammalian Ova Research*, 32(1), 37-40. [HTTPS://DOI.ORG/10.1274/jmor.32.37](https://doi.org/10.1274/jmor.32.37)

Nyachieo, A., Spiessens, C., Chai, D. C., Kiulia, N. M., Mwenda, J. M., & D'Hooghe, T. M. (2012). Baboon spermatology: basic assessment and reproducibility in olive baboons (*Papio anubis*). *J. Med. Primatol.* 41(5), 297-303. [HTTPS://DOI.ORG/10.1111/j.1600-0684.2012.00555.x](https://doi.org/10.1111/j.1600-0684.2012.00555.x)

Oliveira, K. G., Santos, R. R., Leão, D. L., Brito, A. B., Lima, J. S., Sampaio, W. V., & Domingues, S. F. (2016). Cooling and freezing of sperm from captive, free-living and endangered squirrel monkey species. *Cryobiology*, 72(3), 283-289. [HTTPS://DOI.ORG/10.1016/j.cryobiol.2016.03.004](https://doi.org/10.1016/j.cryobiol.2016.03.004)

Parker, G. A. (1970). Sperm competition and its evolutionary consequences in the insects. *Biol. Rev.* 45(4), 525-567. [HTTPS://DOI.ORG/10.1111/j.1469-185X.1970.tb01176.x](https://doi.org/10.1111/j.1469-185X.1970.tb01176.x)

Piña-Aguilar, R. E., López-Saucedo, J., Ruiz-Galaz, L. I., de Jesús Barroso-Padilla, J., Gallegos-Rivas, M. C., González-Ortega, C., & Gutiérrez-Gutiérrez, A. M. (2016). A human reproductive approach to the study of infertility in chimpanzees: An experience at Leon's Zoological Park, Mexico. In *Veterinary research forum* (Vol. 7, No. 3, p. 255). Faculty of Veterinary Medicine, Urmia University, Urmia, Iran. PMID:27872723

Pukazhenth, B., Comizzoli, P., Travis, A. J., & Wildt, D. E. (2005). Applications of emerging technologies to the study and conservation of threatened and endangered species. *Reprod. Fertil. Dev.* 18(2), 77-90. [HTTPS://DOI.ORG/10.1071/RD05117](https://doi.org/10.1071/RD05117)

Robson, S. K., Rouse, G. W., & Pettigrew, J. D. (1997). Sperm ultrastructure of *Tarsius bancanus* (Tarsiidae, Primates): implications for primate phylogeny and the use

of sperm in systematics. *Act. Zool.* 78(4), 269-278. [HTTPS://DOI.ORG/10.1111/j.1463-6395.1997.tb01011.x](https://doi.org/10.1111/j.1463-6395.1997.tb01011.x)

Sampaio, W. V., Oliveira, K. G., Leão, D. L., Caldas-Bussiere, M., Queiroz, H. L., Paim, F. P., ... & Domingues, S. F. (2017). Morphologic analysis of sperm from two neotropical primate species: comparisons between the squirrel monkeys *Saimiri collinsi* and *Saimiri vanzolinii*. *San Diego Zoo Global Library Sperm Atlas*. (2020) San Diego Zoo Global. Last Updated: Dec 31, 2019 7:19 PM <https://ielc.libguides.com/c.php?g=692908&p=4909133>

Schaffer, N., Cranfield, M., Meehan, T., & Kempcke, S. (1989). Semen collection and analysis in the conservation of endangered nonhuman primates. *Zoo. Biol.* 8(S1), 47-60. [HTTPS://DOI.ORG/10.1002/zoo.1430080507](https://doi.org/10.1002/zoo.1430080507)

Seier, J. V., Conradie, E., Oettle, E. E., & Fincham, J. E. (1993). Cryopreservation of vervet monkey semen and recovery of progressively motile spermatozoa. *J Med Primatol.* 22(6), 355-359. [HTTPS://DOI.ORG/10.1111/j.1600-0684.1993.tb00684.x](https://doi.org/10.1111/j.1600-0684.1993.tb00684.x)

Shang, E. Y., Ji, W. Z., Yang, S. C., Chen, J. C., Zou, R. J. (1993). Electron Microscopical Study of Tibetan Macaque (*Macaca thibetana*) Sperm. *Zool. Res.* 14(1):1-4.

Steinberg, E. R., Nieves, M., Ascunce, M. S., Palermo, A. M., & Mudry, M. D. (2009). Morphological and genetic characterization of *Saimiri boliviensis*. *International journal of primatology*, 30(1), 29-41. [HTTPS://DOI.ORG/10.1007/s10764-008-9328-8](https://doi.org/10.1007/s10764-008-9328-8) Thomsen, R. (2014). Non-invasive collection and analysis of semen in wild macaques. *Primates.* 55(2), 231-237. [HTTPS://DOI.ORG/10.1007/s10329-013-0393-z](https://doi.org/10.1007/s10329-013-0393-z)

Thomson, J. A., Iliff-Sizemore, S. A., Gliessman, P. M., & Wolf, D. P. (1992). Collection and fertilization potential of sperm from the Sulawesi crested black macaque (*Macaca nigra*). *Am. J. Primatol.* 28(4), 289-297. [HTTPS://DOI.ORG/10.1002/ajp.1350280407](https://doi.org/10.1002/ajp.1350280407)

World Health Organization (2010). WHO laboratory manual for the examination and processing of human semen - 5th ed.

Wickings, E. J., & Nieschlag, E. (1980). Seasonality in endocrine and exocrine testicular function of the adult rhesus monkey (*Macaca mulatta*) maintained in a controlled laboratory environment. *Int. J. Androl.* 3(1-6), 87-104. [HTTPS://DOI.ORG/10.1111/j.1365-2605.1980.tb00099.x](https://doi.org/10.1111/j.1365-2605.1980.tb00099.x)

Zainuddin, Z., Kang, Y. C., Tarmizi, M. R. M., Ahmad, A. H., Payne, J. B. (2019). Seminal evaluation and cryopreservation of sperms from the pig-tailed macaque, *Macaca nemestrina*. *J. Sust. Sci. Manag.* 14(3), 92-99.

TABLES

Table 1. Sperm morphometric data in our sample of seven *Cercopithecinae* species.

Species	Head									Flagellum		Total length (μM)
	Length (μM)	Width (μM)	Perimeter (μM)	Area (μM^2)	Volume (μM^3)	Ellipticity (L/W)	Elongation (L-W)/(L+W)	Roughness ($4\pi(A/P^2)$)	Regularity ($\pi(LW/4A)$)	Midpiece length (μM)	Total length (μM)	
<i>A. lhoesti</i>	5.28±0.16	3.59±0.15	14.46±0.42	14.87±0.70	52.3	1.48	0.19	0.89	1.00	8.47±0.78	66.22±1.50	71.50±1.51
<i>C. neglectus</i>	5.21±0.17	3.65±0.15	14.78±0.46	16.21±0.98	51.8	1.43	0.18	0.93	0.92	10.32±0.57	37.35±5.38	42.56±5.43
<i>C. cephus</i>	5.39±0.40	2.76±0.26	13.51±0.78	11.85±1.19	42.0	1.98	0.32	0.82	0.99	11.3±1.05	44.59±2.49	49.98±2.54
<i>C. roloway</i>	4.77±0.20	3.17±0.17	13.10±0.55	11.57±0.91	37.8	1.51	0.20	0.85	1.03	6.65±0.61	47.66±1.86	52.44±1.89
<i>M. sphinx</i>	5.11±0.15	3.68±0.17	14.07±0.60	15.62±0.88	50.3	1.39	0.16	1.00	0.95	9.09±0.51	65.23±1.15	70.34±1.17
<i>P. Anubis</i>	5.23±0.17	3.33±0.12	14.09±0.32	14.48±0.75	47.7	1.57	0.22	0.92	0.95	10.43±0.21	69.11±1.85	74.35±1.93
<i>P. papio</i>	5.27±0.15	3.49±0.11	14.30±0.37	14.90±0.72	50.7	1.51	0.20	0.92	0.97	10.76±0.89	69.32±1.83	74.59±1.87

Table 2. Sperm morphometric data of *Cercopithecinae*. All measurements are presented uncritically and as mean when multiple sources. References: ¹1963 Mastroianni, ²1967 Bedford, ³1975 Fléchon, ⁴1975 Martin, ⁵1976b Fléchon, ⁶1978 Gould, ⁷1980 Gould, ⁸1982 Carrick, ⁹1985 Cummins, ¹⁰1990 Bedford, ¹¹1993 Shang, ¹²1998 Gage, ¹³1998 Gago, ¹⁴1999 Gago, ¹⁵2000 Cseh, ¹⁶2005 Anderson, ¹⁷2011 Maree, ¹⁸2012 Nyachieo, ¹⁹2019 Gadea, ²⁰2019 San Diego Zoo, ²¹This study.

Species	Head										Flagellum				Total length (μM)	References
	Length (μM)	Width (μM)	Perimeter (μM)	Area (μM ²)	Volume (μM ³)	Ellipticity (L/W)	Elongation (L-W)/(L+W)	Roughness (4π(A/P ²))	Regularity (π(LW/4A))	Midpiece length (μM)	Principal piece length (μM)	Terminal piece (μM)	Flagellum length (μM)			
<i>Allenopithecus</i> genus																
<i>A. nigroviridis</i>	5.6	3.3	-	-	54.9	1.69	0.26	-	-	9.32	-	-	57.54	66.49	20	
<i>Allochocebus</i> genus																
<i>A. lhoesti</i>	4.64	3.04	14.46	14.87	52.3	1.52	0.21	0.89	0.75	8.73	-	-	53.61	62.75	20,21	
<i>Cercocebus</i> genus																
<i>C. galeritus</i>	6.8	-	-	-	-	-	-	-	-	13.30	-	-	73.00	93.10	12	
<i>Cercopithecus</i> genus																
<i>C. cephus</i>	5.39	2.76	13.51	11.85	42.0	1.98	0.32	0.82	0.99	11.35	-	-	44.59	49.98	21	
<i>C. neglectus</i>	5.21	3.65	14.78	16.21	51.8	1.43	0.18	0.93	0.92	10.32	-	-	37.35	42.56	21	
<i>C. nictitans</i>	5.3	-	-	-	46.2	-	-	-	-	12.30	-	-	40.50	-	16	
<i>C. petaurista</i>	5.7	3.0	-	-	41.4	1.67	0.25	-	-	9.60	-	-	38.95	73.00	16,20	
<i>C. roloway</i>	4.77	3.17	13.10	11.57	37.8	1.51	0.20	0.85	1.03	6.65	-	-	47.66	52.44	21	
<i>C. wolffi</i>	5.0	4.0	-	-	52.4	1.25	0.11	-	-	-	-	-	68.00	73.00	20	
<i>Chlorocebus</i> genus																
<i>C. aethiops</i>	5.8	3.3	14.0	13.3	44.0	1.60	0.23	0.86	1.13	11.40	52.26	2.87	65.10	77.32	2,4,7,9,16,17	
<i>Erythrocebus</i> genus																
<i>E. patas</i>	7.7	-	-	-	63.2	-	-	-	-	13.55	-	-	69.90	89.50	12,16	
<i>Lophocebus</i> genus																
<i>L. albigena</i>	5.8	-	-	-	37.2	-	-	-	-	11.10	-	-	17.30	-	16	
<i>L. aterrimus</i>	5.2	3.8	15.2	16.6	53.4	1.36	0.15	0.90	0.93	8.51	4.54	-	-	-	19	
<i>Macaca</i> genus																
<i>M. arctoides</i>	5.9	3.4	-	-	52.5	1.64	0.24	-	-	10.52	61.46	-	64.10	77.61	4,7,11,16	
<i>M. fascicularis</i>	5.7	3.7	15.0	16.7	58.7	1.54	0.21	0.93	0.99	11.15	57.04	-	58.60	77.97	4,7,9,11,13,14,16	
<i>M. mulatta</i>	5.3	3.3	15.9	17.1	51.7	1.71	0.26	0.85	0.80	11.19	57.88	2.97	62.58	75.86	1,4,7,10,11,16,17	
<i>M. nemestrina</i>	7.4	-	-	-	48.7	-	-	-	-	13.50	-	-	69.25	90.40	12,16	
<i>M. radiata</i>	5.5	-	-	-	-	-	-	-	-	10.50	50.00	-	75.00	-	3	

<i>M. silenus</i>	5.7	3.2	-	-	49.7	1.50	0.20	-	-	10.83	-	-	29.93	60.04	16,20
<i>M. sinica</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	69.10	9
<i>M. sylvanus</i>	5.5	-	-	-	49.5	-	-	-	-	12.80	-	-	62.10	-	16
<i>M. thibetana</i>	6.0	3.5	-	-	64.9	1.72	0.26	-	-	11.98	-	-	62.01	79.96	11
Mandrillus genus															
<i>M. leucophaeus</i>	4.5	3.0	-	-	31.3	1.33	0.14	-	-	12.10	-	-	36.30	70.00	16,20
<i>M. sphinx</i>	5.86	4.02	14.07	15.62	44.85	1.46	0.19	0.99	1.18	11.12	-	-	54.37	69.77	6,7,9,15,20, 21
Papio genus															
<i>P. anubis</i>	5.6	3.29	14.09	14.48	50.0	1.71	0.26	0.92	1.00	8.91	-	-	67.8	75.06	12,15,16,18, 21
<i>P. cynocephalus</i>	4.7	3.9	-	-	47.7	1.23	0.10	-	-	10.02	58.03	3.50	64.07	75.40	4,5,6,7,8,16
<i>P. hamadryas</i>	6.5	-	-	-	47.2	-	-	-	-	12.70	-	-	58.00	-	16
<i>P. papio</i>	5.27	3.49	14.30	14.90	50.7	1.51	0.20	0.92	0.97	10.76	-	-	69.32	74.59	21
<i>P. ursinus</i>	5.6	3.5	15.4	16.3	56.3	1.60	0.23	0.86	0.94	9.97	58.02	3.37	70.92	76.49	17
Theropithecus genus															
<i>T. gelada</i>	6.8	-	-	-	61.9	-	-	-	-	12.20	-	-	68.80	87.30	12,16

Table 3. Sperm morphologic data.

Species	<i>A. lhoesti</i>	<i>C. neglectus</i>	<i>C. cephus</i>	<i>C. roloway</i>	<i>M. sphinx</i>	<i>P. anubis</i>	<i>P. papio</i>
n individuals	1	1	1	1	2	3	2
n ejaculate	1	1	1	1	2	3	2
Abnormal base (%)	9.00	5.26	9.91	11.00	2.78	9.00	4.00
Abnormal or absent acrosome (%)	8.00	2.63	14.41	12.00	3.70	4.00	5.00
Macro head (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Micro head (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tapered (%)	7.00	0.00	0.90	0.00	0.00	0.00	0.00
Elongated (%)	2.00	0.00	0.00	0.00	0.00	0.00	0.00
Multiple head (%)	0.00	0.00	0.90	0.00	0.00	0.00	0.00
Total head defects (%)	26.00	7.89	26.13	23.00	6.48	13.00	9.00
Midpiece defects (%)	0.00	1.75	0.00	0.00	1.85	1.00	0.00
Simple bent tail (%)	0.00	1.75	0.00	0.00	1.85	4.00	2.00
Coiled tail (%)	5.00	2.63	6.31	7.00	10.19	9.00	8.00
Multiple tail (%)	2.00	0.00	0.00	2.00	1.85	2.00	1.00
Short/Hairpin tail (%)	0.00	1.75	1.80	4.00	4.63	1.00	3.00
Irregular caliber (%)	0.00	2.63	0.00	1.00	0.00	2.00	0.00
Destructured (%)	0.00	3.51	1.80	1.00	0.93	0.00	3.00
Total flagellum defects (%)	7.00	12.28	9.91	15.00	19.44	18.00	17.00
Cytoplasmic droplet (%)	0.00	0.00	0.00	0.00	0.00	1.00	0.00

Morphology (% normal)	67.00	78.07	63.96	62.00	72.22	67.00	74.00
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For Peer Review

Table 4. Sperm morphologic data of *Cercopithecinae*. All measurements are presented uncritically and as mean when multiple sources. EE: epididymal extraction, ES: electrostimulation, M: masturbation.

Species	IUCN red list status	Sperm collection method	n		Normal morphology (%)	% defects				Reference
			individuals	samples		Head	Midpiece	Tail	Cytoplasmic droplet	
<i>Allochocebus</i> genus										
<i>A. lhoesti</i>	Vulnerable	EE	1	1	67	26	0	7	0	This study
<i>Cercocebus</i> genus										
<i>C. galeritus</i>	Endangered	ES	4	26	83.8	4.67	0	10.54	0	Kyaligonza <i>et al.</i> 1998
<i>Cercopithecus</i> genus										
<i>C. neglectus</i>	Least concern	ES	3	17	71	10.1	1.36	16.26	0.16	Kyaligonza <i>et al.</i> 1998
<i>C. neglectus</i>	Least concern	EE	1	1	78.07	7.89	1.75	12.28	0	This study
<i>C. cephus</i>	Least concern	EE	1	1	63.96	26.13	0	9.91	0	This study
<i>C. roloway</i>	Critically endangered	EE	1	1	62	23	0	15	0	This study
<i>Chlorocebus</i> genus										
<i>C. aethiops</i>	Least concern	ES	2	6	67	-	-	-	-	Ackerman <i>et al.</i> 1968
<i>C. aethiops</i>	Least concern	ES	20	20	61.04	1.64	8	29.32	-	Mdhului <i>et al.</i> 2004
<i>Erythrocebus</i> genus										
<i>E. patas</i>	Least concern	ES	5	19	59.5	-	-	-	-	Ackerman <i>et al.</i> 1968
<i>Macaca</i> genus										
<i>M. arctoides</i>	Vulnerable	ES	5	10	70	-	-	-	-	Ackerman <i>et al.</i> 1968
<i>M. fascicularis</i>	Least concern	ES	2	7	67	-	-	-	-	Ackerman <i>et al.</i> 1968
<i>M. fascicularis</i>	Least concern	-	14	-	82.5	0.4	6.3	12.1	-	Gago <i>et al.</i> 1999
<i>M. fuscata</i>	Least concern	M	32	48	94.4	-	-	-	-	Thomsen <i>et al.</i> 2014
<i>M. mulatta</i>	Least concern	ES	7	23	63.5	-	-	-	-	Ackerman <i>et al.</i> 1968
<i>M. mulatta</i>	Least concern	ES	11	-	58.37	-	-	-	-	Wickings <i>et al.</i> 1980
<i>M. nemestrina</i>	Vulnerable	ES	4	22	70.57	-	-	-	-	Zainuddin <i>et al.</i> 2019
<i>M. nigra</i>	Critically endangered	ES	4	40	96.95	1.25	0	14	-	Thomson <i>et al.</i> 1992
<i>M. radiata</i>	Least concern	ES	7	121	87.2	-	-	-	-	Kholkute <i>et al.</i> 2000
<i>M. silenus</i>	Endangered	ES	4	12	82	-	-	-	-	Cranfield <i>et al.</i> 1988
<i>M. silenus</i>	Endangered	ES	7	7	18	-	-	-	-	Schaffer <i>et al.</i> 1989
<i>Mandrillus</i> genus										
<i>M. sphinx</i>	Vulnerable	EE	3	3	72.22	6.48	1.85	19.44	0	This study
<i>Papio</i> genus										
<i>P. anubis</i>	Least concern	ES	1	1	53.25	8	3.5	33.5	2.5	Chan <i>et al.</i> 1999
<i>P. anubis</i>	Least concern	ES	1	-	49.5	8	0	41	2.5	Cseh <i>et al.</i> 2000

<i>P. anubis</i>	Least concern	ES	9	27	89.22	3.88	3.11	3.77	-	Nyachieo et al. 2012
<i>P. anubis</i>	Least concern	ES	3	3	67	13	1	18	1	This study
<i>P. papio</i>	Least concern	ES	2	2	74	9	0	17	0	This study
<i>Theropithecus</i> genus										
<i>T. gelada</i>	Least concern	ES	1	1	81	-	-	-	-	Ackerman et al. 1968

For Peer Review