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# Dimensional Analysis of Selected Linear and Curved Measurements of Human and Baboon Brains

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**Abstract**

Brains of primates show morphometric differences that may be influenced by the process of functional complexity, evolution and adaptation. Comparative topographic measurements of the primate brains have been used to explain functional and evolutionary trends between the species and to highlight differences in salient functions. Variations in selected linear measurements of the human and baboon brains have demonstrated functional complexity. Some neuro-pathological conditions of the brain may show characteristic morphometric changes. Selected dimensional linear and curved measurements of 4 human and 4 baboon brains from the superior, inferior and lateral aspects were analyzed using ratios to evaluate variability in the morphology of the brains. The ratios for the same species (linear *vs* curved) provide the extent of the curvature on that measurement. This could be interpreted that more curving suggests more neurons and greater volume. With inter-species ratios; a bigger value implies a higher density of neurons or greater volume for the aspect under consideration. Intra-species co-efficient of variation comparison indicates that curved measurements had a higher variability than the linear in both species. Comparison of symmetry in terms of ratios of both linear and curved measurements indicated no significant difference between hemispheres for both species. There was similarly no significant intra-species difference in terms of curvature between the left and right aspects, but the measurement landmarked by summit of central sulcus and inferior temporal gyrus showed the highest difference in curved measurements. This study provides baseline data for certain morphometric measurements that may be used to assess pathological changes in brain disorders as found in imaging studies. Ratios may also be used to show structural, functional and evolutionary differences and trends between primate brains.

**Keywords:** Linear; Curved; Measurements; Analysis; Human; Baboon brains

## Introduction

The purpose of this study was to compare the brain parameters of human and baboon brains. The linear and curved measurements from the superior, inferior and lateral aspects were analyzed using various ratios to study variability in the morphology of human and baboon brains. Studies comparing body size, body weight and cranial capacity of hominids show that brain size correlates isometrically with body size [1-3]. Morphological variations in the primate brain reflect functional complexity, evolutionary trends with respect to body size and functional adaptations [4-7]. Body size and weight have been associated with the size of the brain and its components, but this has not been addressed explicitly [8,9].The parameters of the various parts of the cerebral hemisphere may show differences that reflect their functional aspects between and within species [9]. Comparative analysis of human and baboon cerebral linear measurements has demonstrated morphometric differences between the two species [10]. Linear brain parameters have been used in regression models to predict body weight and height [11]. Morphometric equations have been used to predict body weight for large bodied mammals such as polar bears in wildlife research, which would otherwise be difficult using direct scale weighing of individuals [12].

Studying brains in evolutionary contexts requires examination of large numbers of specimens and species, and all major parts of the brain. Thus; evolutionary studies of many species and of whole brains still tend to be based upon simpler data, such as sizes of brains and brain components [13]. Deacon's replacement hypothesis indicates that changes in the amount of connectivity within a system results in correlated reorganization of circuitry, producing plasticity changes that are species specific [14]. Several morphometric parameters are considered to be important for understanding the relationship between various parts of the cerebrum [7]. Recent reports indicate that humans and apes show consistently different brain morphologic parameters [15]

The present study analyzed ratios of selected linear and curved measurements in the brains of humans and baboons with a view to elucidate differences in functional and evolutionary aspects of the brains. The ratios of curved and linear measurements would indicate differences in the volume of the selected brain parameters. The baseline data obtained could be used as a reference to compare with morphometric changes with brain anomaly seen in functional imaging and Magnetic Resonance Imaging (MRI) [16,15].




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## Materials and Method

### Human brains

Four formalin fixed whole adult human brains of unknown sex were obtained from the Department of Human Anatomy, University of Nairobi. The brains were harvested from bodies obtained for educational purposes, as per the Human Anatomy act (2008). The bodies were fixed by perfusion with 10% formalin. The average body weight for humans was used (65 kg). Each of the brain was given an index number 1 to 4.

### Baboon brains

Four whole formalin fixed Olive baboon brains were obtained from the Institute of Primate Research, National Museums of Kenya. The available baboon brains were all male, from a feral troop trapped from Tinga, Kajiado district and subsequently taken through a 90 day quarantine period at the Institute. During this period the animals underwent a general physical examination, screening for infectious agents, de-worming and testing for tuberculosis, prior to allocation to experimental groups. The four baboons were mature adult males designated Pan 2921, 2924, 2927 and 2929 with body weights ranging from 23.3 to 26.5 kilograms.

The four baboons were sacrificed due to old age, oral and other pathologies and the brains harvested. Firstly, the animals were sedated with a ketamine/Xylazine mixture of the ratio 10ml of 10% ketamine/2.5ml of 2% xylazine at the dose rate of 1ml of mixture/10kg body weight and then sacrificed with an intravenous dose of Euthatal® (20% pentobarbital) at 0.5 mg/kg, then followed by trans-cardiac perfusion through the left ventricle using 10% formalin. Whole brain was then harvested and preserved in 10% formalin. The human and baboon brains were weighed using a weighing scale. Ethical approval for the study was granted by the Institutional Review Committee.

### Topographic measurements

Linear and curved topographic measurements of the brains from superior, lateral and inferior aspects in coronal or sagittal plane were carried out as described. Three observers carried out the measurements in terms of the superior, inferior and lateral perspectives of whole brains either as coronal, or sagittal, linear or curved measurements and the means from the three readings were obtained. The reference points for the selected linear and curved measurements were established by the three observers who carried out the measurements after repeated standardization. Inter and intra observer errors were less than 5%. All measurements were done using a flexible metric tape and vernier calipers to the nearest millimeter.

The legend and illustrations below describe the linear and curved measurements taken from the three aspects using the reference points (Figures 1, 2 and 3). Linear distances are shown by a solid line and curved by a broken line. The following linear and curved measurements were taken in sagittal and coronal planes. Measurements were carried out on right (Rt) and left (Lt) hemispheres. (Figure 1, 2 and 3).

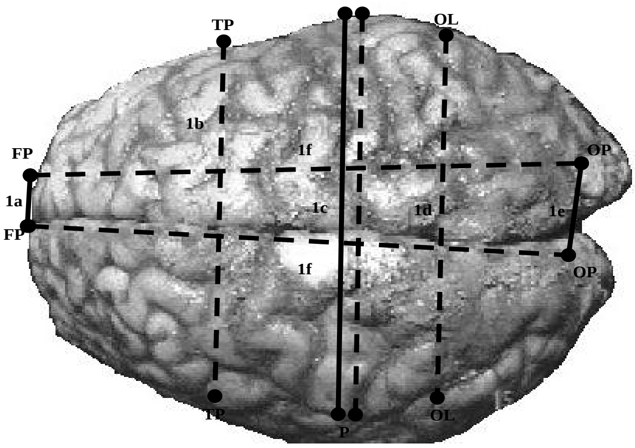


**Figure 1:** Showing landmarks and parameters for linear (____) and curved (-----) measurements from superior aspect of the human brain.
1a: Interfrontal pole (FP - FP) – Coronal: Linear
1b: Intertemporal pole (TPs - TPs) – Maximum coronal curved distance along the superior surface
1c: Interparietal (P - P): - Coronal: Linear and curved (junction of central sulcus and lateral sulcus (width of brain)
1d: Interoccipital (OL- OL) – maximum distance between occipital lobes – Coronal: Linear
1e: Interoccipital poles (OP – OP) – Coronal: Linear
1f: Frontal pole – Occipital pole (FPs - OPs): Maximum curved saggital distance along the superior surface: (Right and left).

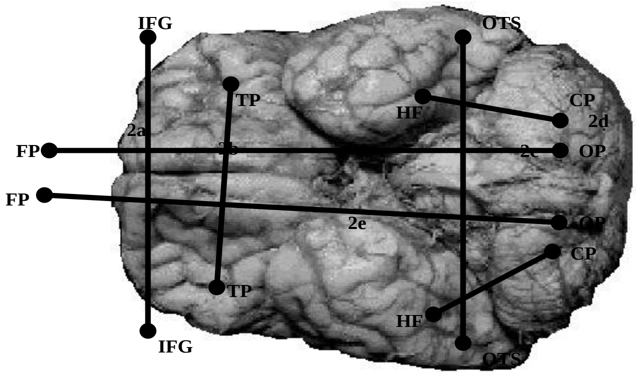


**Figure 2:** Showing landmarks and parameters for linear (-------) measurements from inferior aspect of the human brain.
2a: Inferior frontal gyrus (IFG -IFG) – Coronal: Linear
2b: Intertemporal pole (TPi - TPi) – Coronal: Linear
2c: Occipitotemporal sulcus (OTS – OTS) - Coronal: linear
2d: Cerebellum: Horizontal Fissure (HF) – Cerebellar Pole (CP)
2e: Frontal pole – Occipital pole (FPi - OPi) – Sagittal: Linear/Left, Right (length of brain).

## Results

### Intra and inter-species comparison

The weights of the four human brains were 1150 g (Human 1), 1275 g (Human 2), 1225 g (Human 3) and 1275 g (Human 4). The weights of the baboon brains were 128.8 g (Pan 2921), 154.8 (Pan 2924), 160.9 (Pan 2924) and 154.8 (Pan 2929). Three readings were taken for each linear and curved parameter and the mean and standard deviation were computed. Intra-species and inter species comparison of ratios of the selected curved versus linear measurements, for the superior, lateral and inferior aspects was determined for the human and baboon brains This determined the extent of curvature and variability in the values of selected parameters of human and baboon brains. The means of selected measurements are presented in (Table 1).

The relative extent of width of the brain, FP-FP, P-P, OL-OL and OP-OP is shown by the ratios. The FP-FP/OP-OP ratios were

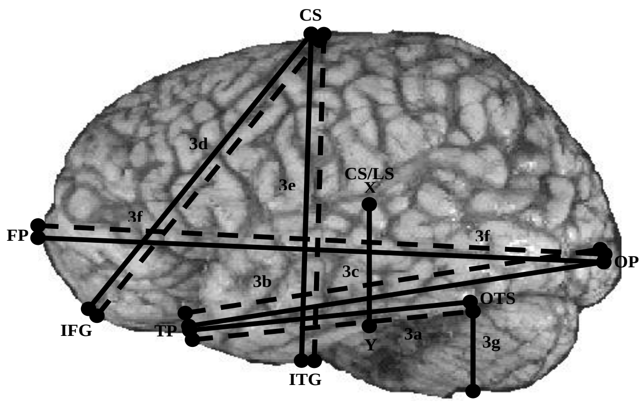


**Figure 3:** Showing landmarks and parameters for linear ( _____) and curved ( ------) measurements from lateral aspect of the human brain.
3a: Temporal pole (TP) – Occipitotemporal sulcus (OTS) - Sagittal: Linear/Curved: Left/Right
3b: Temporal pole (TP) – Occipital pole (OP) - Sagittal: Linear/Curved: Left/Right
3c: Height of temporal lobe i.e. Junction of Central and Lateral sulcus (CS/LS) – Occipitoparietal sulcus (OPS) - Coronal: Linear/Curved: Left/Right
3d: Inferior frontal gyrus (IFG) – Central sulcus (CS) - Coronal: Linear/Curved: Left/Right
3e: Summit of central sulcus (CS) – inferior temporal gyrus (ITG) - Coronal: Linear/Curved: Left/Right (Height of brain)
3f: Frontal pole (FP) – occipital pole (OP) – Sagittal: Linear/Curved: Left/Right
3g: Height of cerebellum (HC) - Left/Right (inferior).

**Table 1:** Mean values (cm) of selected linear and curved measurements of the cerebrum in the human and baboon.

| | Human Brains | | | Baboon Brains | | |
|---|---|---|---|---|---|---|
| Measurement | Length | Width | Height | Length | Width | Height |
| Linear | 165.67 | 114.88 | 109.63 | 83.9 | 64.75 | 50.5 |
| Curved | 240.3 | 200.71 | 157.44 | 99.45 | 94.38 | 83.21 |
| HTL | 46.73 | | | 22.58 | | |

The Tables 2a, 2b and 2c summarize the human and the baboon ratios from the three aspects. Units 1 and 2 represent the means of first and second measurement of the indices used to compute the ratio respectively (eg. linear versus curved, left versus right).

0.669 and 0.267 for humans and baboons respectively, indicating that the interoccipital distance was 1.5 times the interfrontal distance in human brains and 3.75 times in the baboon brains. From the ratios1b:1c, there was greater antero-posterior expansion in the baboon brain. Ratios 1b and 1c for the frontal and parietal cortices respectively, indicate that the human brains had a greater curvature compared to the baboon brains. There was greater mediolateral narrowing in the human brains from the parietal to the occipital lobe (1h: 1d) compared to the baboon brains. The ratios 1d: 1b and 1d: 1c were nearly similar in both. In terms of symmetry of the two hemispheres, FP-OP (1f), the left hemisphere was bigger in the human brains, while baboon brains had a bigger right hemisphere (ratios 0.998 and 1.187 respectively).

Analysis of TP-TP (2b) and IFG-IFG (2a), showed a ratio of 0.506 in the human brains indicating nearly two-fold increase in diameter while in the baboon, the ratio was 0.605 indicating a 1.65 fold increase. OTS-OTS (2c) to IFG-IFG (2b) showed a marginal narrowing in humans by a ratio of 0.984 and expansion in baboons by a ratio of 1.21. From the maximum distance of the cerebellum, coronally (2d) analysis of linear symmetry gave a ratio of 1.005 in the human brains, representing a slightly larger right side. In the baboon the ratio was 0.96 implying a larger left lobe and for curved symmetry, a larger left lobe in both species. From the ratios of FP-OP, a larger left hemisphere in the human and a larger right one in the baboon.

From the landmarks 3a and 3b representing the length of the temporal lobe, for 3a in the human brains, the right lobe was slightly longer than the left, though the left lobe had a greater curvature. In the baboon brains, the left lobe was longer and had greater curvature compared to the right lobe. Between the species, the human brains have greater curvature compared to the baboon brains.

For parameter 3b, both species had a longer left lobe with a more curved right lobe.

Parameter 3g represented the height of the temporal lobe. Both species had a longer left temporal lobe, though the curvature was greater in the right lobe. Human brains showed greater curvature on this aspect for both left and right lobes. From the height of the frontal parietal cortex, 3d, the human brains had a larger left side, with greater right curvature; the baboon brains had a slightly larger right height with greater left curvature. From the height of the brain 3e; this was greater on the left lobe for both species, with a greater left lobe curvature. The height of cerebellum (3h) was greater on the right lobe in human brains while it was greater on the left lobe of baboon brains.

## Symmetry and curvature

The intra-species and inter- species ratios for the linear versus curved measurements are shown in Table 2a and 2b below. Comparison of symmetry in terms of ratios of both linear and curved measurements indicated no significant difference between hemispheres for both species. There was similarly no significant intra-species difference in terms of curvature between the left and right aspects, but the measurement landmarked by summit of Central Sulcus (CS) and Inferior Temporal Gyrus (ITG) showed the highest difference in curved measurements. Intra species comparison of the right aspect revealed that the baboon ratio was higher by 0.24 than the human, while the left differed by 0.183. In humans, the left curved measurement was higher than the right by 0.075, while the same measurements differed by 0.018 in the baboon.

## Degree of variability

Coefficient of variation was calculated for the superior, inferior and lateral measurements for both species. These are presented in (Figures 4, 5 and 6) respectively. From selected measurements taken from superior aspect, the highest variability in human brains was observed in measurements 1e (19.44%) and 1h (14.44%), while in the baboon it was in 1a (27.31%) and 1e (16.31%). The lowest variability in human brains, (2.21%) and (1.49%) was found in the linear measurements 1c and 1b respectively, while in the baboon these were, 1h (2.23%) and linear 1b (4.81%). For the parameters with both linear and curved measurements 1b and 1c, the curved measurements had a comparatively greater variability. (Figure 4) summarizes this information.

Inferior aspect measurements showed that human brains had highest variability in intertemporal pole distance, 2a (24.56%), while the highest variability in baboon brains was observed in 2a (10.51%)

**Table 2a:** Human and baboon ratios from the superior aspect.

| Superior | Human Ratios | | | Baboon Ratios | | | Interspecies Ratios | | |
|---|---|---|---|---|---|---|---|---|---|
| Dimensions (mm) | Unit 1 | Unit 2 | Ratio | Unit 1 | Unit 2 | Ratio | Human | Baboon | Ratio |
| 1a:1e (linear) | 16.63 | 24.84 | **0.669** | 4.54 | 17.08 | **0.267** | 0.669 | 0.267 | **2.506** |
| 1b (linear /curved) | 114.63 | 202.67 | **0.566** | 59.83 | 96.34 | **0.621** | 0.566 | 0.621 | **0.911** |
| 1b:1c (Linear) | 114.63 | 114.88 | **0.998** | 59.83 | 64.75 | **0.924** | 0.998 | 0.924 | **1.08** |
| 1b:1c (Curved) | 202.67 | 200.71 | **1.009** | 96.34 | 94.38 | **1.02** | 1.009 | 1.02 | **0.989** |
| 1c (linear/ curved) | 114.88 | 200.71 | **0.572** | 64.75 | 94.38 | **0.686** | 0.572 | 0.686 | **0.834** |
| 1d:1b (curved) | 319.17 | 202.67 | **1.575** | 150.96 | 96.34 | **1.567** | 1.575 | 1.567 | **1.005** |
| 1b:1c (curved) | 319.17 | 200.71 | **1.59** | 150.96 | 94.38 | **1.599** | 1.59 | 1.599 | **0.994** |
| 1f (right/left) (curved) | 240 | 240.6 | **0.998** | 106.88 | 90.02 | **1.187** | 0.998 | 1.187 | **0.841** |
| 1h:1e (curved) | 165 | 319.17 | **0.517** | 101.88 | 150.96 | **0.675** | 0.517 | 0.675 | **0.766** |

**Table 2b:** Human and baboon data from the inferior aspect.

| Dimension | Human Ratios | | | Baboon Ratios | | | Interspecies Ratios | | |
|---|---|---|---|---|---|---|---|---|---|
| | Unit 1 | Unit 2 | Ratio | Unit 1 | Unit 2 | Ratio | Human | Baboon | Ratio |
| 2a (TP-TP):2b (IFG-IFG) | 46.38 | 91.67 | **0.506** | 30.25 | 49.99 | **0.605** | 0.506 | 0.605 | **0.836** |
| 2c (OTS-OTS):2b | 90.21 | 91.67 | **0.984** | 60.5 | 49.99 | **1.21** | 0.984 | 1.21 | **0.813** |
| 2d (Cerebellum (L Rt / L Lt)) | 50.96 | 50.71 | **1.005** | 20.34 | 21.18 | **0.96** | 1.005 | 0.96 | **1.047** |
| 2d (Curved R vs Curved L) | 64.25 | 64.58 | **0.995** | 23.42 | 24.33 | **0.963** | 0.995 | 0.963 | **1.033** |
| 2d (Linear R vs Curved R) | 50.96 | 64.25 | **0.793** | 20.34 | 23.42 | **0.868** | 0.793 | 0.868 | **0.914** |
| 2d (Linear L vs Curved L) | 50.71 | 64.58 | **0.785** | 21.18 | 24.33 | **0.871** | 0.785 | 0.871 | **0.901** |
| 2e:1g (Linear R vs Linear L) | 165.46 | 165.87 | **0.998** | 84 | 83.79 | **1.003** | 0.998 | 1.003 | **0.995** |

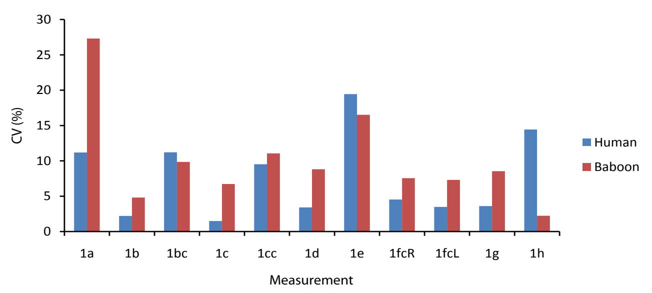


**Figure 4:** Coefficient of variation for selected dimensions of the superior aspect. Comparative coefficient of variation (CV) for superior measurements.

and cerebellar maximum sagittal distance, 2d8 (10.3%). The lowest variability was in the sagittal right and left cerebellar measurements 2d5(1.19%) and 2d6(1.89%) in human brains. In the baboon brains, this was observed in the coronal cerebellar measurements 2d2(3.73%) and 2d3(3.16%). Generally, the curved measurements had greater variability compared to linear measurements in both species (2d3 and 2d4 compared to 2d1 and 2d2, and 2d7 and 2d8 compared to 2d5 and 2d6).

The highest variability in the human brains was observed in the measurements 3c (curved left), 3e (curved right) and 3a (curved left) while the lowest was in 3b (curved left) and 3e (linear left). In terms of symmetry, the variability in the left aspect was lower compared to the right aspect, except for the measurements, 3a (curved), 3b (linear) and 3c (curved) in the human brains. Comparing the linear and curved measurements, it was observed that curved measurements showed greater variability for all measurements except for 3c for the right aspect and 3b and 3d for left aspect measurements in human brains.

In the baboon brains 3b (curved left), 3a (linear left) and 3c (curved left) had the greatest variability while 3g (HTL right) and 3d (curved right) showed the lowest variability. Except for the measurements, 3c (linear) and 3h (linear), the left aspect had greater variability compared to the right. Comparing linear versus curved measurements, curved measurements had a greater variability except for 3a and 3d for both right and left aspects. Inter species comparison indicated higher linear measurement (Coefficient of Variation values) for baboon brains compared to human brains.

## Discussion

Ratios of linear and curved measurements of the human and baboon brains from superior, inferior and lateral aspect has shown inter and intra species differences brain morphometry in linear and curved expansion, regionally, in width, length and height of the

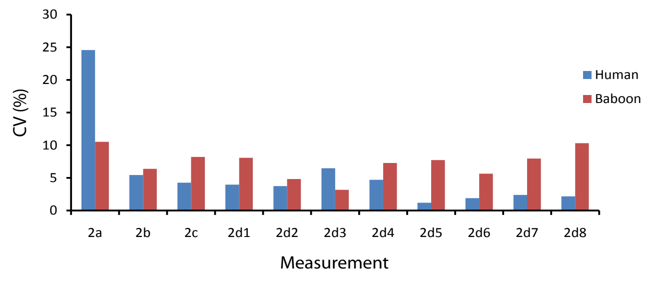


**Figure 5:** Coefficient of variation for selected dimensions of the inferior aspect. Comparative coefficient of variation (CV) for inferior measurements.

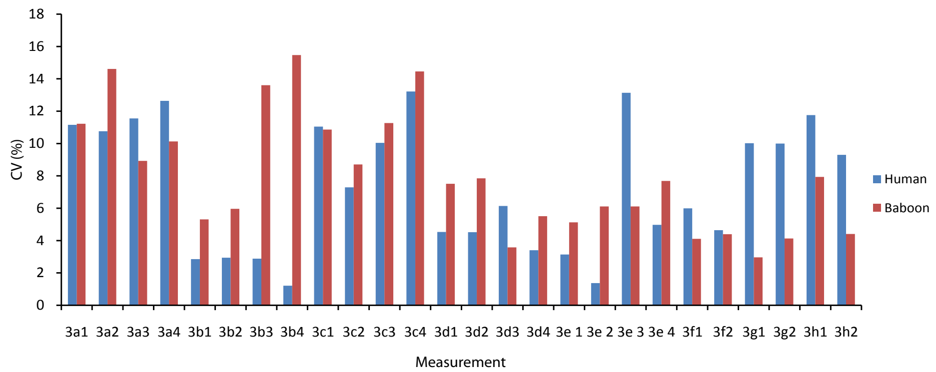


**Figure 6:** Coefficient of variation for selected dimensions of the lateral aspect. Comparative coefficient of variation (CV) for lateral measurements.

**Table 2c:** Human and baboon data from the Lateral aspect.

| Dimension | Human Ratios | | | Baboon Ratios | | | Interspecies Ratios | | |
|---|---|---|---|---|---|---|---|---|---|
| Lateral | Unit 1 | Unit 2 | Ratio | Unit 1 | Unit 2 | Ratio | Human | Baboon | Ratio |
| 3c (Linear R vs Linear L)(LS-OPS) | 88.86 | 93.96 | **0.946** | 49.46 | 49.59 | **0.997** | 0.946 | 0.997 | **0.949** |
| 3c (Curved R vs Curved L) | 123.29 | 121.5 | **1.015** | 60.25 | 58.63 | **1.028** | 1.015 | 1.028 | **0.987** |
| 3c (Linear R vs Curved R) | 88.86 | 123.29 | **0.721** | 49.46 | 60.25 | **0.821** | 0.721 | 0.821 | **0.878** |
| 3c (Linear L vs Curved L) | 93.96 | 121.5 | **0.773** | 49.59 | 58.63 | **0.846** | 0.773 | 0.846 | **0.914** |
| 3e (Linear R vs Linear L)(CS-ITG) | 108.58 | 110.67 | **0.981** | 50.46 | 50.54 | **0.998** | 0.981 | 0.998 | **0.983** |
| 3e (Curved R vs Curved L) | 151.71 | 163.17 | **0.93** | 82.59 | 83.83 | **0.985** | 0.93 | 0.985 | **0.944** |
| 3e (Linear R vs Curved R) | 108.58 | 151.71 | **0.716** | 50.46 | 82.59 | **0.611** | 0.716 | 0.611 | **1.172** |
| 3e (Linear L vs Curved L) | 110.67 | 163.17 | **0.678** | 50.54 | 83.83 | **0.603** | 0.678 | 0.603 | **1.124** |
| 3f(Curved R vs Curved L)(FP-OP) | 224.17 | 227.58 | **0.985** | 112.63 | 112.96 | **0.997** | 0.985 | 0.997 | **0.988** |
| 3g (Linear R vs Linear L)(HTL) | 46.5 | 46.96 | **0.99** | 22.62 | 22.54 | **1.004** | 0.99 | 1.004 | **0.986** |
| 3h (Linear R vs Linear L)Ht Cerebellum | 38.53 | 38.08 | **1.012** | 16.25 | 16.33 | **0.995** | 1.012 | 0.995 | **1.017** |

The curved length of the brain (3f), height of the brain (3e), and height of the temporal lobe (3g) are summarized.

**Table 3a:** The Tables below (3a and 3b) present a summary of intra and inter species comparative ratios of the left and right hemispheres, linear and curved measurements. The ratios indicate specific differences of the parameters described. In Table 3a linear right and curved right, measurements were compared.

| | HUMAN | | BABOON | | HUMAN:BABOON | |
|---|---|---|---|---|---|---|
| Parameter | $L_R$:$L_L$ | $L_R$:$C_R$ | $L_R$:$L_L$ | $L_R$:$C_R$ | $L_R$:$L_L$ | $L_R$:$C_R$ |
| 2d (Inferior) | 1.005 | 0.793 | 0.96 | 0.868 | 1.047 | 0.914 |
| 3a (Lateral) | 1.01 | 0.83 | 0.994 | 0.901 | 1.016 | 0.921 |
| 3b(Lateral) | 0.98 | 0.737 | 0.995 | 0.688 | 0.985 | 1.071 |
| 3c(Lateral) | 0.946 | 0.721 | 0.997 | 0.821 | 0.949 | 0.878 |
| 3d(Lateral) | 0.974 | 0.761 | 1.006 | 0.769 | 0.968 | 0.99 |
| 3e(Lateral) | 0.981 | 0.716 | 0.998 | 0.611 | 0.983 | 1.172 |

brains. Comparing the brain parameters on the right and left sides has indicated the degree of asymmetry within and between the species. Topographic linear and curved measurements of mammalian brains have previously been used to predict measurements of body parameters with acceptable degrees of accuracy [11].

Within species, morphometric measurements of linear and circumferential parameters have been shown to have a statistical relationship with body weight. Using multiple linear and non-linear regression, a strong relationship was identified between polar bear

**Table 3b:** This table present the comparision of left hemispher curved linear measurements with linear left and curved rightfor human and baboon brain parameters for inferior and lateral aspects.

| | HUMAN | | BABOON | | HUMAN:BABOON | |
|---|---|---|---|---|---|---|
| Parameter | $C_L$ :$L_L$ | $C_L$ :$C_R$ | $C_L$ :$L_L$ | $C_L$ :$C_R$ | $C_L$:$L_L$ | $C_L$:$C_R$ |
| 2d (Inferior) | 1.274 | 1.005 | 1.148 | 1.038 | 1.11 | 0.968 |
| 3a(Lateral) | 1.266 | 1.041 | 1.129 | 1.022 | 1.121 | 1.019 |
| 3b(Lateral) | 1.335 | 1.003 | 1.447 | 1.002 | 0.923 | 1.001 |
| 3c(Lateral) | 1.293 | 0.985 | 1.182 | 0.972 | 1.094 | 1.013 |
| 3d(Lateral) | 1.28 | 1.014 | 1.307 | 0.999 | 0.979 | 1.015 |
| 3e(Lateral) | 1.475 | 1.075 | 1.658 | 1.015 | 0.89 | 1.059 |

body weight and linear measures of straight line length and auxiliary circumferential growth [12].

Morphometric methods have been used to enhance diagnostic performance in the staging of the lesion profile in CNS disease syndromes manifesting with differentiated alterations in gray and white matter volumes, symmetry and overall shape.

In this study, comparisons were made between human and baboon linear and curved measurements with a view to highlight morphometric differences between the lateral, superior and inferior aspects of the brain from a perspective of the various cortices (Frontal, temporal, parietal and occipital cortices and the cerebellum.

Medio-laterally, the landmarks inferior frontal gyrus and summit of central sulcus of linear and curved measurements showed asymmetry in both species with the left being higher in humans and the right being higher in baboons, but the degree of symmetry was higher in baboons compared to humans. This finding corroborates previous studies indicating no major asymmetry in baboons and detectable asymmetry in humans [10,8]. implying a functional dominance of the left hemisphere in humans.

The measurement temporal pole to occipito-temporal sulcus showed asymmetry in terms of both linear and curved parameters, with humans showing right asymmetry for the linear parameters and left asymmetry for the curved implying a higher cortical surface area in the left hemisphere but probable conservation of volume of the temporal lobe. In baboons left asymmetry was demonstrated for both linear and curved parameters suggesting greater surface area and volume of the left temporal lobe. Further, the measurement temporal pole to occipital pole showed left hemispheric dominance in both species and the measurement lateral sulcus to occipito-parietal sulcus showed left dominance for linear measurements and right dominance for the curved measurements for both species suggesting a possible conservation of the volume parameter.

It is plausible that a wider application of these observations may be used to predict parameters of other body parts from linear and non-linear measurements of easily accessible measurable parameters. Many mammalian species including primates manifest diseases with similar symptoms, but with substantially different morphometric substrates [16].

The 3D MRI study showed that a pattern of brain morphology that is consistently different between all apes and humans [15]. In addition, they showed patterns morphologically unique to human brains, there are also patterns that differentiate human from non-human ape species. Analysis of TP-TP (2b) and IFG-IFG (2a), a ratio of 0.506 in the human brains indicated a two-fold increase in diameter while in the baboon, 0.605, indicated a 1.65 fold increase. Comparing humans and baboons ratio, 0.836 showed that the human brain expands more than the baboon.

From the maximum distance of the cerebellum, coronally (2d) analysis of linear symmetry gave a ratio of 1.005 in the human brains, representing a larger right side. In the baboon the ratio was 0.96 implying a larger left lobe and for curved symmetry, (0.998 and 0.963) a larger left lobe in both species. From the ratios of FP-OP, (0.998 and 1.003), a larger left hemisphere in the human and a larger right one in the baboon. This implies a converse association of symmetry between the cerebrum and the cerebellum, the cerebrum having a larger left hemisphere and the cerebellum having a larger right lobe in humans, and the converse case in baboons.

Humans have medio-lateral parameters with broader frontal regions and the temporal poles also differ. Humans show mediolaterally expanded parietal cortices as characterized by the increased distance between the terminations of the intraparietal sulci The absolute expansion of the human brain is a relative feature with respect to ape brain size [15].The pattern showing differences Fronto-Parietal-Temporal region are not confined to a single region and the evolution of the brain in the human is not accompanied by isolated change in any structure. The reorganization in the circuitry is marked by changes in cortical and subcortical structural ratios between species. Behavior differences may be explained by functional and morphometric differences [17,5].

For symmetry, there was no marked difference in the linear measurements of the parameters in the right and left hemispheres in the baboon, whereas these measurements were slightly higher in the left hemisphere in humans. These findings corroborate previous studies [10]. And could reflect a dominance of the left hemisphere [8]. Baseline data may be used to determine the morphological changes in a human brain following pathology e.g. Alzheimer's disease [18].The present study provides data to support findings from 3D MRI studies being used to determine distinct changes as shown by [15].

In conclusion, the ratios of linear and curved measurements between and within species support the suggestion that although brain morphologies have evolved in a coordinated manner, various anatomical and functional regions of the brain have distinct patterns [15].

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