Int. J. Morphol.,
34(1):244-251, 2016.

Sex Determination Using Morphometric and Morphological Dimensions of the Clavicle within the KwaZulu-Natal Population

Determinación de Sexo dentro de la Población KwaZulu-Natal Mediante el Uso de Dimensiones Morfométricas y Morfológicas de la Clavícula

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ISHWARKUMAR, S.; PILLAY, P.; HAFFAJEE, M. R. & RENNIE, C. Sex determination using morphometric and morphological dimensions of the clavicle within the KwaZulu-Natal population. *Int. J. Morphol., 34(1)*:244-251, 2016.

SUMMARY: Sex determination plays an essential role in forensic anthropology in the identification of an individual from skeletal remains. The aim of the study was to determine sex of an individual using the clavicle in a KwaZulu-Natal population. Various morphometric and morphological parameters were measured using 100 clavicles of known sex (66 male and 34 female) and age (range 25–95 years). The mean maximum length, mid-shaft circumference and maximum breadth of the sternal and acromial ends of the male clavicles were greater in females. However, the mean medial curve of the clavicle was greater in females than in males on both sides, and on the right side the female clavicles also had a greater mean lateral curve than the males. The maximum length and mid-shaft circumference alone could be used to predict sex with an accuracy of 89 %. Therefore, the provision of morphometric data pertaining to the clavicle may assist forensic investigators, anthropologists and anatomists to sex the clavicle.

KEY WORDS: Clavicle; Clavicular length; Mid-shaft circumference; Sex determination.

INTRODUCTION

Sex determination plays an essential role in forensic anthropology, in the identification of an individual from skeletal remains (Singh & Chavali, 2011). It may reduce the number of possible matches of unknown individuals by fifty percent i.e. it is either male or female, immediately (DiGangi & Moore, 2013). Skeletal remains such as the skull, pelvis, upper and long lower limb bones, sternum, patella and clavicle have been used for the identification of unknown individuals (Akhlaghi *et al*., 2012). The clavicle is the first bone in the body to ossify and is the only long bone that lies horizontally in the body (Standring *et al*., 2008). It is a long bone that is relatively resistant to environmental degradation and has been proposed as a reliable bone to determine sex (Akhlaghi *et al*.). Standring *et al*. found variations in the anatomical features of the male and female clavicle. The female clavicle was found to be shorter, less curved, thinner and smoother than the male. Male bones are heavier and the muscular markings are more prominent than in females (Chavda *et al*., 2013). Prado *et al*. (2009) stated that the presence of the rhomboid fossa could be used for the determination of sex, in that it can specify with a relative degree of accuracy whether the remains belong to a male or female. In their study, they recorded that 97.1 % of female sample did not have a rhomboid fossa present. There have been different levels of accuracy for sex determination using the clavicle, and the anthropometric measurements of different bones are unique in each race and geographical area (Akhlaghi*et al*.). This study aims to determine the sex of an individual from the clavicle in a KwaZulu-Natal population.

MATERIAL AND METHOD

A total of 100 dry adult clavicle specimens (66 Male and 34 Female) of known age and sex were obtained from the Discipline of Clinical Anatomy, University of KwaZulu-Natal and the Durban University of Technology, Durban, South Africa in accordance with the National Health Act No. 61 of 2003, to formulate a statistical equation for determination of sex from the various morphometric parameters of the clavicle. Ethical clearance was obtained (LMMSEC 002/12) for the study. The clavicles sampled ranged between 25–95 years of age (Mean Age= 58.32). Any clavicles that showed degradation or deformities were

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excluded from this study.

Morphology. The following anatomical features were determined:

Shape. The shape of the bone was measured according to Kaur *et al*. (2002). The curves of the clavicle were measured by tracing the contour of the clavicle on graph paper. Next, the midpoint of the acromial and sternal end was found on the contour of the clavicle and these points were marked 'a' and 'b'. These two points were then joined using a straight line. The middle axis of the clavicle was drawn as a straight line between the centre points of the anterior and posterior ends for the length of the clavicle. The midpoint of the straight line was calculated and marked on the diagram, and the midpoint of each half was then calculated and was marked as 'c' and'd'. The points 'a c d' were joined to show the curvature of the medial two-thirds and the points 'c d b' were joined to indicate the lateral third of the curvature. These angles were then measured with the aid of a protractor (Kaur *et al.*) (Fig. 1).

Grooves and Impressions. The presence or absence of the rhomboid fossa was recorded.

Morphometry. The following measurements were made three times using a digital Vernier caliper and the mean value was calculated:

Maximum linear length of the clavicle. The maximum linear length of the clavicle was measured from the sternal end to the acromial end, while the clavicle was positioned flat on a hard surface (Fig. 2).

Mid-Shaft circumference. The midpoint of the shaft was established and the mid-shaft circumference was calculated using a length of flexible soft wire and a digital vernier caliper (Fig. 2).

Breadth of the sternal (medial) end. The maximum superior to inferior and anterior to posterior lengths of the sternal end were measured.

Breadth of the acromial (lateral) end. The maximum superior to inferior and anterior to posterior lengths of the articular surface of the acromial end was measured.

Dry weight. The dry weight of the clavicle was measured in grams (to the first decimal point) with the aid of a digital scale.

Statistical Analysis. The collected data was captured and analysed using the Statistical Package for Social Sciences (SPSS version 21.0) and Statistical Analysis Software (SAS) with the assistance of a biostatistician. The Pearson Chi-Square test and logistic regression model was used to analyse the relationship between sex and the morphometric parameters of clavicle. A 95 % confidence level was adhered to for all statistical tests. A p-value of less than 0.05 was considered to be statistically significant.

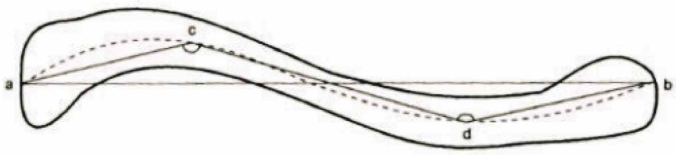

Fig. 1. The contour measurement of the right clavicle from above (Adapted by Kaur *et al*., 2002).
Key: a= Midpoint of sternal end; b= Midpoint of acromial end; c= Deepest point of Medial curvature; d= Deepest point of Lateral Curvature; "a c d" = Medial Angle; "c d b" = Lateral Angle.

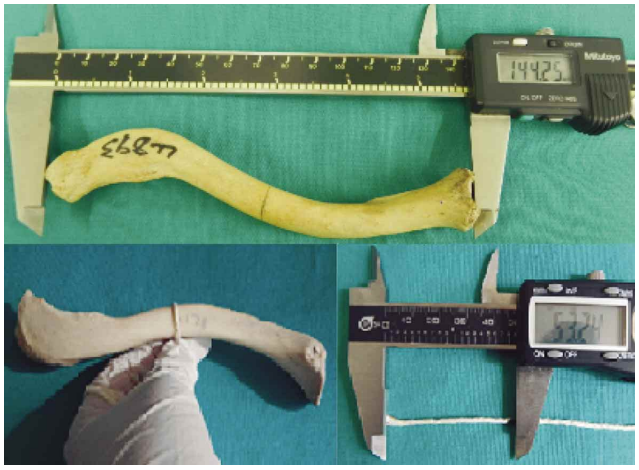

Fig. 2. Morphometry - length and mid-shaft circumference of the clavicle.

RESULTS

Morphology. The presence and absence of the rhomboid fossa in the clavicle. The rhomboid fossa was present in 97 % male and 85 % female clavicles (Table I and Fig. 3).

Medial angle of the clavicle. Despite the absence of statistically significant correlations between sex and the medial angle of the clavicle (p-value= 0.5554), the mean medial angle in male clavicles (R= 151.20±6.70º and L= 151.16±6.83º) was smaller than the female clavicles (R= 152.11±5.90º and L= 153.73±5.91º) on both sides of the body (Table I).

Lateral angle of the clavicle. The mean lateral angle for the right male clavicle was 148.03±9.05º, while the female was 150.32±8.58º, whereas the left male and female clavicle was recorded to be 152.39±9.04º and 147.60±7.77º, respectively (Table I). Although difference between the male and female clavicle was recorded, no statistically significant correlation between the lateral angle of the clavicle and sex was recorded (p-value= 0.6535) (Table I).

Table I. The various morphometric and morphological parameters of the male and female clavicle (mm).

Parameters	Side	Sex		*p-value*
		Male	Female	
Maximum length (mm)	Right	153.52±8.79	138.02±7.36	0.0004
	Left	151.82±10.96	141.04±5.72	
	Right and left	152.49±9.85	139.36±6.76	
Mid-shaft circumference (mm)	Right	38.60±3.55	33.58±2.52	0.0040
	Left	38.68±3.82	34.93±3.28	
	Right and left	38.64±3.95	34.18±2.92	
Maximum breadth of sternal end (Sup – Inf) (mm)	Right	23.33±4.12	20.73±2.94	0.3549
	Left	22.85±3.18	20.03±3.60	
	Right and left	23.10±3.69	20.42±3.21	
Maximum breadth of sternal end (Ant – Post) (mm)	Right	21.96±3.71	21.13±2.59	0.6017
	Left	21.86±3.73	20.20±3.51	
	Right and left	21.91±3.69	20.72±3.01	
Maximum breadth of acromial end (Sup – Inf) (mm)	Right	12.83±3.32	10.74±2.06	0.6176
	Left	12.03±2.94	10.50±2.55	
	Right and left	12.46±3.15	10.63±2.26	
Maximum breadth of acromial end (Ant – Post) (mm)	Right	23.25±5.28	21.07±4.31	0.1625
	Left	23.76±4.04	18.90±3.77	
	Right and left	23.49±4.71	20.11±4.16	
Dry mass (g)	Right	21.91±4.68	15.74±3.84	0.1130
	Left	21.48±5.58	14.93±5.06	
	Right and left	21.71±5.10	15.38±4.37	
Incidence of rhomboid fossa (%)	Presence	97	85	0.0410
	Absence	3	15	
Medial angle (inº)	Right	151.20±6.70	152.11±5.90	0.5554
	Left	151.16±6.83	153.73±5.91	
	Right and left	151.18±6.71	152.82±5.87	
Lateral angle (inº)	Right	148.03±9.05	150.32±8.58	0.6535
	Left	152.39±9.04	147.60±7.77	
	Right and left	150.08±9.24	149.12±8.23	

Morphometry

Maximum length of the clavicle. The maximum length of the male clavicles ranged from 122.38 mm to 172.21 mm with a mean maximum length of 152.49±9.85 mm, while the females clavicles ranged from 124.23 mm to 156.86 mm with mean maximum length of 139.36±6.76 mm (Table I). Sex determination from the maximum length of the clavicle was seen to be statistically significant with a p–value of 0.0004.

Fig. 3. The presence and absence of the rhomboid fossa. A= Absence of the rhomboid fossa; B= Presence of the rhomboid fossa.

Mid-shaft circumference of the clavicle. The mid-shaft circumference of the right and left male clavicle was longer than their female counterparts, with a mean mid-shaft circumference of 38.64 mm and 34.28 mm in males and females, respectively (Table I). The mid-shaft circumference was statistically significant in sex determination (p-value= 0.0040).

Maximum breadth of the sternal end (superior to inferior) of the clavicle. The mean maximum breadth of the sternal end of the right male clavicle was 23.33±4.12 mm, while in females it was recorded to be 20.73±2.94 mm. However, the mean maximum breadth of the left sternal end was found to be 22.85±3.18 mm and 20.03±3.60 mm in males and females, respectively (Table I).

Maximum breadth of the sternal end (anterior to posterior) of the clavicle. The mean maximum breadth of the right sternal end in male and female clavicles was recorded to be 21.96±3.71 mm and 21.13±2.5 mm, respectively. Whereas, the left clavicle was 21.86±3.73 mm and 20.20±3.51 mm in males and females, respectively (Table I).

Maximum breadth of the acromial end (superior to inferior) of the clavicle. In male clavicles the mean maximum breadth of the acromial end on the right side was recorded to be 12.83±3.32 mm and the female clavicle was 10.74±2.06 mm and the left male clavicle was 12.03±2.94 mm and the left female was 10.50±2.55 mm (Table I).

Maximum breadth of the acromial end (anterior to posterior) of the clavicle. The mean maximum breadth of the acromial end in both, the right and left male clavicle was longer than the female clavicle with a mean difference of 2.18 mm and 4.86 mm, respectively (Table I).

Dry mass of the clavicle. The male clavicle was measured to be 21.91±4.68 g and 21.48±5.58 g on the right and left, respectively and the female clavicle was 15.74±3.84 g on the right and 14.93±5.06 g on the left (Table I).

Logistic regression model for ordinal responses. In this study, logistic regression models were used to predict the sex of the specimens from the various morphometric parameters. The maximum length and mid-shaft circumference was highly significant in determining the sex of the clavicle with p–values of 0.0004 and 0.0040, respectively. The logistic regression model showed an 89 % accuracy in the prediction of the sex of the clavicle from the maximum length and mid-shaft circumference.

The formula used for the prediction of the sex from these parameters of the clavicle is:

$$\pi 2\,(x) = e^{[ß0+ß1x1+ß2x2]} / 1 + e\,[ß0+ß1x1+ß2x2]$$

$$\pi 2\,(x) = e\,[30.9797 – 0.1451x1 – 0.2959x2] / 1 + e\,[30.9797 – 0.1451x1 – 0.2959x2]$$

$x1$= Maximum length of the clavicle
$x2$= Mid-shaft circumference of the clavicle

ß0, ß1, ß2= Constant variables (Estimated values of the intercept; maximum length; mid – shaft circumference (MSC), respectively (Table II).

Table II. Standard estimates of the logistic regression model for sex determination in this study.

	Analysis of Maximum Likehood Estimates					
Parameter	**Sex**	**DF**	**Estimate**	**Estándar Error**	**Wald Chi-Square**	**Pr > ChiSq**
Intercept	2	1	30.8797	6.4017	23.2676	<0.0001
Maxil Length	2	1	-0.1451	0.0410	12.5154	0.0004
MSC	2	1	-0.2859	0.0993	8.2803	0.0040

DISCUSSION

In this study, an effort has been made to determine the sex of an adult clavicle using various morphometric and morphological parameters. In addition, there have been different levels of accuracy for sex determination using the clavicle and the anthropometric dimensions of different bones which are unique in each race and geographical area (Akhlaghi *et al.*).

Morphology

Absence and presence of the rhomboid fossa. When compared to previous studies (Jit & Kaur, 1986; Roger *et al*., 2000; Prado *et al*.), the high frequency of the presence of the rhomboid fossa in this study was remarkably unique in that it was present in majority of the clavicles sampled (M= 97 % and F= 85 %) (Fig. 4). Therefore, this study suggests that population-specific differences in the morphology of the clavicle exist, and that it is not a useful method to determine the sex of a clavicle alone.

Medial angle. This study found that the female clavicle had a greater medial angle on both the right and left sides than the male clavicle, thus confirming the findings of previous studies (Kaur *et al*.; Parson, 1916; Olivier, 1956). However, Terry (1932) recorded that right male clavicle had a greater medial angle than the right female clavicle. However, he found that medial angle of the left female clavicle was greater than left male clavicle (Table III). Therefore, the medial angle of the clavicle may be used to predict the sex of an individual as females generally have a greater medial angle than males, however this may not be the most reliable method (p-value= 0.5554) and these differences may be population-specific.

Lateral angle. The mean lateral angle of the right female clavicle is greater than the right male clavicle, however the left male clavicle had a greater lateral angle than their female counterparts. Contrary to this study, previous studies reported that lateral angle of the female clavicle is greater than the male clavicle on both sides of the body (Parson; Terry; Kaur *et al*.) (Table III). This result, may suggest population-specific difference among the different populations groups.

Morphometry

Length of the clavicle. Akhlaghi *et al*., stated that the sex of an individual can be determined by using clavicle dimensions with a relatively high degree of accuracy as the male clavicle is longer than the female clavicle, which is confirmed in this study, where the mean maximum length of the male clavicle was recorded to be significantly longer than the female clavicle (Table III). In addition, a statistically significant correlation between the

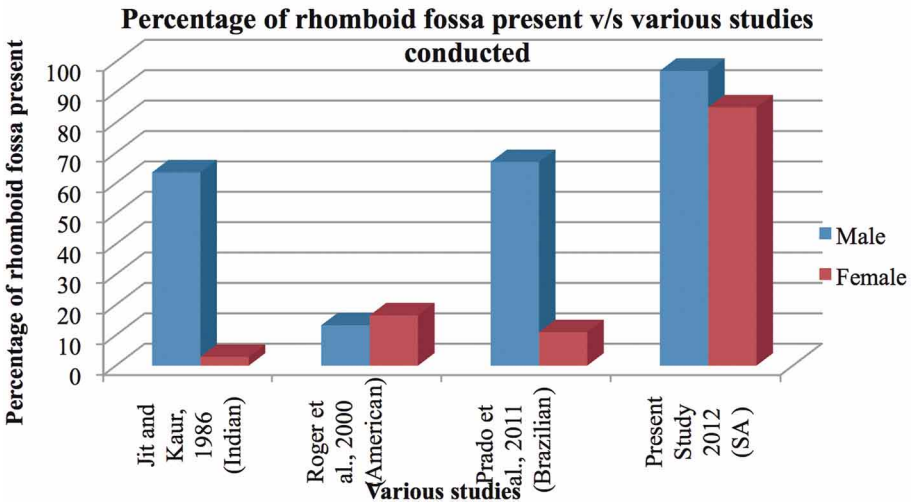

Fig. 4. A comparison of presence of a rhomboid fossa on a clavicle in male and female samples with the present study.

Table III. A comparison of various morphometric parameters of the male and female clavicle with the present study (mm).

	Sex	Side	Parson (1916)	Olivier (1956)	Jit & Singh (1966)	Singh & Gangrade (1968)	Jit & Sahni (1983)	Kaur *et al.* (2002)	Mohammed (2006)	Andermahr (2007)	Patel *et al.* (2009)	Rani *et al.* (2011)	Papaioannu (2011)	Present study (2012)
Nationality			English	French	Indian	Indian	Indian	Indian	Iraqi	German	Indian	Indian	Greek	South African
Sample size	M	B	50	110	236	97	280	748	63	90	107	70	81	66
	F		50	60	112		80	2552	37	106	109	30	66	34
Maximum Length (mm)	M	R	152.00	154.20	145.58	141.49	148.00	149.40	155.20	---	141.85	149.74	---	153.52
		L	152.00	155.00	147.59	144.18	149.80	151.14	155.67	---	142.30	146.18	---	151.82
	F	R	138.00	137.90	130.36	125.78	132.40	134.53	137.42	---	125.90	118.44	---	138.02
		L	139.00	138.70	129.80	122.77	134.00	136.21	139.21	---	125.88	115.60	---	141.04
Mid-Shaft Circumference (mm)	M	R	40.00	---	36.17	35.09	36.20	---	---	---	37.10	---	---	38.60
		L	38.00	---	35.70	34.64	35.90	---	---	---	36.44	---	---	38.68
	F	R	33.00	---	29.69	28.52	30.40	---	---	---	30.15	---	---	33.58
		L	32.00	---	29.51	28.00	30.00	---	---	---	30.16	---	---	34.93
Maxi breadth of sternal end (mm)	M	B	---	---	---	---	---	---	---	26.00	---	---	27.41	21.91
	F		---	---	---	---	---	---	---	24.00	---	---	24.94	20.72
Maxi breadth of acromial end (mm)	M	B	---	---	---	---	---	---	---	24.00	---	---	18.41	23.49
	F		---	---	---	---	---	---	---	21.00	---	---	16.03	20.11
Dry mass (g)	M	R	---	---	18.89	21.46	25.78	---	---	---	19.50	---	---	21.91
		L	---	---	18.68	21.32	25.34	---	---	---	18.70	---	---	21.48
	F	R	---	---	12.47	12.83	17.55	---	---	---	12.26	---	---	15.74
		L	---	---	12.03	12.84	17.21	---	---	---	11.73	---	---	14.93
Medial angle (°)	M	R	153.00	150.20	---	---	---	150.80	---	---	---	---	---	151.20
		L	153.00	151.40	---	---	---	150.90	---	---	---	---	---	151.20
	F	R	155.00	151.00	---	---	---	152.60	---	---	---	---	---	152.10
		L	155.00	-	---	---	---	152.40	---	---	---	---	---	153.70
Lateral angle (°)	M	R	148.00	141.80	---	---	---	143.30	---	---	---	---	---	148.00
		L	148.00	143.00	---	---	---	148.20	---	---	---	---	---	152.40
	F	R	150.00	145.00	---	---	---	144.70	---	---	---	---	---	150.30
		L	151.00	---	---	---	---	148.70	---	---	---	---	---	147.60

B= Both, F= Female, L= Left, M= Male, R= Right.

mean maximum length of the clavicle and sex was recorded in this study (p–value= 0.0004).

Mid-shaft circumference. Patel *et al*. (2009) reported that the mid-shaft circumference is the most reliable criterion that enabled sex determination in a large number of clavicles without a great deal of difficulty. In this study, the mean mid-shaft circumference in males was greater than in females, which correlated with previous studies (Parson; Jit & Singh 1966; Singh & Gangrade, 1968; Jit & Sahni, 1983; Patel *et al*.) (Table III). The mid-shaft circumference recorded in this study correlated with the findings of Parsons, as the male clavicle was recorded to be 40.00 mm and 38.00 mm on the right and left side, respectively, while the female clavicle was 33.00 mm on the right and 32.00 mm on the left side. A statistically significant correlation between the mid-shaft circumference and sex was recorded in this study (p–value= 0.0040).

The breadth of the sternal and acromial ends (anterior to posterior). The mean breadth of the sternal and acromial ends in males was greater than that of females, and these finding correlated with previous studies (Andermahm *et al*., 2007; Papaioannu *et al*., 2011) (Table III).

The breadth of the sternal and acromial ends (superior-inferior). The superior to inferior breadth of the sternal and acromial ends was a new parameter recorded in this study, but no statistically significant correlation between the aforementioned parameter and sex was recorded. The mean breadth of the male clavicle was greater than the female clavicle in both the sternal and acromial ends (Table III).

The dry weight. This study confirmed the findings of Jit & Singh; Singh & Gangrade; Jit & Sahni and Patel *et al*., in which the male clavicle was recorded to be heavier than the female clavicle (Table III).

Logistic Regression Model. The logistic regression model of the Statistical Analysis Software (SAS) was employed to determine which of the parameters measured in this study can be most effective in determining the sex of an individual from the clavicle. From all the parameters investigated, only the maximum length and mid-shaft circumference was recorded to be statistically significant (p-values= 0.0004 and 0.0040, respectively). A combination of the maximum length and mid-shaft circumference in a logistic regression model showed an 89 % accuracy in prediction of sex when the formula below was employed. This correlated with Standring *et al*., as they observed that the mid-shaft circumference of the clavicle is the most reliable single indicator of sex, and when this is combined with weight and length it produces better results.

CONCLUSION

This study found that the maximum length and the mid-shaft circumference are indispensible parameters in the determination of sex from the clavicle (p-value= 0.0004 and 0.0040, respectively). Furthermore, the logistic regression model employed in this study indicated an 89 % accuracy in the determination of sex from the maximum length and mid-shaft circumference of the adult human clavicle. Despite a difference between the male and female clavicles, the morphology parameters in this study displayed no statistical significant correlation with sex. Therefore, these findings may assist forensic investigators, anthropologists and anatomists in the identification of individuals.

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RESUMEN: La determinación del sexo juega un papel esencial en la antropología forense e identificación de un individuo con restos óseos. El objetivo fue determinar el sexo de un individuo mediante la clavícula en una población KwaZulu-Natal. Se midieron varios parámetros morfométricos y morfológicos utilizando 100 clavículas (66 hombres y 34 mujeres) con un rango etario entre 25–95 años. La longitud máxima media, circunferencia media del eje y la amplitud máxima de los extremos esternal y acromial de las clavículas de los hombres fueron mayores que en las mujeres. Sin embargo, la curva medial media de la clavícula fue mayor en mujeres que en hombres en ambos lados, y en el lado derecho las mujeres también tenían una curva lateral media de las clavículas mayor que en los hombres. La circunferencia máxima y la circunferencia media del eje por sí solas podrían ser utilizadas para predecir el sexo con una precisión de 89 %. Por tanto, la información de datos morfométricos relativos a la clavícula pueden ayudar a los investigadores forenses, antropólogos y anatomistas en la determinación del sexo.

PALABRAS CLAVE: Clavícula; Largo clavicular; Circunferencia del eje medio; Determinación de sexo.

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Received: 17-08-2015
Accepted: 04-11-2015