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Sex Differences in the Cerebellum and its Correlates with Some Body Traits in the African Grasscutter (Thryonomys Swinderianus – Temminck, 1827): Morphometric Study

Obadiah Byanet[1*], Barth Izuchukwu Onyeanusi [2], Samuel Adeniyi Ojo[2].

1. Department of Veterinary Anatomy, College of Veterinary Medicine, University of Agriculture, Makurdi, Nigeria.
2. Department of Veterinary Anatomy, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria.

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ABSTRACT

Introduction: Sexual dimorphisms in biological structures such as brain and behaviour have been widely recognized in animals and humans. The purpose of this study was to examine whether there are sex differences in the size of the cerebellum with other body traits, such as the head, tail and brain.

Methods: Twelve grasscutters comprising of 6 males and 6 females were used in this study. Each brain was extracted from the skull by standard procedures and the mean values of the weights, dimensions and volumes of the brain, cerebellum, head and tail were compared in male and female using quantitative analytical statistical method.

Results: The results showed that the absolute mean brain weight and volume obtained in the male was slightly higher than that of the female, while the cerebellar mean weight was slightly higher in the female; although these values were not statistically significant ($P > 0.05$). The mean cerebellar lengths and widths did not differ between the two sexes (> 0.05), but the mean cerebellar circumference in the male was statistically higher than in the female ($P < 0.05$). The female cerebellar length was positively correlated with the length of the brain, head, body and tail.

Discussion: In conclusion, the brain weight was slightly higher in the male than female, while the cerebellar weight was higher in the female than male. The significantly higher value of the cerebellar circumference in the male may partly be responsible for the big round head seen in the live male grasscutter.

1. Introduction

Numerous biological and biohevioural sexual dimorphic features have been identified both in humans and animals (Cowell et al., 1994; Murphy et al., 1996; Luders et al., 2004). Halpern et al. (2007) noted that among these differences the most controversial is neuroanatomical differences, because of the implication that behavioral differences could be due to fundamental differences in brain organization or neural potential.

Sexual differences in the nervous system have been described at virtually every anatomical level, including cellular and neural system (Cooke et al. 1998), such as the cerebral volume (Willerman et al. 1991; Andreasen et al. 1993), cerebellar weight (Byanet et al., 2008, 2009), cerebellar volume (Filipek et al. 1994) and gray

** Corresponding Author:*
Obadiah Byanet, PhD,
Tel: +23480344871981.
Email: byaneto@yahoo.com

matter proportion (Allen et al., 2003). Neuroimaging and morphometric studies of human and animal subjects have shown sexual dimorphisms in certain brain regions such as the amygdala (Goldstein et al., 2001), in hypothalamus and in the cerebellum (Fan et al., 2010; Ramirez and Jimenez, 2002; Ampatzis and Dermon, 2007). The findings of Leonard et al. (2008) showed that women and men have very reliable differences in cerebral volume that account for much of the variance in brain structure size that at first glance might appear to be attributable to sex. In agreement to this report, Lampen (2011) showed that in human, the male cerebellum is larger than the female.

The cerebellum is a brain structure that, among other tasks, is essential for motor coordination (Fletcher, 2006). While the cerebellum is vital in motor coordination, balance and posture, it is also involved in emotion and cognition. Cerebellar involvement in some sexually dimorphic disorders such as autism, schizophrenia and Parkinson’s, suggests that sex differences in the cerebellum may have implications for human motor coordination, as well as cognitive difficulties (Lampen, 2011). The cerebellar involvement in these disorders, together with their sexually dimorphic expression, indicates that any sex difference present in the cerebellum can have major implications for motor coordination as well as higher cognitive function and neurological disorders (Nguon et al., 2005). In another study, Jahanshahi (2012) observed that increase in astrocytes in the cerebellum of experimental rats helped in the spatial learning such as working memory methods, though no sex difference was reported.

In rodents such as rat, it has been reported that female cerebellum has more extensive dendritic branching (Sajdel-Sulkowska, 2005) than the male cerebellum. These differences may have implications for motor function in the rat species and might be of importance to investigate these differences in other rodent’s species such as the grasscutter used in this study. In accord with the reports in the literature, grasscutter males are usually larger than the females and usually lead the group (colony) when foraging in the wild (Raymond, 2010). This behavior in the males may be related to certain part of the brain, particularly the cerebellum that is involved in motor functions such as muscles coordination and non-motor functions like emotion and cognition (Fletcher, 2006).

2. Methods

2.1. Source of Animals and Study Location

A total of twelve (12) grasscutters, comprising 6 males and 6 females, were used in this study. The information concerning their ages was obtained from the farm record; in addition, the adult males had brownish perineal staining, which was taken as an index of sexual maturity in male as reported by Adu and Yeboah (2003). The animals were purchased from a local breeder in Benue State, Nigeria. On physical examination, the animals were apparently healthy at source before being purchased. They were transported by road in constructed wooden laboratory cages measuring 50 cm (height) by 40 cm (width) and 40 cm (length), to the Anatomy Research Laboratory, Department of Veterinary Anatomy, University of Agriculture, Makurdi, Nigeria, where they were kept at room temperature (26 0C) for acclimatization. The rodents were given access to water, and fed on elephant grass (Pennisetum purpureum) and supplemented with grower’s chick mash ad libitum throughout the period of acclimatization.

2.2. Brain Extraction and Morphometry

Each animal was weighed alive using Mettler Balance (Model P 1210, AG, Switzerland, with sensitivity of 0.01g) and sacrificed after anaesthesia with chloroform (within 2-5 minutes) in a closed container. Each tail was cut from the base and weighed. The head of each animal was decapitated at the atlanto-axial joint using sharp knife and forceps and weighed. Each head was skinned and the surface of the skull cleared of all muscles using forceps and scissors. Little cuts were made on the frontal and occipital bones using knife, but with care to avoid damaging the brain. Bones were gently removed starting from the cut areas of the frontal and advanced to the nasal bone rostrally and temporal bones laterally using bone cutter. This gradually continued to the base of the skull, where the cranial nerves were cut through and finally the brain was removed and meninges gently removed from the brain according to the method described by Fletcher (2006), but with modifications due to peculiarity of the rodents.

The extracted brains were fixed in 10% formalin for one month before they were weighed using a sensitive electronic balance (Mettler balance P 1210, Mettler instruments AG. Switzerland; sensitivity: 0.001 g). The volumes of the brains were estimated by the weight displacement method as described by Scherle W (1970). Brain dimensions were obtained using a digital vernier caliper with sensitivity of 0.01 mm, meter rule and twine. The cerebellum of each rodent was separated from the brain stem by cutting through the cerebellar peduncles using forceps and surgical blade. Cerebellar weights and dimensions (such as the length, width, height and circumference) were obtained using the same instruments described above for the whole brain.

For terminology in both gross and histo-morphology, Nomina Anatomica Veterinaria (2005), 5th Edition was used, complimented by Sisson and Grossman (1953).

2.3. Statistical Analysis

All Statistical analyses were performed using the Statistical Analysis Package (Graph Pad Prison, Version 3.10, 2009). The weights and dimensions were expressed as mean and standard error of the mean (Mean + SEM). The differences in weight between the male and female cerebella, the brain, the body and head were analyzed using the student - t - test. Pearson's Correlation Coefficient (r) was used to compare the relationships in weights and dimensions between cerebellum and body variables (the brain, the body and the head) and also between the cerebella in the two age groups weights. Values of $P \leq 0.05$ were considered significant.

3. Results

Gross Findings: Grossly, there were no observed differences in males and females whole brain and cerebellar structures. The cerebellum of grasscutter was observed to be irregularly globular in shape and located on the dorsal aspect of the brain stem (the pons and the medulla-oblongata), forming the roof of the fourth ventricle. The cerebellar surface revealed numerous folia and sulci that pass from the median vermis to the lateral cerebellar hemispheres. Ventrally, three cerebellar peduncles were observed in the cerebella of both sexes; the rostral, middle and caudal cerebellar peduncles.

Morphometric Findings: The morphometric values of the cerebellum, brain, body and tail weights of the males and females are presented in Table 1 and figure 1. The summary of the sexual dimorphism in the dimensions of the cerebellum are presented in table 2 and figure 2. The mean body weight of 1241.67 ± 398.4g in males was higher than 876.67 ± 310.20g of the females, but was not statistically significant. Females have larger mean tail weight than males (P= 0.0508). The differences in the weights of the cerebellum, the brain and the volume of brain were not statistically significant between the sexes. In the female, the cerebellar mean width (21.17 ± 1.14mm) was higher than its mean length (13.83 ± 0.61mm), but smaller than its mean circumference (29.67±0.33). In the male, the mean cerebellar circumference (32.5 ± 0.72mm) was statistically higher than in the female (29.67 ± 0.33) (P = 0.005) (Table 2).

Table 3 shows the correlation data of sex differences between the weight of the cerebellum and dimensions of the brain, body, head and tail. Even though the cerebellum weight was positively correlated with all the body variables (brain, body and tail) in the males and females, there was more strong positive correlation in females. In males, the cerebellum length was negatively correlated with the body and head weights (r = -0.3900 and r = -0.2984), respectively. In addition, the female cerebellar length was positively correlated with the length of the brain, head, body and tail.

Table 1. Weights of the cerebellum and other variables in the male and female grasscutter

Weight (g)	Male (n = 6)		Female (n = 6)		P value
	Min- Max	Mean ± SEM	Min- Max	Mean ± SEM	
Body	550-2500	1241.67±398.48	360-2400	876.67±310.20	0.48
Head	50-300	158.33±45.77	20-220	101.67±27.13	0.41
Tail	10-40	21.67±6.01	03-100	32.17±15.59	0.05*
Brain	6.89-10.67	8.22±0.71	6.72-10.77	8.06±0.59	0.87
Brain volume	7.50-8.25	8.01±0.15	7.45-10.0	7.91±0.42	0.83
Cerebellum	0.87-1.26	1.07±0.05	0.89-1.47	1.12±0.08	0.61

n, sample size; Min, minimum; Max, maximum; SEM, standard error of the mean, *, significant value (P ≤ 0.05)

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Table 2. Dimensions of the cerebellum in the male and female grasscutter

Parameter (mm)	Male (n = 6)		Female (n = 6)		P value
	Min- Max	Mean ± SEM	Min- Max	Mean ± SEM	
Cerebellum Length	12-15	14. 17±0.54	11-15	13.83±0.61	0.69
Cerebellum Width	18-24	20.83±0.91	18-25	21.17±1.14	0.82
Cerebellum Circum.	30-34	32.5±0.72	28-30	29.67±0.33	0.005*
Vermal Length	19-22	20.83±0.54	18-20	19.50±0.34	0.06

n, sample size; Min, minimum; Max, maximum; SEM, standard error of the mean, *, significant value (P ≤ 0.05)

Table 3. Correlation matrix of the weights and dimensions of the cerebellum with other variables showing the correlation coefficient (Pearson r) and (P < 0.05)

Parameter	Sex	Variable					
			Cerebellum	Brain	Body	Head	Tail
Cerebellum weight (g)	Male	r	1.0000	0.7055*	0.7115*	0.5725	0. 5725
		p	-	0.1173	0.1128	0.2350	0.2350
	Female	r	1.0000	0.9882*	0.9033*	0.8445*	0.8614*
		p	-	0.0002	0.0136	0.0344	0.0275
Cerebellum length (mm)	Male	r	1.0000	0.1802	-0.3900	-0.2984	0.2041
		p	-	0.7327*	0.4447	0.5657	0.6982*
	Female	r	1.0000	0.3440	0.3792	0.6439*	0.1761
		p	-	0.5044	0.4585	0.1676	0.7416*

*, significant value (P ≤ 0.05)

4. Discussion

Biological and behavioral differences between male and female in structure may range from obvious to subtle or nonsexist (Leonard et al., 2008). Neuroanatomical differences are said to show sex differences in brain regions in birds and mammals; correlating differences in sex-species behavior with anatomical sexual dimorphism (Ampatzis and Dermon, 2007). Although they commonly forage in groups, grasscutters are generally solitary, nocturnal and travel at night through trails in reeds and grass (National Research Council, (NRC) USA, 1991). According to NRC, most of the species seen in markets are males, possibly because males lead the groups and are thus most prone to being trapped and killed. Based on these reports (Ampatzis and Dermon, 2007; NCR, 1991), the behavioral differences between the male and female grasscutter in the wild is suggestive of brain region differences, such as cerebellum that control the motor functions in this species.

In the present study, the mean brain weight and volume were higher in the males than in females, although these values were not statistically significant. These findings agreed with Byanet et al. (2009) who observed no significant differences in the brain weight of both sexes in this same species. Leonard et al. (2008) hypothesize that individual differences in brain volume in both men and women account for what appear to be sex differences in the proportion of various tissues components. Studies in recent years have demonstrated differences in brain to be important for explaining many physiological and pathological processes occurring in humans' bodies. The classical view of brain sexual differentiation is built around the dogma that hormones secreted by gonads are solely responsible for differences in the brain sexes.

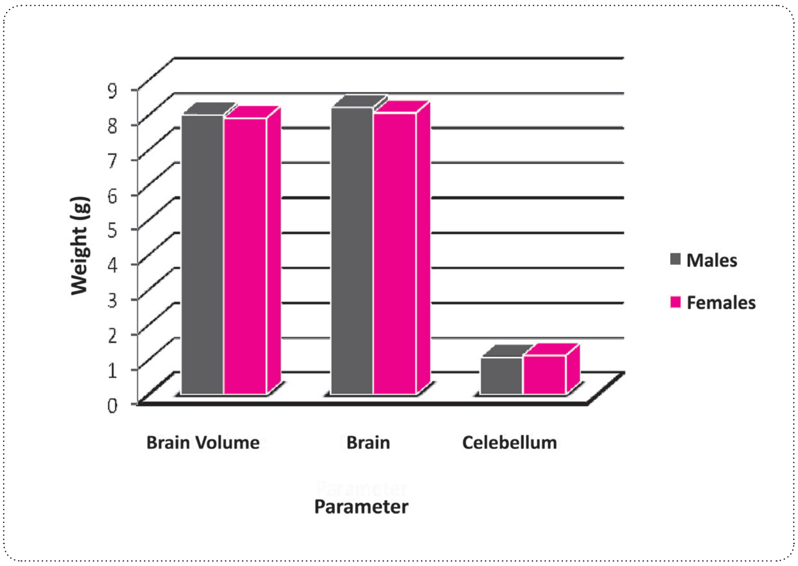

Figure 1. Histogram comparing the sex differences in the brain and cerebellum weights of the grasscutter.

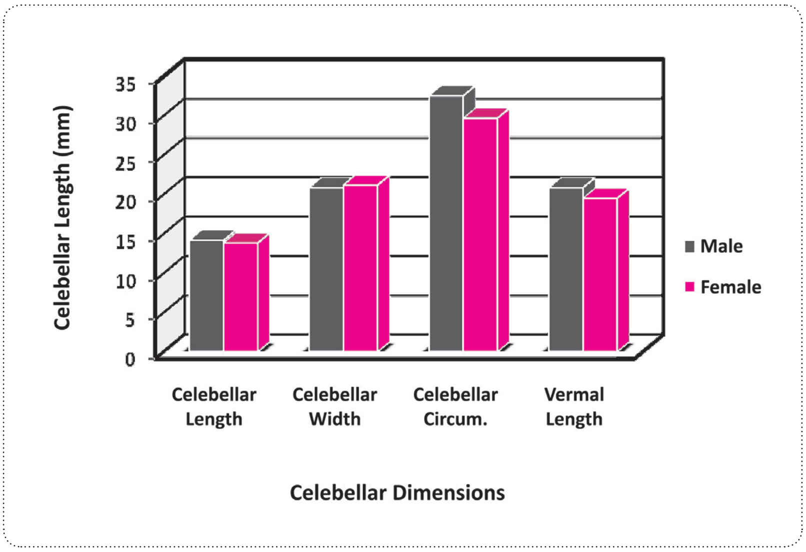

Figure 2. Histogram comparing the sex differences in the cerebellum dimensions of the grasscutter.

The slightly higher mean brain weight and significantly higher circumference length observed in male than female in this study may partly be responsible for the bigger rounded head seen in the male grasscutter. Some magnetic resonance imaging (MRI) studies (Dean and McCarthy, 2009) in the humans showed that cerebellum is larger in adult men than women, even when controlling for height. Earlier report by Supple et al. (1987) showed that children and adolescents MRI reveals an 8% differences in cerebellar volume, with cerebellum of males being larger even when controlling for height and weight. Examination of fixed human tissues, using the same MRI by Blumberg et al. (2002) and Malhotra et al. (1959), failed to show volumetric differences in the cerebella of men and women. Using cerebellar cells, Heath et al. (1978) reported that men and women have equal number of Purkinje cells.

In females, the mean weight of the cerebellum was slightly higher than in males, and the tail weight was also significantly higher than in males (P < 0.05). Furthermore, the female cerebellar weight was strongly correlated with the brain, body, head and tail weights (r = 0. 9882, 0. 9033, 0.8445 and 0. 8616), respectively. These findings showed that the female grasscutter cerebellum is slightly larger than male and is correlated with tail weight. Owens et al. (2002) showed that rats control their body temperature through their tails by dilating or constricting their tail blood vessel, that is, it serves as a variable heat exchanger. Since tail is a thermoregulatory organ, increase in its size as seen in female may suggest a greater thermoregulatory function; enabling the females to have a better control of the body temperature than males. The cerebellum has also been examined for physiological differences. Adult women have a slightly higher rate of metabolism in the cerebellum as determined by positron emission tomographic analysis (Dean and McCarthy, 2009).

5. Conclusion

From the results of this study, we concluded that the slightly higher mean brain weight and significantly higher circumference length in the male than female may partly be responsible for the bigger rounded head seen in the male grasscutter. The female cerebellum was slightly larger than male and correlated with tail weight, suggesting a better thermoregulatory function in female grasscutter than their male counterpart.

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