Original Research Paper

Observations on Symmetry and Sexual Dimorphism from Morphometrics of Foramen Magnum and Orbits In Adult Bengali Population

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Abstract

Human body exhibits bilateral symmetry along the sagittal plane. Symmetry in nature is approximate. Human bones show sexual dimorphism. Determination of sex is necessary from skeletal remains for establishment of an identity. In this study conducted on 53 skulls, the measurements of foramen magnum and orbits were taken by digital slide calipers. The mean length, breadth and areas calculated from Radinsky and Texeria formulae for male skulls were 3.4 cm, 2.8 cm, 7.52 cm^2 and 7.6 cm^2 and those for female skulls were 3.3 cm, 2.74 cm, 7.15 cm^2 and 7.22 cm^2 respectively. The orbital indices for the male skulls fall in the Mesoseme category (86.89) while that for the female skulls fall in the Megaseme category (90.31). Asymmetry exists between right and left orbits of each individual. The interorbital distance between male and female skulls were significantly different and may be used as an indicator for sex determination from skulls.

This study conducted first time on Bengali population aims for formation of a craniometric database; provide clues on facial asymmetry for facial reconstructions and superimposition and newer methods for determination of sex from dry adult cranial bones.

Key Words: Symmetry, Craniometrics, Foramen Magnum, Orbits, Identification, Bengali

Introduction:

Symmetry can be defined as the quality of being made up of exactly similar parts facing each other or around an axis. [1] On simpler terms it can also be said as similarity or exact correspondence between different things. Symmetry essentially reflects order. Scientists have recognized that symmetry has relation with aesthetic appeals and human beings are attracted to it. Symmetry is abundant in nature from plant leaves and sea anemones to higher vertebrates including human body.

Human body exhibit bilateral or mirror symmetry and is symmetrical along the sagittal plane which divides it into two equal halves with identical limbs and identical facial halves with eyes and ears. However symmetry in nature is very approximate and humans tend to over generalize it.

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No two things in nature are exactly symmetrical including the anatomy of the human body. Essentially male and female are different in nature and abundant dimorphism exists in human body. Human bones are also different in males and females. In Forensic Medicine determination of sex is very necessary particularly from skeletal remains. Identification is an utmost necessity for Forensic experts from skeletal remains and sex determination stands as the first pillar for establishment of an identity.

The determination of sex is based mainly upon the appearances of the pelvis, skull, sternum and the long bones.

According to Krogman the degree of accuracy in sexing adult skeletal remains is: Entire skeleton-100%, Pelvis alone-95%, Skull alone-90%, Pelvis and Skull-98% and Long bones alone-80%. [2] Skull is extensively used for sex determination in day to day autopsy practice and various traits are looked after.

The most commonly looked after traits are: general appearance, architecture, glabella, frontonasal junction, **orbits**, supraorbital ridge, zygomatic arch, nasal aperture, external auditory meatus, occipital area, mastoid process, digastric groove, palate, **foramen magnum**, teeth etc. [3]

The male orbits are square, relatively smaller with rounded margins while in female it is rounded relatively larger with sharp margins.

The foramen magnum is relatively large and longer in males and small and rounded in females. [4] Measurements of different cranial features or craniometrics are very important for Forensic experts. Craniometric database formation for different population is not only of anthropometric importance but also for Forensic interest. Craniometric measurements such as inter and bi-orbital diameter from skull helps in superimposition and also facial reconstruction.

It is beyond any doubt that superimposition and facial reconstruction are very important for establishment of identity in this modern era of Forensics.

The foramen magnum is a wide communication between posterior cranial fossa and the vertebral canal. The foramen magnum is surrounded by different parts of the occipital bone, squamous part lies behind and above, basilar part in front and a condylar part on either side. On each side its antero-lateral margin is encroached by occipital condyles, hence the foramen magnum is narrow anteriorly.

The anterior edge of the foramen magnum is slightly thickened and lies between the anterior ends of the condyles. The posterior half of the foramen magnum is thin and semicircular. Upper ends of anterior and posterior atlanto-occipital membranes are attached to the anterior and posterior margins of the foramen magnum respectively, and their lower ends are attached to the superior surface of anterior and posterior arches of the atlas respectively.

Foramen magnum is about 3 cm wide by 3.5 cm antero-posteriorly and is located midway between and on a level with mastoid processes. [5] The orbits are bilateral structures in the upper half of the face below the anterior cranial fossa and anterior to the middle cranial fossa that contain the eyeball, the optic nerve, the extra-ocular muscles etc. Seven bones contribute to the framework of each orbit.

They are the maxilla, zygomatic, frontal, ethmoid, lacrimal, sphenoid, and palatine bones. Together they give the bony orbit the shape of a pyramid, with its wide base opening anteriorly onto the face, and its apex extending in a posteromedial direction.

Completing the pyramid configuration are medial, lateral, superior, and inferior walls. The average dimensions of the orbit are as follows: Height of orbital margin - 40 mm, Width of orbital margin - 35 mm, Depth of orbit - 40-50 mm, Interorbital distance - 25 mm, Volume of orbit - 30 cm^3. [6]

The present study was conducted to find out the baseline measurements of foramen magnum and both orbits in Indian Bengali subjects. The morphometric differences between two sexes were observed and orbital symmetry for each individual was assessed.

Materials and Methods:

In the present study dried specimens of human skull which were at the Museum of The Department of Forensic Medicine, Burdwan Medical College, Burdwan were used. The sex of the specimen skulls were already known and retrieved from the catalogue.

Then the measurements were taken using a digital Vernier calipers [AEROSPACE Digital Caliper] to the nearest of 0.01mm. All the measurements were taken by a single individual on two different occasions and the average of the two readings were taken.

Measurements of the Foramen Magnum: [7]

a. **Longitudinal diameter (LD)** of the foramen magnum: It is distance between basion and opisthion.
b. **Transverse diameter (TD)** of the foramen magnum: It is maximum distance between two lateral margins.

Area of the foramen magnum was calculated by using two different formulae: [8, 9]

- **Texeria Formula**: Area= $\pi * \{(LD+TD)/4\}^2$
- **Radinsky Formula**: Area= $0.25 * \pi * LD * TD$

Measurements of the Orbit: [10]

The ectochion, the intersection of the most anterior surface of the lateral border of the orbit and a line bisecting the orbit along its long axis, was used as a landmark for the most lateral point of the orbit.

Orbital Breadth: The sloping distance between the dacryon, (the point on the medial border of the orbit at which the frontal, lacrimal, and maxilla bones intersect), and the ectochion was taken to be the orbital breadth.

Orbital Height: The direct distance between the superior and inferior orbital margins perpendicular to the orbital breadth.

Orbital Index: This was calculated by dividing the orbital height with the orbital breadth and multiplying the result by 100.

Interorbital distance: The direct distance between the most medial points of the right and left orbit was taken as the interorbital distance.

The data was analyzed statistically using SPSS version 19.0 computer software (SPSS, Inc., Chicago, IL, USA) for descriptive and inferential statistics.

Result Analysis:

1. For Foramen Magnum:

The mean length of foramen magnum in male skulls (n=31) was 34.02 mm (Table 1) and the mean length of foramen magnum in female skulls (n=22) was 33.03 mm. (Table 2)

The mean breadth of foramen magnum in male skulls was 28.1 mm (Table 1) and that of female skulls was 27.46 mm. (Table 2) The area of foramen magnum as calculated by **Radinsky Formula** was 752.26 mm^2 (Table 1) for male skulls and 715.31 mm^2 (Table 2) for female skulls. Similarly the area calculated from **Texeria Formula** was 760.25 mm^2 (Table 1) for male and 722.11 mm^2 (Table 2) for female.

The comparison of foramen magnum length, breadth and areas between male and female skulls were depicted in graph. (Graph 1)

2. For Orbits:

The distribution of orbital length, breadth, index and inter-orbital distances in male and female skulls are discussed. (Table 4, 5)

The comparison of these parameters between male and female skulls is shown graphically too. (Graph 2) The comparison between Right Orbital Indices, Left Orbital Indices and Inter orbital distances were done. (Table 6, 7 and 8) This comparison is also shown graphically. (Graph 3)

Discussion:

There has been no previous documented evaluation of foramen magnum dimensions and orbital measurements in Bengali population. In this study the baseline measurements of foramen magnum and orbits were taken and were compared with previous studies done in India and abroad.

Sex determination from human cranium is usually done on difference in sizes and robustness. However these differences depend on various other factors like genetic, environmental and socio-economic factors. Again these differences also vary according to the place. So there is widespread necessity for these types of studies and formation of a worldwide craniometric database.

The foramen magnum reaches its adult size rather early in childhood and is therefore unlikely to respond to significant secondary sexual changes. [11] There is no significant muscular attachment around the foramen magnum area and its prime function is the passage of medulla oblongata.

The nervous system attains maturity in the childhood and so there is very little effect of its growth in the foramen magnum. A large foramen magnum usually results from chronic increased intracranial pressure or from direct effects of an expanding process within foramen magnum like syringomyelia, Arnold Chiari malformations. Asymmetry of foramen magnum occurs with cranio-vertebral anomalies or premature synostoses of one or more of occipital synchondroses. [12] Key-hole shaped foramen magnum has been described in hydrolithalus syndrome. [13]

The measurements obtained in this study was compared with previous other studies (Table A) in a tabular form. [14] The results of the present study was similar to that of Sayee done in Karnataka where length and breadth of foramen magnum for male skulls were 33.4 mm and 28.5 mm respectively and that for female were 33.5 mm and 28.0 mm respectively. [15]

The results of these studies were consistent with other studies to find out that dimensions of foramen magnum are larger in male skulls than female.

Again the differences were not significant enough to discriminate between the male and female skulls, which are consistent with the previous studies. However this study is dissimilar with that of Tanuj Kanchan et al who found out statistically significant sex differences in the area of foramen magnum as derived by formula given by Texeira and Radinsky. [16]

The orbital index for the male skulls in this study was 86.89 while that of female skulls was 90.31.The interorbital distance for male and female skulls was 1.85 mm and 1.97 mm respectively. The mean orbital index for right side (86.59) was lower than that of left side (90.05) which was not consistent with previous studies. [17] Statistically significant differences were observed between male and female skulls in their interorbital distances. Again the orbital index of the left side had significant difference between male and female skulls.

Taking the orbital index as the standard, three classes of orbit have been classically described:

a. **Megaseme (Large)**: The orbital index is 89 or over. This type is seen in Orientals except Eskimos. [18]
b. **Mesoseme (Intermediate)**: The orbital index range between 89 and 83. This type is seen in the Caucassians. [19]
c. **Microseme (Small)**: Orbital index 83 or less. This type is characteristics of the Africans. [20]

This places the male skulls (86.59) of this modern Bengali population into the MESOSEME group and the female skulls (90.05) into the Megaseme group. This result is quite contrary to previous study conducted on north Indian population, [17] which placed the skulls in **Microseme** group.

The results of this study were quite similar to those conducted on male Nigerian skulls which also placed the skulls in Megaseme group quite contrary to previous results. [21]

The results of this study is also similar to study conducted by Igbigbi and Ebite on the Malawian population. [22]

The significant differences of inter orbital distances between male and female skulls can be a new dimension of sexual dimorphism of human crania. This can also provide important guidelines for facial reconstruction and superimposition techniques. No previous studies could be found on inter orbital distances to corroborate with the present study.

Many factors have been implicated in the transformation of the facial skeleton into the adult form. Although the basic structure is determined in accordance with genetically regulated blueprint while in utero, that is modified pre- and postnatal through functional matrices responding to environmental and epigenetic influence such as climate, activity patterns and masticatory functions. [23]

This study can create an adjustment which will help in correction of orbital fractures, orbito-ethmoid disjunctions and bony pathologies of the face. This can also help in a near perfect design of cranio-facial prosthesis.

The slight difference observed between the right and left side, though not significant, could be attributed to the differential growth of the two sides of the brain.

This difference should be kept in considerations while surgical correction of the bony orbits. However further investigations are necessary using a larger sample.

In the present study it was observed the left orbital index differed between two sexes. This difference was significant. Regarding the right side there was no significant differences between the two sexes.

This interesting observation should be kept in mind while conducting future studies. Asymmetry exists in each individual cranium. In an individual two orbits are of different dimensions. This shows we tend to over generalize symmetry in the facial region. These aspects should be explored further in future studies with large sample using different craniometric variables.

Conclusion:

1. Foramen Magnum dimensions including its area are larger in male skulls compared to the female skulls.
2. Foramen Magnum dimensions are not reliable indicators for determination of sex in adult Bengali population.
3. Orbital indices of the skulls of the Bengali population fall in the Mesoseme-Megaseme category.
4. Orbital indices of the female skulls are greater than that of the male skulls.
5. Orbital indices of the left side were greater than of the right side for both the male and female skulls.
6. The left orbital index was significantly different for both male and female skulls.
7. The inter-orbital distance was significantly different in male and female skulls.

References:

1. https://www.google.co.in/?gfe_rd=cr&ei=t5SuVIrsNqjM8gfrqIGADg&gws_rd=ssl#q=symmetry+definition. Accessed on 16.11.2014
2. **Iscan MY, Steyn M.** The Human Skeleton in Forensic Medicine.Springfield, Illinois. Charles C Thomas • Publisher, Ltd; 2013. Chapter 4, Sex; p.143.
3. **Reddy K S N.** The Essentials of Forensic Medicine and Toxicology. 32nd ed. Hyderabad: K Suguna Devi; 2013. Chapter 4, Identification; p.60
4. **Mukherjee J B.** Forensic Medicine and Toxicology. In: Karmakar R N, editor. Personal Identification. 4th ed. Kolkata. Academic Publishers; 2011. p.86-175.
5. **Standarding S. Gray's anatomy.** The anatomical basis of clinical practice. 39th ed. London: Elsevier Churchill Livingstone; 2005 .p.460.
6. http://emedicine.medscape.com/article/835021-overview. accessed on 16.11.2014
7. **Routal RR, Pal GP, Bhagwat SS, Tamankar BP.** Material studies with sexual dimorphism in foramen magnum of human crania. J. Anat Soc. India. 1984; 33(2):85-89.
8. **Radinsky L.** Relative brain size e a new measure. Science 1967; 155:836-8
9. **Teixeria WR.** Sex identification utilizing the size of Foramen Magnum. Am J Forensic Med pathol 1983; 3:203-206.
10. **Jeremiah M, Pamela M, Fawzia B.** Sex differences in the cranial and orbital indices for a black Kenyan population. Int. J. Med. Med. Sci. 2013; 5(2):81-84.
11. **Scheuer L, Black S.** The Juvenile Skeleton. London.Elsevier Academic Press; 2004. Chapter 4, The Head and Neck; p.76.
12. **Shapur PM, Magi M, Nanjundappa B, Havaldar PP, Gogi P, Saheb SH.** Morphometric Analysis of Foramen Magnum. Int. J. Anat. Res. 2014; 2(1):249-55.
13. **Stevenson RE, Hall JG.** Human malformations and related anomalies. 2nd ed. Cleveland; 2006.p.260-61
14. **Ukoha U, Egwu OA, Okafor IJ, Anyabolu AE, Ndukwe GU, Okpala I.** Sexual Dimorphism in the Foramen Magnum of Nigerian Adult. Int. J Biol. Med Res. 2011; 2(4):878–81.
15. **Sayee R, Jankiram S, Thomas IM.** Foramen magnum measurements of crania from Karnataka. J. Anat Soc. India. 1987; 36(2):87-89.
16. **Kanchan T, Gupta A, Krishan K.** Craniometric Analysis of Foramen Magnum for Estimation of Sex. International Journal of Medical, Health, Pharmaceutical and Biomedical Engineering. 2013; 7(7):166-68.
17. **Kaur J, Yadav S, Singh Z.** Orbital dimensions- A direct measurement study using dry skulls. J. Acad. Indus. Res.2012; 1(6):293-95.
18. **Cassidy PJ.** "Megaseme" webster dictionary. answers.com (homepage on the internet) 1913a; available from http://www.answers.com/topic/megaseme. accessed on 20.11.2014
19. Mcgraw hill dictionary of scientific and technical terms "mesoconch" Mcgraw hill company inc, answers .com(homepage on the internet)

2003; available from http://www.answers.com/topic/mesoconch. accessed on 20.11.2014
20. Cassidy PJ. "microseme" webster dictionary. answers.com (homepage on the internet) 1913b; available http://www.answers.com/topic/microseme. accessed on 20.11.2014
21. **Ukoha U, Egwu OA, Okafor IJ, Ogugua PC, Onwudinjo O, Udemezue OO.** Orbital dimensions of adult male Nigerians: a direct measurement study using dry skulls. Int. J Biol. Med Res. 2011; 2(3): 688-90.
22. **Igbigbi PS, Ebite LE.** Orbital Index of Adult Malawians. Anil Aggrawal's Internet Journal of Forensic Medicine and Toxicology. 2010; 11(1).
23. **Vidarsdotir US, O'Higgins P. Stinger C.** A geometric morphometric study of regional differences in the ontogeny of the modern human facial skeleton. Journal of Anatomy. 2002; 201(3):211.

Table 1: Foramen Magnum Length, Breadth & Area in Male Skulls (N=31)

Parameters	Max	Min.	Mean	SD	Range
FML	38.40	31.50	34.02	1.79	37.60-30.44
FMB	31.00	23.70	28.10	2.16	32.42-23.78
FMA-R	927.14	600.29	752.26	86.81	925.88-578.64
FMA-T	937.91	616.00	760.25	85.45	931.15-589.35

Table 3: Comparison of Means of Foramen Magnum Dimensions in Male and Female Skulls

Parameters	Sex	N	Mean	SD	T-value	p-value
FML	M	31	34.02	1.79	1.71	0.09
	F	22	33.03	2.42		
FMB	M	31	28.10	2.16	0.99	0.32
	F	22	27.46	2.51		
FMA-R	M	31	752.26	86.81	1.38	0.17
	F	22	715.31	106.46		
FMA-T	M	31	760.25	85.45	1.45	0.15
	F	22	722.11	105.13		

[FML=foramen magnum length, FMB=foramen magnum breadth, FMA-R=foramen magnum area calculated from RADINSKY formula, FMA-T= foramen magnum area calculated from TEXERIA formula]

Table 4: Orbital Length, Breadth, Index & Inter-Orbital Distance in Male Skulls (N=31)

Parameters	Max	Min	Mean	SD	Range
ROL	3.76	2.79	3.18	0.26	3.7-2.66
LOL	3.7	2.92	3.25	0.24	3.73-2.77
ROB	4.05	3.21	3.73	0.27	4.27-3.19
LOB	4.22	3.2	3.7	0.30	4.3-3.1
ROI	97.89	74.07	85.54	7.27	100.08-71
LOI	95.20	72.03	88.25	6.22	100.69-75.81
IOD	2.32	1.52	1.83	0.21	2.25-1.41

[ROL-Right side orbital length, ROB- Right side orbital breadth, LOL- Left side orbital length, LOB- Left side orbital breadth, ROI-ORBITAL INDEX of right side, LOI-ORBITAL INDEX of left side, IOD-Inter-orbital distance]

Table 6: Comparison of Right Orbital Index, Left Orbital Index & Inter-Orbital Distance in Male and Female Skulls

Parameters	Sex	N	Mean	SD	P-Value
ROI	Male	31	85.54	7.27	0.22
	Female	22	88.05	7.37	
LOI	Male	31	88.25	6.23	***0.01***
	Female	22	92.57	5.91	
IOD	Male	31	1.85	0.23	***0.02***
	Female	22	1.97	0.24	

Table 5: Orbital Length, Breadth, Index & Inter-Orbital Distance in Female Skulls (N=22)

Parameters	Max	Min	Mean	SD	Range
ROL	3.51	2.77	3.21	0.23	3.67-2.75
LOL	3.85	2.78	3.34	0.32	3.98-2.7
ROB	4.17	3.09	3.66	0.33	4.32-3.0
LOB	4.13	3.15	3.61	0.34	4.29-2.93
ROI	99.71	78.87	88.05	7.37	102.97-73.31
LOI	98.74	79.74	92.57	5.92	104.41-80.73
IOD	2.35	1.68	1.97	0.23	2.43-1.51

[ROL-Right side orbital length, ROB- Right side orbital breadth, LOL- Left side orbital length, LOB- Left side orbital breadth, ROI-ORBITAL INDEX of right side, LOI-ORBITAL INDEX of left side, IOD-Inter-orbital distance]

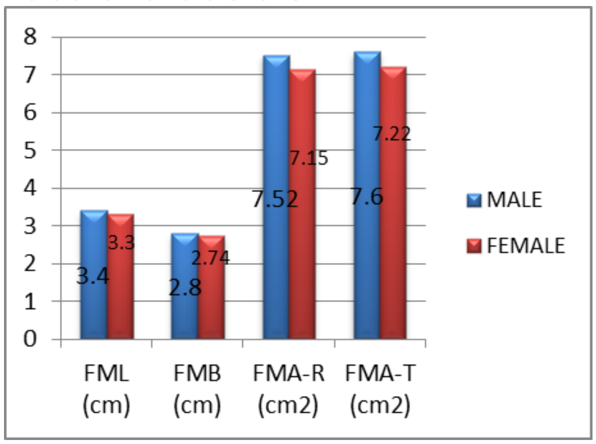
Table 7: Comparison of Orbital Indices of Right & Left Sides (For Male and Female)

Orbital Index	N	Mean	SD	P-Value
Right Side	53	86.59	7.26	0.08
Left Side	53	90.05	6.35	

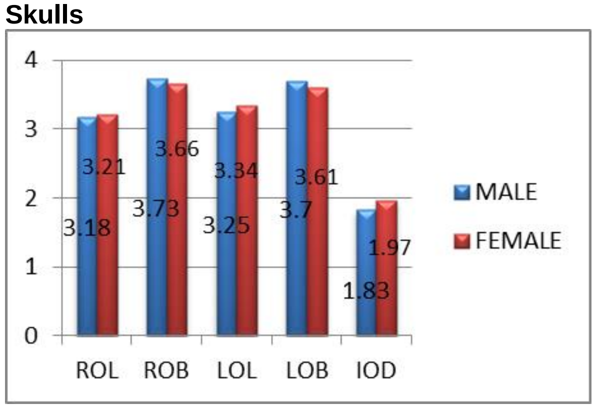
Table 8: Comparison of Orbital Indices of Male and Female Skulls (Considering Right &Left Side Together)

Orbital Index	N	Mean	SD	P-Value
Male	31	86.89	6.75	0.07
Female	22	90.31	6.64	

Graph 1: Comparison of Means of Foramen Magnum Length, Breadth &Area between Male and Female Skulls



Graph 2: Comparison of Means of ROL, ROB, LOL, LOB & IOD between Male and Female Skulls



Graph 3: Comparison of Means of ROI, LOI and Mean OI between Male and Female Skulls

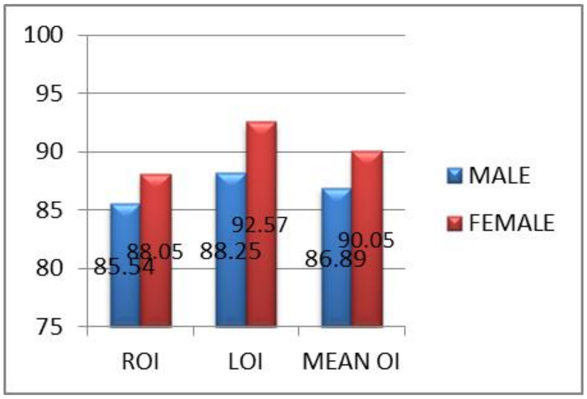


Table 2
Foramen Magnum Length, Breadth & Area in Female Skulls (N=22)

Parameters	Maximum	Minimum	Mean	SD	Range
FML	37.00	29.70	33.03	2.42	37.87-28.19
FMB	31.40	22.50	27.46	2.51	32.48-22.44
FMA-R	889.43	594.00	715.31	106.46	928.23-502.39
FMA-T	892.33	605.05	722.11	105.13	932.37-511.85

Table A
Comparison of Various Studies

STUDY	FML(M) [Mean±SD]	FML(F) [Mean±SD]	FMB(M) [Mean±SD]	FMB(F) [Mean±SD]	FMA(M) [Mean]	FMA(F) [Mean]
Present 2014	34.02±1.79	33.03±2.42	28.1±2.16	27.46±2.51	760.25	722.11
Routeal et al 1984	35.5±2.8	32.0±2.8	29.6±1.9	27.1±1.6	819.0	771.0
Murshed et al 2003	37.2±3.2	34.6±3.16	31.6±2.99	29.3±2.99	931.7	795
Catalina 1987	36.2±2.6	34.3±2.04	31.1±2.6	29.6±1.53	888.4	801.0
Gapert et al 2008	35.91±2.41	34.71±1.91	30.51±2.6	29.6±1.53	783.82	730.28
Suazo et al 2009	36.5±2.6	35.6±2.5	30.6±2.5	29.5±1.9		
Ukoha U et al 2011	36.26±2.3	34.39±3.88	30.09±2.5	28.16±1.9	857.30	760.94