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Testing the Validity of Patellar Measurements in Sex Estimation – A Computed Tomography Study in a Contemporary Polish Population

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Abstract

Introduction and purpose: Human skeleton-based sex estimation is a major topic of interest for forensic anthropologists. Various bones have been examined for sex heterogeneity. The most commonly used include skull and pelvis, however they may not always be used due to damage or fragmentation. The patella has been shown to be resistant to postmortem changes, which creates a potential use for determining the sex of unknown human remains.

Materials and methods: The samples were gathered from patients examined by computed tomography angiography (CTA) of lower extremities in University Hospital No. 4 in Lublin. Exclusion criteria included patellar fractures, knee replacement and advanced osteoporosis. A total of 120 CTA examinations of 65 males and 55 females, were included in the analysis.

Four measurements for every patella: craniocaudal patella dimension (CCP), transverse dimension (TP), anteroposterior dimension (APP) and patellar angle (PA), were obtained from CTA images.

Results: The statistical analysis proved that sex differences of all variables, except for PA, were statistically significant ($p < 0{,}001$).

Conclusions: Patellar measurements can be helpful in sex determination in the Polish population. CT is a useful tool for skeleton-based sex identification.

Keywords: Sex Estimation; Sexual Dimorphism; Patella; Forensic Anthropology; Multidetector Computed Tomography

INTRODUCTION AND PURPOSE

Sex estimation is a fundamental task performed by forensic anthropologists and is necessary for the creation of a biological profile of the human remains. Standard methods of estimating the sex of remains are based on morphometric and metric methods. However, these methods are subject to the subjectivity of the examiner. Modern methods of estimating the sex of a cadaver are based, among others, on radiological examinations such as computed tomography (CT) or magnetic resonance imaging (MRI). In some cases, radiological methods of sex assessment may be a better alternative to classical methods [1].

Bones typically used to assess sex are the skull and pelvis. The skull provides 92% accuracy, the pelvis 95%, and when both are present, accuracy reaches 98%. The presence of the entire skeleton provides close to 100% accuracy [2]. However, the skeleton's incompleteness or the destruction of bones crucial to making an unambiguous sex assessment is often a significant problem for forensic anthropologists. In these situations, sex assessment based on individual bones becomes a valuable method. In addition to the skull and pelvis, the other bones examined for sexual differences are the long bones of the limbs [3], ribs [4,5], scapula [6,7], clavicle [8,9], sternum [10,11], vertebrae [12,13], sacrum and coccyx [14,15], bones of the hands and feet [16,17] or the hyoid bone [18,19].

The patella is the largest sesamoid bone in the human body, located in front of the knee joint

in the tendon of the quadriceps femoris muscle. It is a thick, flat, triangular bone with its apex pointing downwards. Patellas have been shown to be resistant to postmortem changes [28], which increases their relevance in skeletal research. The usefulness of kneecaps in sex determination has been studied more than once [20–38], however never on the contemporary Polish population [39].

MATERIALS AND METHODS

Data Collection

The data used in the present study were obtained from participants undergoing computed tomography (CTA) examinations of the lower limbs in University Hospital No. 4 in Lublin. The study sample consisted of 160 CTA examinations. Exclusion criteria included patellar fractures, knee replacement, advanced osteoporosis and or arthrosis. Only patients with both patellas eligible for the study were included.

Imaging Data

CTA scans were performed using a 64-row scanner (GE Medical Systems) using standard protocol with spiral acquisition and 1,2 mm slice thickness. CTA studies have been used for the analysis due to high spatial resolution, and referral due to vascular conditions of the lower limbs, unrelated to trauma or arthrosis.

Measurements

Before taking the measurements, adjustments of measurement planes with multiplanar reformation (MPR) and maximum intensity projection (MIP) had been made. Using the adjusted CTA scans four linear measurements – craniocaudal patella dimension (CCP), transverse patella dimension (TP), anteroposterior patella dimension (APP) and patellar angle (PA) – were taken (Table 1 and Fig. 1). Measurements had been obtained from CTA images using AW4.7 workstation (GE Medical Systems).

Statistical Analysis

All statistical analyses were performed using Microsoft Excel and JASP statistical package (Version 0.17.3).

Descriptive statistics and independent T-Test were used to determine the degree of significance in the metric differences between both genders. Paired samples T-Test was performed to determine whether there was a difference between the measured parameters in right and left patellas. In all cases, the level of significance was set at $p < 0.05$.

Table 1. The definitions of linear parameters of the patella.

Parameter	Definition
Craniocaudal patella dimension (CCP)	The distance between base and apex of patella, obtained from oblique plane
Transverse patella dimension (TP)	The distance between medial and lateral borders of patella, obtained from oblique plane
Anteroposterior dimension (APP)	The greatest distance between the anterior and the posterior sides, obtained from adjusted axial plane
Patellar angle (PA)	The angle between the lines parallel to the medial and lateral patellar facets, obtained from adjusted axial plane

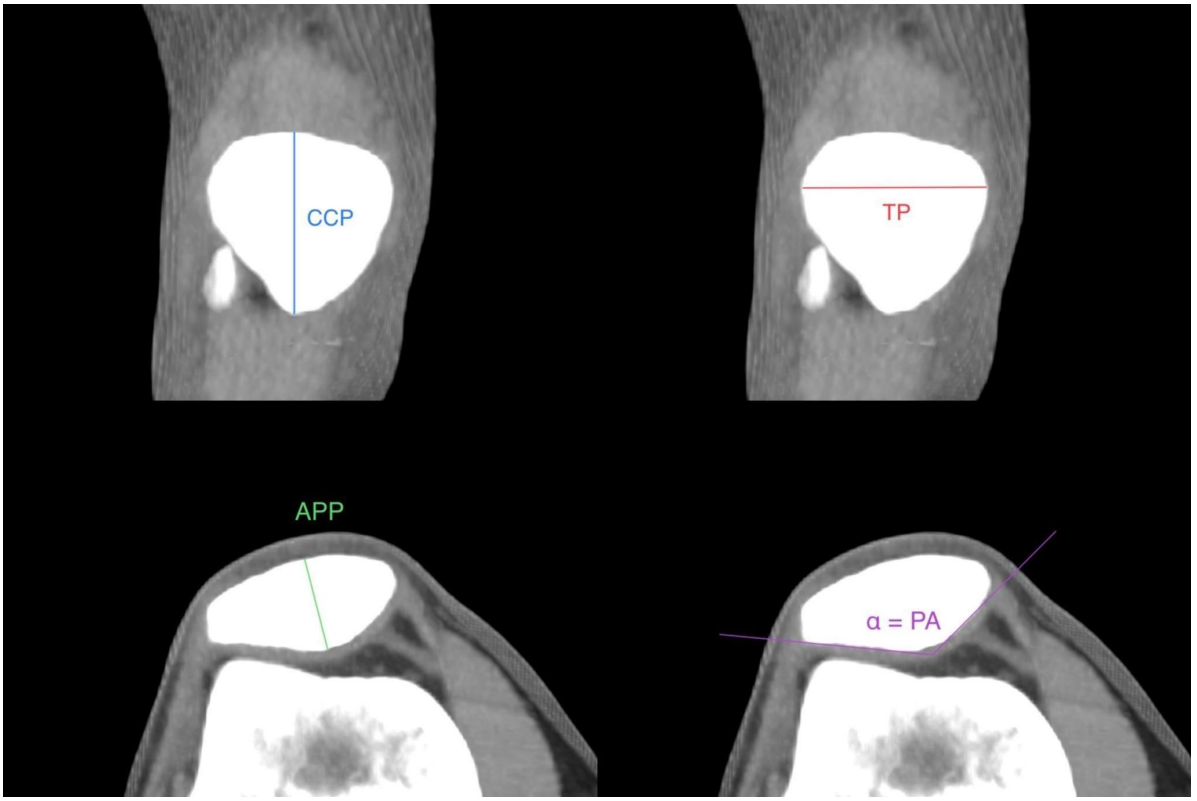

Fig. 1. Linear parameters of patella: CCP – craniocaudal patella dimension, TP – transverse patella dimension, APP – anteroposterior dimension, PA – patellar angle.

RESULTS

The analysis included 120 patients, 65 males and 55 females. The average age was 60.76 years for males and 59.82 years for females. The mean age for all subjects was 60,25 years and ranged from 18 to 93 years. Male to female ratio was 13:11 (54%:46%). No significant difference of age in males and females was observed. In total, 240 patellas (120 right and 120 left) were examined.

Descriptive statistics (minimal and maximal values, mean, standard deviation, standard error and coefficient of variations) of all variables for both sexes and bilateral patellas are shown in Table 2. Independent samples T-Test showed all patella measurements, except for PA, for the male subjects to be significantly greater than those for the female subjects ($p < 0.001$) (Table 2 and 3). For all statistically significant variables minimal values belonged to females, and maximal values – to males.

Paired samples T-Test showed that most of the analysed parameters have shown significant differences between right and the left side of the body (Table 4).

Table 2. Descriptive statistics for both sexes and bilateral patellas.

Variables		Males (n = 65)				Females (n = 55)			
		Min.	**Max.**	**Mean**	**SD**	**Min.**	**Max.**	**Mean**	**SD**
Age [years]		20	93	59.82	16.30	18	86	60.76	16.74
CCP [mm]	Right	36.10	53.90	44.37	3.74	33.30	45.60	38.40	2.95
	Left	36.10	55.00	44.68	3.71	33.50	45.20	38.64	2.99
TP [mm]	Right	40.50	56.70	47.85	3.02	35.30	49.90	42.59	3.25
	Left	40.10	57.40	48.32	3.26	35.60	49.40	42.63	3.14
APP [mm]	Right	18.10	26.30	22.89	1.67	17.00	25.00	21.04	1.63
	Left	18.20	26.00	23.12	1.64	17.00	24.00	21.13	1.60
PA [°]	Right	105.8	156.1	131.8	10.3	114.0	144.9	129.6	8.00
	Left	103.5	152.9	133.0	9.4	118.3	141.6	129.5	5.8

CV – coefficient of variation, SD – standard deviation, SE – standard error

Table 3. Descriptive statistics and independent samples T-Test results.

Variables		Total (n = 120)						*p*-value
		Min.	Max.	Mean	SD	SE	CV	
Age [years]		18	93	60.25	16.44	–	–	0.658
CCP [mm]	Right	33.30	53.90	41.63	4.52	0.41	0.11	< 0.001
	Left	33.50	55.00	41.91	4.54	0.41	0.11	< 0.001
TP [mm]	Right	35.30	56.70	45.44	4.08	0.37	0.09	< 0.001
	Left	35.60	57.40	45.71	4.28	0.39	0.09	< 0.001
APP [mm]	Right	17.00	26.30	22.04	1,89	0.17	0.09	< 0.001
	Left	17.00	26.00	22.21	1.90	0.17	0.09	< 0.001
PA [°]	Right	105.8	156.1	130.8	9.4	0.85	0.07	0.292
	Left	103.5	152.9	131.4	8.1	0.74	0.06	0.010

CV – coefficient of variation, SD – standard deviation, SE – standard error

Table 4. Paired samples T-Test.

Paired variables		t-value	df	*p*-value
Right	**Left**			
CCP	CCP	-1.798	119	0.075
TP	TP	-1.990	119	0.049
APP	APP	-2.048	119	0.043
PA	PA	-0.979	119	0.330

df – degrees of freedom

DISCUSSION

Radiological methods are becoming increasingly common and valued in forensic anthropology. These examinations enable reliable and repetitive measurements, providing a powerful tool in the daily practice of forensic anthropologists [1]. Numerous studies rely on radiological methods, also the ones carried out on patellas [30–34, 36, 38] Postmortem CT scans have been incorporated into Disaster Victim Identification (DVI) studies, facilitating, among other things, the identification of the gender of victims [40]. The choice of CT for the current study was also dictated by its non-invasiveness and increasing prevalence of this type of studies.

To this date, no study of sex estimation based on measurements of the patella of the contemporary Poles has been conducted [39]. Therefore, the current study aimed to identify the best possible parameters describing the sex differences of the patella in the Polish population based on CT examinations.

In the present study, CCP, TP and APP values were significantly larger in males than in females ($p < 0{,}001$). PA values did not prove to be statistically greater for male subjects than those for the female subjects. Measurements carried out on most bones showed higher average values for males compared to those for females. Previous studies have also shown that the mean values for patellar measurements in males tended to be larger than for females. Patellar angle was not statistically significant in the present study. This parameter has only been investigated in the past by Ahmed et al. [36]. In that study, carried out on MRI images of contemporary Egyptians, PA was insignificant in only one age group (41-50 years old). Interestingly, PA in that study showed the highest statistically significant difference for age differentiation in all age groups. Three of the four parameters measured on the patella of the Polish population showed statistically significant sex differences between males and females, indicating that the patella is sexually dimorphic in this population.

One of the limitations of the current study is the small size of the study group and the higher average age of its participants in comparison with other similar studies. Another limitation of the study is the sexual dimorphism found in different populations. The results obtained in this study cannot be used for sex estimation in other populations. Possible explanations for slight variations in the studies are differences in methodology and tools, genetics, differences in characteristics of the population or geographical factors, sex- and age-related changes in the knee.

CONCLUSIONS

The study has shown that patellar measurements, except PA, can be helpful in sex determination in the Polish population. CT is an advantageous tool for skeleton-based sex identification – it provides the possibility of standard osteometric methods for forensic anthropology.

Author's Contribution

Conceptualization: KJ and GS

Methodology: KJ and GS

Formal analysis, KJ and GS

Investigation: KJ and MJ

Resources and data curation: GS

Writing - rough preparation: KJ, MJ, MG and AN

Writing - review and editing: KJ, GS, JK, and PP

Visualization: KJ, MJ, MG and AN

Supervision: GS, JK and PP

Project administration: GS, KJ, JK and PP.

All authors have read and agreed with the published version of the manuscript.

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Not applicable due to the retrospective nature of the study and the analysis used anonymized clinical data.

Informed Consent Statement

Informed consent was waived due to the retrospective nature of the study and the analysis used anonymized clinical data.

Data Availability Statement

All data can be obtained upon request from the first author.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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