The Congruence Between Craniometric Of Adult Head CT Scan With Age And Gender

A Study In Radiodiagnostic Department Of Dr. Soetomo General Hospital Surabaya At August-December 2019

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Abstract

BACKGROUND: Enforcement of the identification of dead victims is very important for personal, social and legal interests. However, identification of large numbers of victims (mutilation, decomposition, burning, destroyed) is not easy. This study conducted a craniometric study of adult head CT scans in Indonesia, particularly at the dr. Soetomo General Hospital Surabaya, related to the identification of a person, so that it can be used in Disaster Victim Investigation (DVI). OBJECTIVE: Analyzing craniometric data from adult head CT scans at the Radiodiagnostic Installation of dr. Soetomo General Hospital Surabaya to identify age and gender. METHODS: Retrospective analytic observational. RESULT: A total of 204 adult head CT scans at the Radiodiagnostic Installation of dr. Soetomo General Hospital in August-December 2019 were evaluated retrospectively, consisting of 112 men (54.9%) and 92 women (45.1%). Of the 22 craniometrics evaluated, the test results showed no correlation between age with 15 male craniometrics and 17 female craniometrics ($\rho>0.05$), weak correlations in 6 male craniometrics and 5 female craniometrics ($\rho<0.05$; r= 0.21 to 0.40), and a very weak correlation in 1 male craniometrics ($\rho<0.05$; r= 0.00 to 0.20). There are 10 craniometrics that have differences with statistically strong evidence between male and female groups ($\rho<0.001$). Discriminant analysis showed a cutting score of -0,00025, with an accuracy rate of gender identification of 91.2%. CONCLUSION: Craniometrics from adult head CT scans can be used for gender identification with an accuracy rate of 91.2%, but cannot be used for age identification.

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Keywords: Craniometrics; CT Scan; Adult; Age; Gender; DVI

1. Introduction

Upholding the identification of dead victims is very important for personal, social and legal purposes (Ohoiwutun, 2017). However, identification of large numbers of victims (mutilation, decomposition, burning, destruction) is not easy (Thali et al., 2011). In May 2014, the International Society of Forensic Radiology and Imaging (ISFRI) issued a consensus on the use of PMCT in a DVI process (Brough et al., 2015). The use of

CT scans in identification has several advantages, that are non-invasive and relatively fast, enabling multilayer reconstruction, manipulating virtual images of bones, being able to assess craniometrics more objectively, able to evaluate internal and smaller structures which may be difficult to measure using conventional methods (Raghina et al., 2017).

Research using the craniometric method with CT scans relating to age and gender identification has been widely carried out. The Uthman et al study using 88 head CT scans in the Iraq population described a significant difference in the size of the foramen magnum in men and women with an accuracy rate of sex determination of 81% (Uthman et al., 2012). The Abdelaleem et al study used 250 head CT scans in the Egyptian population shows that piriform aperture can be used for sex determination (Abdelaleem et al., 2016). This study conducted a craniometric study of adult head CT scans in Indonesia, especially in dr. Soetomo General Hospital Surabaya, related to the identification of age and gender, so that it can be used in Disaster Victim Investigation.

2. Material and Methods

This retrospective observational analytic study evaluated 204 adult head CT scans, consisting of 112 men and 92 women, ranging in age from 19 to 97 years. The craniometric data from head CT scan were evaluated by four people (three radiologist and one radiology resident under the supervision of one radiologist). The average value of four craniometric evaluations will be the basis for calculations in the next statistical analysis.

The target population was all patients who underwent a head CT scan at the Radiodiagnostic Installation of dr. Soetomo General Hospital Surabaya. The affordable population was all patients who underwent a head CT scan at the Radiodiagnostic Installation of dr. Soetomo Hospital Surabaya in August-December 2019, and who met the inclusion criteria. The technique of taking research subjects used a consecutive method. The inclusion criteria were patients in the Radiodiagnostic Installation of Dr. Soetomo Hospital Surabaya, carrying out a head CT scan, and being an adult (age 18 years or more). Exclusion criteria were the presence of cranium deformity which could be caused by trauma, surgery, congenital abnormalities, or tumors in the head. Determination of adult age as an inclusion criterion based on WHO rules that define adult as people who are over 19 years old, unless local national law defines adult at a younger age. In addition, according to Law on Child Protection (No. 23/2002) in Indonesia, states that a child is someone who is not yet 18 (eighteen) years old, including children who are still in womb.

The research variable data collection was obtained from the head CT scan at the Radiodiagnostic Installation of RSUD Dr. Soetomo Surabaya, which consisted of three CT scan machines, that are Siemens 16 slices, Hitachi 16 slices and Philips 128 slices. Measurement of the research variables (22 craniometrics) was carried out using the Radiant Dicom Viewer application, in the form of axial, coronal, sagittal images and three-dimensional reconstructions (Figures 1 to 5). Statistical data processing used Microsoft Excel and IBM SPSS 22.0. Descriptive analysis was carried out to obtain group characteristics, based on age and gender. The next statistical analysis were Pearson correlation test between age with craniometric data, normality test (Kolmogorov-Smirnov), test for differences between craniometric data for male and female groups, and discriminant analysis. This study has been declared worthy of ethics from the Health Research Ethics Committee of dr. Soetomo General Hospital, Surabaya.

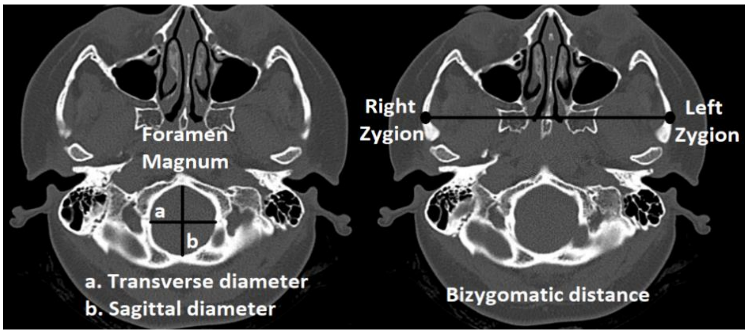

Fig. 1. Foramen magnum and bizygomatic distance measurement

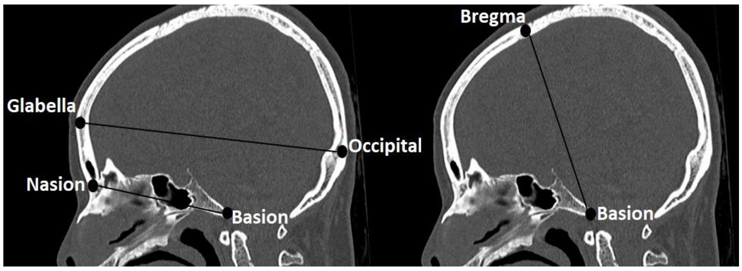

Fig. 2. Glabella-occipital, basion-nasion, and basion-bregma distance measurement

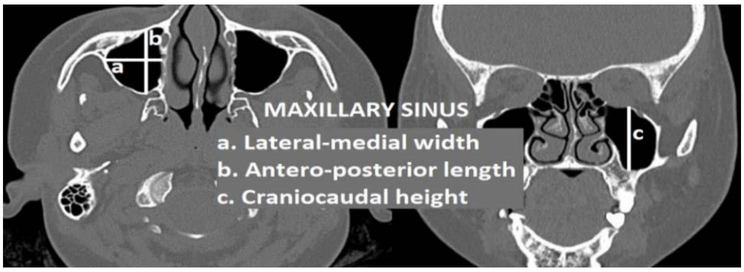

Fig. 3. Maxillary sinus measurement

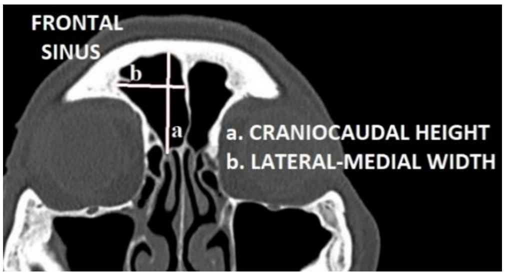

Fig. 4. Frontal sinus measurement

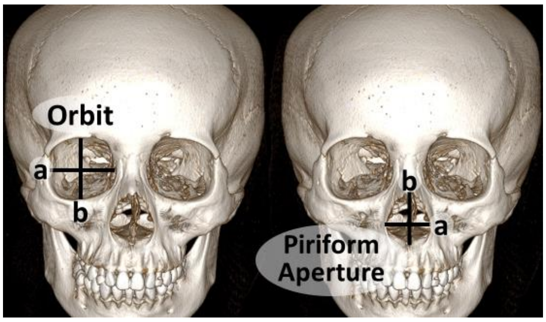

Fig. 5. Orbital and piriforme aperture measurement, lateral-medial width (a) and craniocaudal height (b)

3. Results

A total of 204 head CT scan results were evaluated retrospectively, consisting of 112 men (54.9%) and 92 women (45.1%), with an age range of 19-97 years. The largest number of male subjects is in the age range of 58-68 years, while the largest number of female subjects is in the age range of 48-58 years.

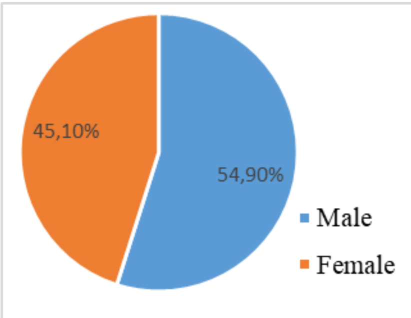

Fig. 6. Distribution Subjects by Gender

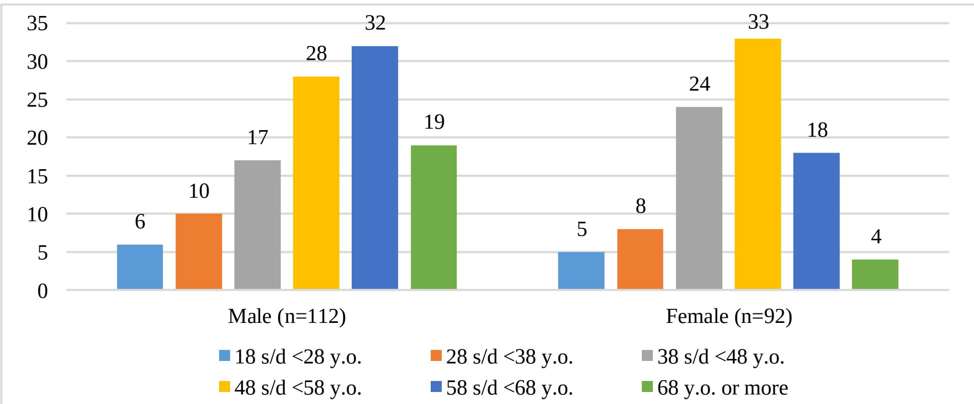

Fig. 7. Frequency Distribution Based on Age in Male and Female Groups

Each craniometric variable from 204 adult head CT scans was tested for correlation with the subject's age using the Pearson correlation test (Table 1). Of the 22 craniometrics evaluated, the correlation test showed that subject's age has no correlation with 15 male craniometrics and 17 female craniometrics (ρ>0.05), weak correlations with 6 male craniometrics and 5 female craniometrics (ρ<0.05; r= 0.21 to 0.40), and a very weak correlation with 1 male craniometrics (ρ<0.05; r= 0.00 to 0.20) (Sujarweni, 2019).

Table 1. The results of Pearson correlation test (ρ value and correlation coefficient) between age and craniometric

No	Craniometric	Male		Female	
		ρ	r	ρ	r
1	Foramen magnum transverse diameter	0,345	-0,090	0,529	-0,067
2	Foramen magnum sagittal diameter	0,758	0,029	0,336	-0,101
3	Bizygomatic distance	0,460	0,070	0,317	0,106
4	Right maxillary sinus lateral-medial width	0,039*	-0,196	0,338	-0,101
5	Right maxillary sinus antero-posterior length	0,126	-0,145	0,228	0,127
6	Right maxillary sinus craniocaudal height	0,012*	-0,238	0,399	-0,089
7	Left maxillary sinus lateral-medial width	0,017*	-0,225	0,041*	-0,213
8	Left maxillary sinus antero-posterior length	0,112	-0,151	0,389	0,091
9	Left maxillary sinus craniocaudal height	0,025*	-0,211	0,747	-0,034
10	Right frontal sinus lateral-medial width	0,057	-0,180	0,851	-0,020
11	Right frontal sinus craniocaudal height	0,074	-0,170	0,756	0,033
12	Left frontal sinus lateral-medial width	0,083	-0,164	0,551	-0,063
13	Left frontal sinus craniocaudal height	0,271	-0,105	0,194	-0,137
14	Glabella-occipital distance	0,387	-0,083	0,453	0,079
15	Basion-bregma distance	0,017*	-0,225	0,507	-0,070
16	Basion-nasion distance	0,455	-0,071	0,026*	0,232
17	Right orbit lateral-medial width	0,019*	-0,222	0,087	0,179
18	Right orbit craniocaudal height	0,768	-0,028	0,031*	0,226
19	Left orbit lateral-medial width	0,267	-0,106	0,190	0,138
20	Left orbit craniocaudal height	0,619	-0,048	0,010*	0,268
21	Piriform aperture lateral-medial width	0,033*	0,202	0,001*	0,342
22	Piriform aperture craniocaudal height	0,469	0,069	0,226	0,127

* correlation is significant at the 0,05 level
r, correlation coefficient

The Kolmogorov-Smirnov normality test is conducted to know whether the data has normal distribution or not. From the results of the normality test, it was found that 14 craniometrics met the requirements for normal data distribution (ρ> 0.05), so the parametric difference test was then carried out, namely the independent t test. In contrast, as many as 8 other craniometrics did not meet the requirements for normal data distribution (ρ <0.05), so the next non-parametric difference test was carried out, namely Mann Whitney test.

In the difference test, there was a significant difference (ρ <0.05) on the 15 craniometric variables between the male and female groups (Table 2). Even out of the 15 craniometric variables, 10 craniometric variables showed a statistically strong difference (ρ <0.001) between the male and female groups (Kirkwood & Sterne, 2003). Whereas the other 7 craniometric variables did not show a significant difference (ρ> 0.05) between the male and female groups.

To be able to identify the skull, including groups of male or female, discriminant analysis was performed. In this analysis, we used 10 craniometrics with ρ <0.001 (has statistically strong evidence), which are Foramen Magnum (FM) transversal diameter, FM sagittal diameter, bizygomatic distance, glabella-occipital distance, basion-bregma distance, basion-nasion distance, right orbit width, left orbit width, piriform aperture width, and piriform aperture height.

Table 2. Mean, standard deviation, and ρ value from the difference test between male and female groups

No	Craniometric	Mean ± SD (cm)		ρ value
		Male	Female	
	ρ < 0,05			
1	Diameter transversal foramen magnum	3,03 ± 0,24	2,91 ± 0,22	0,000
2	Diameter sagittal foramen magnum	3,48 ± 0,24	3,33 ± 0,20	0,000
3	Jarak bizygomatic	13,55 ± 0,48	12,77 ± 0,44	0,000
4	Jarak glabella-occipital	17,65 ± 0,63	16,90 ± 0,63	0,000
5	Jarak basion-bregma	13,84 ± 0,49	13,24 ± 0,46	0,000
6	Basion-nasion distance	9,96 ± 0,41	9,48 ± 0,35	0,000
7	Right orbit lateral-medial width	3,81 ± 0,19	3,72 ± 0,14	0,000
8	Left orbit lateral-medial width	3,81 ± 0,18	3,71 ± 0,15	0,000
9	Piriform aperture lateral-medial width	2,72 ± 0,21	2,60 ± 0,20	0,000
10	Piriform aperture craniocaudal height	3,03 ± 0,25	2,70 ± 0,24	0,000
11	Right maxillary sinus craniocaudal height	3,89 ± 0,73	3,65 ± 0,60	0,011
12	Left maxillary sinus craniocaudal height	3,85 ± 0,69	3,60 ± 0,56	0,005
13	Right frontal sinus lateral-medial width	2,33 ± 0,94	2,00 ± 0,91	0,003
14	Left frontal sinus lateral-medial width	2,55 ± 1,00	2,17 ± 0,82	0,001
15	Left frontal sinus craniocaudal height	2,78 ± 0,87	2,54 ± 0,86	0,010
	ρ > 0,05			
16	Right maxillary sinus lateral-medial width	2,82 ± 0,59	2,75 ± 0,47	0,235
17	Right maxillary sinus antero-posterior length	3,73 ± 0,39	3,65 ± 0,36	0,104
18	Left maxillary sinus lateral-medial width	2,77 ± 0,55	2,74 ± 0,44	0,612
19	Left maxillary sinus antero-posterior length	3,69 ± 0,36	3,64 ± 0,30	0,148
20	Right frontal sinus craniocaudal height	2,72 ± 0,93	2,49 ± 0,99	0,083
21	Right orbit craniocaudal height	3,43 ± 0,19	3,41 ± 0,17	0,542
22	Left orbit craniocaudal height	3,44 ± 0,18	3,43 ± 0,18	0,508

SD, standard deviation

Table 3. Canonical Discriminant Function Coefficients

No.	Craniometrics	Coefficients
1.	Foramen magnum transverse diameter	-0,860
2.	Foramen magnum sagittal diameter	0,731
3.	Bizygomatic distance	1,385
4.	Glabella-occipital distance	0,569
5.	Basion-bregma distance	0,371
6.	Basion-nasion distance	0,637
7.	Right orbit lateral-medial width	-1,402
8.	Left orbit lateral-medial width	0,089
9.	Piriform aperture lateral-medial width	-1,147
10.	Piriform aperture craniocaudal height	1,996
11.	Constant	-37,050

From The Canonical Discriminant Function Coefficients (Table 3), the discriminant functions can be written as follows :

Z = -37,050 + (-0,86 x FM transversal diameter + (0,731 x FM sagittal diameter) + (1,385 x bizygomatic) + (0,569 x glabella-occipital) + (0,371 x basion-bregma) + (0,637 x basion-nasion) + (-1,402 x right orbit width) + (0,089 x left orbit width) + (-1,147 x piriform aperture width) + (1,996 x piriform aperture height)

Z is a discriminant score, while the cutting score can be determined from the centroid group using the formula (Ramayah et al., 2010):

$$Z_{CE} = \frac{N_A Z_A + N_B Z_B}{N_A + N_B} \qquad (1)$$

with,

Z_{CE} : an optimal cutting score between grup A dan B

Z_A : centroid for grup A

Z_B : centroid for grup B

N_A : number of subjects in grup A

N_B : number of subjects in grup B

In this study, group A was male and group B was female. From the centroid group discriminant analysis, the values of :

Z_A = 1,106

Z_B = -1,347

N_A = 112

N_B = 92

From this formula (1), the cutting score used to classify the skull into groups of male or female is as follows:

$$Z_{CE} = \frac{(1{,}106 \times 112) + (-1{,}347 \times 92)}{(112 + 92)}$$

$$Z_{CE} = -0{,}00025$$

That is, if the value of Z>(-0,00025) then included in the group of male and if the value of Z<(-0,00025) then included in the group of female.

The classification results table in discriminant analysis (Table 4) shows the number of cases that can be grouped correctly, both in the male and female groups, using the discriminant function and cutting score that has been obtained. In the male group data, 103 cases out of a total of 112 cases can be properly classified as male, with an accuracy rate of 92%. In the female's group data, 83 cases out of a total of 92 cases can be properly classified as female, with an accuracy rate of 90.2%. In general, the use of 10 craniometric measurements in this study provides an accuracy rate of 91.2% in identifying gender.

4. Discussion

4.1. Age identification

In this study, 22 craniometrics were evaluated, both in the male and female groups. The results of the correlation test showed that subject's age has no correlation with 15 male craniometrics and 17 female craniometrics (ρ>0.05), weak correlations with 6 male craniometrics and 5 female craniometrics (ρ<0.05; r= 0.21 to 0.40), and a very weak correlation with 1 male craniometrics (ρ<0.05; r= 0.00 to 0.20). The results of this study provide information that craniometric measures in adult cannot be used for age identification. This is in accordance with the theory that the growth rate of the cranium becomes minimal after 10 years of age, so that the size of the adult cranium does not change significantly (Libby et al., 2017).

4.2. Gender identification

The difference test (the independent t and Mann Whitney test) showed significant differences (ρ <0.05) on the 15 variables craniometric between men and women. Even of the 15 craniometrics, 10 craniometric variables showed a difference with statistically strong evidence (ρ <0.001). Meanwhile, the other 7 craniometric variables did not show a significant difference (ρ> 0.05) between men and women.

The difference in craniometric size in the male group that is greater than the female group in this study is in accordance with the theory that in general the male cranium size is larger than that of women. This can be due to the faster bone growth in men due to the influence of androgen hormones. In addition, males have a prepubertal period of 1-2 years longer than females, so that the growth period in males is longer than females, which explains that males have a longer stature and larger bone size (Burns et al., 2009).

To be able to identify the skull, including groups of men or women, then discriminant analysis is performed. In this analysis, we used 10 craniometrics with a value of ρ <0.001 (has statistically strong evidence) from the results of the difference test. From this analysis we obtained a discriminant function of 10 craniometrics with a cutting score (Z_{CE}) of -0,00025. That is, if the value of Z> (-0,00025) then included in the group of men and if the value of Z <(-0,00025) then included in the group of women. The classification results table in discriminant analysis (Table 4) shows the number of cases that can be grouped correctly, both in the male and female groups, using the discriminatory function and cutting score that has been obtained. In the male group data, 103 cases out of a total of 112 cases can be properly classified as men, with an accuracy rate of 92%. In the women's group data, 83 cases out of a total of 92 cases can be properly classified as women, with an accuracy rate of 90.2%. In general, the use of 10 craniometric measurements in this study provides an accuracy rate of 91.2% in identifying gender.

Table 4. Classification Results

			Predicted group membership		
		Gender	**Male**	**Female**	**Total**
Original	count	Male	103	9	112
		Female	9	83	92
	%	Male	92,0	8,0	100,0
		Female	9,8	90,2	100,0
Cross-validated[b]	count	Male	100	12	112
		Female	13	79	92
	%	Male	89,3	10,7	100,0
		Female	14,1	85,9	100,0

a. 91,2% of original grouped cases correctly classified

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case

c. 87,7% of cross-validated grouped cases correctly classified

5. Conclusion

Craniometrics from head CT scans in adult can be used for gender identification, but cannot be used for age identification. In the male group data, 103 cases out of a total of 112 cases can be properly classified as men, with an accuracy rate of 92%. In the female's group data, 83 cases out of a total of 92 cases can be properly classified as female, with an accuracy rate of 90.2%. In general, the use of 10 craniometric measurements in this study provides an accuracy rate of 91.2% in identifying gender.

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References

Abdelaleem, S.A., Younis, R.H.A, Kader, M.A., 2016. Sex Determination From The Piriform Aperture Using Multi Slice Computed Tomography: Discriminant Function Analysis Of Egyptian Population In Minia Governorate. Egyptian Journal of Forensic Sciences. http://dx.doi.org/10.1016/j.ejfs.2016.11.003

Brough, A.L., Morgan, B., Rutt, G.N., 2015. The Basics Of Disaster Victim Identification. Journal Of Forensic Radiology And Imaging. http://dx.doi.org/10.1016/j.jofri.2015.01.002

Burns, S.I, Hopper, J., Seeman, E., 2009. The Age Of Puberty Determines Sexual Dimorphism In Bone Structure: A Male/Female Co-Twin Control Study. The Endocrine Society. doi: 10.1210/jc.2008-1522

Kirkwood, B.R., & Sterne, J.A.C., 2003. Medical Statistics, Second Edition. Blackwell Science Ltd.

Libby, J., Marghoub, A., Johnson, D., Khonsari, R.H., Fagan, M.J., Moazen, M., 2017. Modelling Human Skull Growth: A Validated Computational Model. DOI: 10.1098/rsif.2017.0202

Ohoiwutun, 2017. Ilmu Kedokteran Forensik (Interaksi Dan Dependensi Hukum Pada Ilmu Kedokteran). Retrieved from: http://repository.unej.ac.id/bitstream/handle/123456789/79197/ikk1%20Proof%20Reading%20Ponca.pdf?sequence=1.

Raghina, D.T., Perlea. P., Marinescu, M., 2017. Forensic Anthropology From Skeletal Remains To CT Scans: A Review On Sexual Dimorphism Of Human Skull. Romanian Society of Legal Medicine. Rom J Leg Med [25] 287-292 [2017] DOI: 10.4323/rjlm.2017.287

Ramayah, T., Ahmad, N.H., Halim, H.A., Zainal, S.R.M., Lo, M.C., 2010. Discriminant Analysis : An Illustrated Example. African Journal of Business Management Vol. 4(9), pp. 1654-1667, 4 August, 2010. http://www.academicjournals.org/AJBM

Sujarweni, V.W., 2019. SPSS Untuk Penelitian. Pustaka Baru Press. Yogyakarta.

Thali, M.J., Viner, M.D., Brogdon, B.G., 2011. Brogdon`s Forensic Radiology, Second Edition. Taylor and Francis Group. Boca Raton

Uthman, A.T., Al-Rawi, N.H., Al-Timimi, J.F., 2012. Evaluation Of Foramen Magnum In Gender Determination Using Helical CT Scanning. The British Institute of Radiology, Dentomaxillofacial Radiology (2012) 41, 197–202. http://dmfr.birjournals.org