Sex Identification Using Adult Pelvic 3D CT Scan: An Anthropometric Study

Ika Ruriana[a*], Rosy Setiawati[b], Prijambodo[b]

[a] *rurianaika@gmail.com*

[a]Resident, Radiology Department, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[b]Staff, Radiology Department, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia

Abstract

Background: In anthropological assessments, pelvic indices are used as additional measurements. Computed tomography (CT) is used to examine modern human variation and extending osteological assessment resources to researchers, which provides more quantitative data. This study aims to obtain data on age distribution of adults who were performed 3D CT pelvis and radiometric variables in pelvic anthropometry studies. **Methods:** This study used observational analytical design with cross-sectional approach. Population of study was all patients in Radiology Installation of Dr. Soetomo General Hospital, Surabaya, Indonesia who underwent pelvic 3D CT examination from September to December 2019. Radiologic component and demographic data were collected and statistically analyzed. **Results:** There were 204 samples included, where it was found that the patients' mean age was 50.23 ± 14.36 years. All radiologic components were also significantly different between sexes ($p<0.05$), except for transverse diameter of sacral segment ($p=0.180$). **Conclusion:** There were differences in age distribution of adults undergoing pelvic 3D CT as well as radiometric variables in pelvic anthropometric studies. Multicentric studies are needed to obtain a greater variety of data and produce more accurate data and formulas.

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1. Introduction

Human bone remains' sex identification is the first thing to do in order to help forensic anthropologists identify a person (Franklin et al., 2014). Metric and non-metric observational analyses have been the conventional methods that anthropologists have relied on (Decker et al., 2011). For sex discrimination purposes, a person's sex determination is usually done by performing morphological techniques because of their simplicity and accuracy. However, this technique is highly dependent on an assessor's expertise (Decker et al., 2011; Spradley, 2016).

In adults, the most reliable sex indicator because of its sexual dimorphism is hipbone (Decker et al., 2011). Various attempts have been made to 'metricize' or measure non-metric properties accurately in several body areas (Mahfouz et al., 2007; Krishan et al., 2016). With metricization of certain non-metric areas in pelvis, a more reliable result for sex estimation could be obtained because the data will be more objective (Franklin et al., 2014). In anthropological assessments, pelvic indices are used as additional measurements. Each population must have a special identification standard (Decker et al., 2011).

Computed tomography (CT), one of medical imaging modalities, is used to examine modern human variation and extending osteological assessment resources to researchers, which provides more quantitative data. Previous studies reported that there were improvements in reproducibility and accuracy compared to conventional linear methods of constructing a person's biological profile (Zech et al., 2012; Krishan et al., 2016). This study aims to obtain data on age distribution of adults who were performed 3D CT pelvis and radiometric variables in pelvic anthropometry studies.

2. Materials and Methods

2.1 Study design

This study used observational analytical design with cross-sectional approach. Population of study was all patients in Radiology Installation of Dr. Soetomo General Hospital, Surabaya, Indonesia who underwent pelvic 3D CT examination from September to December 2019. The hospital's ethics committee had given approval for our study.

2.2 Sample of study

Sample of study was pelvic 3D CT data taken by consecutive sampling that met inclusion and exclusion criteria. Inclusion criteria included: pelvic 3D CT images of male and female patients who came to Radiology Installation who were above 18 years and CT scan image of non-pregnant women. Pelvic 3D CT images of patient's pelvis and sacrum reveal a pathological condition that might interfere measurement, chronic disease and osteoporosis were exclusion criteria.

2.3 Study procedure

Study material included data from pelvic CT scans examinations in the form of digital data. Radiological examination tool used a 16-slices Siemens SOMATOM CT scan machine in Radiology Installation of Dr. Soetomo Surabaya General Hospital. Demographic data were obtained from medical records. Digital documentation was performed by storing digital data in the form of Digital Imaging and Communications in Medicine (DICOM) as study data.

Age distribution and pelvic measurements data were obtained. Pelvic measurements that were obtained in this study are described in Table 1.

Table 1. Anatomical landmarks' definition

Landmarks	Definition
Pelvic inlet	Innermost part of pelvic brim's inner side (superior-inferior aspect)
Pelvic outlet	Inferior apertura's outermost point
Superior iliac crest	Iliac crest's top point
Ischial tuberosity	Ischial tuberosity's lower point
Anterior superior iliac spine	Superior iliac spine's foremost point
Posterior superior iliac spine	Superior iliac spine's aftermost point
Superior acetabular border	Superior border's top point of the arcuate line for acetabular
Superior pubic symphysis	The top point of cartilaginous joint between the pubis' left and right superior rami of the hip bones
Medial acetabular border	The medial point of acetabular border
Lateral acetabular border	The lateral point of acetabular border
Sacro-lumbar articular surface	The top point on articular surface formed between the vertebral bodies of L5 and S1
Ischiopubic ramus	The lowest point on the articulates between the ischium and the inferior ramus of the pubis
Posterior inferior iliac spine	The aftermost point at the inferior iliac spine
Ischial spine	The spine that sticks out in the superior of the lesser sciatic notch
Greater sciatic notch	The notch on ilium's inferior portion posteromedial to the ischial spine

Table 2. Pelvic measurements included in this study

No.	Measurement	Definition
1.	Anterior breadth of the sacrum (ABS)	Sacrum's maximum transverse points at auricular surface's anterior projection
2.	Anterior height of sacrum (AHS)	Distance between sacral/coccyx border and sacral promontory
3.	Anteroposterior pelvic outlet diameter (APOD)	Distance between coccyx and inferior pubic symphysis

4.	Conjugate pelvic inlet diameter (CPID)	Distance between superior pubic symphysis and sacral promontory
5.	Left iliac breadth (LIB)	Distance between anterior superior iliac spine to left superior posterior iliac spine (taken from the left side)
6.	Left ischium length (LIL)	Distance between acetabular junction and the innermost point of ischial tuberosity (taken from the left side)
7.	Left pubic length (LPL)	Distance between a point at acetabular junction and pubic symphysis' superior point (taken from the left side)
8.	Left width of greater sciatic notch (LGSN)	The line between ischial spine, iliac spine, and greater sciatic notch's innermost part (taken from the left side)
9.	Left innominate height (LIH)	Distance between ischial tuberosity's lowest point and iliac crest's most superior point (taken from the left side)
10.	Pubic symphysis length (PSL)	Distance between the pubic symphysis' most inferior and superior points (taken from the left side)
11.	Right ischium length (RIL)	Distance between acetabular junction and the innermost point of ischial tuberosity (taken from the right side)
12.	Right pubic length (RPL)	Distance between a point at acetabular junction and pubic symphysis' superior point (taken from the right side)
13.	Right width of greater sciatic notch (RGSN)	The line between ischial spine, iliac spine, and greater sciatic notch's innermost part (taken from the right side)
14.	Right iliac breadth (RIB)	Distance between anterior superior iliac spine to left superior posterior iliac spine (taken from the right side)
15.	Right innominate height (RIH)	Distance between ischial tuberosity's lowest point and iliac crest's most superior point (taken from the right side)
16.	Sub pubic angle (SPA)	Angle between iliac spine, the innermost part of great sciatic notch and ischial spine
17.	Transverse diameter of sacral segment 1 (TDSS)	Distance between the first sacral segment's two most lateral points
18.	Transverse pelvic inlet (TPI)	Distance between coccyx and inferior pubic symphysis
19.	Transverse pelvic outlet (TPO)	Distance between superior pubic symphysis and sacral promontory
20.	Left IschPub Index	Pubic length (x100) divided with ishcial length

2.4 Statistical analysis

Data analysis included descriptive and frequency analysis. Ratio-scale data were presented as frequency distribution, standard deviation, mean, and percentage in descriptive and frequency analysis. T-test was performed if the data was parametric, and if the data was non-parametric Mann-Whitney test was chosen. Data analysis was performed using SPSS program.

3. Results

3.1 Age distribution

There were 204 patients in this study which was predominantly male, with ratio of male and female was 1:1.13.

The patients' mean age was 50.23 ± 14.36 years, with mean age of male group greater than female group. Table 3 described mean age of patients in this study and its standard deviation.

Patient age was divided according to their age group with an age range of 10 years for each group. Age group with the most patients was 41 - 50 years age group, the second was 51 - 60 years age group, and the third was 61 - 70 years age group. The largest age group for male was in 51 - 60 years age group, while for female the largest age group was 41 - 50 years. Table 4 described the patients' age distribution in this study.

Table 3. Mean age of patients

Demographics		**Mean**	**Standard Deviation**
Age (years)	Total	50.23	14.36
	Male	52.11	14.00
	Female	48.10	14.53

Table 4. Age distribution of patients

Age group (years)	Sex		Total
	Male	Female	
11-20	2	3	5
21-30	7	10	17
31-40	10	11	21
41-50	27	32	59
51-60	31	16	47
61-70	25	21	46
71-80	3	1	4
81-90	3	2	5

3.2 Radiologic components

Pelvic measurement values were taken for the entire sample. The data were divided by sex in the form of of mean, standard deviation, and their significance value (P value). The data is presented in Table 5.

Several variables that had greater value in women than men were APOD, bilateral GSN, RPL, SPA, TPI, TPO, and LIPI.

APOD, CPID, bilateral IB, bilateral IL, bilateral GSN, bilateral IH, SPA, TPI, TPO and LIPI were found to be the most significantly different between the sexes (P<0.001). Other variables that were also significantly different with P value of < 0.05 were ABS, AHS, bilateral PL, and PSL. The only variable with no significant difference between the sexes was TDSS (P = 0.180).

Table 5. Pelvic measurements between the sexes (in millimeters for length and in degree for angle)

Radiologic components	Male		Female		P value
	Mean	Standard Deviation	Mean	Standard Deviation	
Anterior breadth of the sacrum (ABS)	95.89	7.90	91.98	13.44	0,004[a]
Anterior height of sacrum (AHS)	102.86	8.99	100.25	9.00	0.034[a]
Anteroposterior pelvic outlet diameter (APOD)	82.81	8.21	88.58	9.21	<0.001[b]
Conjugate pelvic inlet diameter (CPID)	107.44	7.78	120.68	35.77	<0.001[a]
Left iliac breadth (LIB)	116.97	9.79	113.85	11.59	<0.001[a]
Left ischium length (LIL)	79.05	6.03	75.10	4.61	<0.001[a]
Left pubic length (LPL)	66.04	6.25	66.79	4.13	0.021
Left width of greater sciatic notch	43.89	13.63	47.84	4.97	<0.001[a]
Left innominate height (LIH)	197.53	7.91	178.66	20.03	<0.001[a]
Pubic symphysis length (PSL)	29.71	3.45	28.46	3.00	0.011
Right ischium length (RIL)	79.29	5.82	73.73	10.84	<0.001[a]
Right pubis length (RPL)	65.65	3.80	68.60	21.21	0.024
R width of greater sciatic notch	42.84	4.19	47.16	7.00	<0.001[a]
Right iliac breadth (RIB)	117.69	5.28	112.70	9.24	<0.001[a]
Right innominate height (RIH)	195.96	18.81	178.96	11.54	<0.001[a]
Sub pubic angle (SPA)	99.69	11.78	128.01	14.43	<0.001[a]
Transverse diameter of sacral segment 1	106.87	5.21	108.20	6.81	0.180[b*]
Transverse pelvic inlet (TPI)	114.03	6.64	122.48	6.52	<0.001[b]
Transverse pelvic outlet (TPO)	94.00	7.64	108.90	9.57	<0.001[a]
Left IschPub Index	84.02	11.26	89.12	5.80	<0.001[a]

[a]Non-parametic difference test using Mann-Whitney Test [b]Parametic difference test using t-test [*]Not significant

4. Discussion

Human skeletal sex's identification is crucial in medical field, especially in identifying partial bodies. This has become an important method in related fields of study such as forensics. In adults, the most reliable sex indicator because of its sexual dimorphism is hipbone (Franklin et al., 2014; Decker et al., 2011). This study demonstrates how objective method by using radiological technology, especially 3D CT Scan, is important in human anthropometric determination as it assists gender determination (Gonzales, Berna, and Perez, 2009).

The patients' mean age was 50.23 ± 14.36 years in this study. In a study by Kolesova et al, 2017, pelvic size difference was associated with changes in age. In their study, they observed age-related changes in pelvic cavity's linear parameters and verified a more horizontal sacrum location and sacral floor's anterior tilt in accordance to aging. This study also showed that there was no change in pelvic proportion to ischial height in female, while the distance of transverse pelvic diameter shortens with age. As previously reported, age-related ankylotic processes related to aging decreased the motility of sacroiliac joints and promoted these changes (Amonoo-Kuofi, 1992; Patriquin, Steyn and Loth, 2005; Abdel Moneim et al., 2008).

Significant differences ($p < 0.05$) were found between radiologic components measured between male and female except for transverse diameter of the sacral segment ($p = 0.180$). These significant differences finding was similar to other studies in different populations where there were significant differences in pelvic measurements between the sexes (Patriquin, Steyn and Loth, 2005; Mostafa et al., 2016). Patriquin et al., 2015 demonstrated significant sexual dysmorphism in a population study in South Africa. This study reported differences in pelvic size between sexes as well as differences between races.

From this study, 20 variables had lower results compared to a study conducted by Franklin et al in South Florida, USA. This showed that Indonesians had smaller pelvic size compared to Americans (Franklin et al., 2014). Previous studies also found no differences between the sexes in terms of pubic length (Franklin et al., 2014), (Decker et al., 2011). Furthermore, APOD and CIPD values in a previous study were no different between male and female (Mustafa et al., 2016), while in this study no difference was also found between the sexes in terms of TDSS 1, meaning that pelvic shapes might vary in different regions of the world. However, dysmorphisms is not always clearly found between human pelvis. It was agreed that variation and deviation of individual anatomical structure was allowed by nature from each sex's established norms (Leong, 2016)

The 19 variables that provide significant differences between the sexes as a result of growth in women tends to increase during adolescence, especially in the ischium and pubic area which results in a larger pelvic outlet, longer pubis and a blunter SPA (Klales, Ousley, and Vollner, 2012). This growth difference is related to the sexual dysmorphism associated with the birth process (Torimitsu et al., 2017). Furthermore, hormonal alterations in pregnancy results in pubic symphysis softening and pubic bone movement 1 cm in width which increases the pelvic diameter (Kolesova and Vetra, 2012; Mostafa et al., 2017)

This study still had few data from patients who were below 30 years old. Multicentric studies with more population below 30 years old are needed to obtain a greater variety of data and produce more accurate data. In addition, an analytical study of previously published studies might be conducted to compare differences in pelvic anthropometric values of different races and geographic areas.

5. Conclusion

There were differences in age distribution of adults undergoing pelvic 3D CT as well as radiometric variables in pelvic anthropometric studies (ABS, AHS, APOD, LIB, LIL, LPL, LGSN, LIH, PSL, RIL, RPL, RGSN, RIB, RIH, SPA, TDSS, TPO, LIPI). All radiologic components were also significantly different between sexes, except for transverse diameter of sacral segment.

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