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Sex determination from carpal bone volumes: A Multi Detector Computed Tomography (MDCT) study in a Malaysian population

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ABSTRACT

Purpose: The use of Multi Detector Computed Tomography (MDCT) volume measurements of bones for sex determination allows fragile, fragmented human remains to be assessed without compromising the specimen. We set out to assess the ability of MDCT carpal bone volume measurement in determining sex in a Malaysian population.

Materials and methods: 52 healthy volunteers were scanned in a 16-slice MDCT, and the volume of 104 sets of carpal bones was measured using a Syngo workstation (Both CT and workstation-Siemens Healthcare, Erlangen, Germany).

Results: Male carpal bones were of higher volume compared to the female carpal bones ($p < 0.001$). Area under the curve (AUC) assessment of responder-operator characteristics curves showed that the trapezium bone was best able to predict sex with an AUC of 0.986. At a trapezium bone volume of $\geqslant 1.94\ cm^3$, there was a 93.5% probability that the subject was male. Binary logistic regression analysis found that the highest accuracy was derived using the pisiform, trapezium and capitate bones. There was a strong relationship between sex prediction and grouping of the carpal bone volumes (Nagelkerke $R^2 = 0.923$) with an overall prediction accuracy of 97%.

Conclusion: All 8 carpal bones exhibit sexual dimorphism to varying degrees. A binary regression analysis combining the 5 carpal bones with the highest predictive values for sex produces an accurate predictive model.

1. Introduction

Sex determination is the primary component of the biological profile which plays a crucial role in the identification of human remains to help expedite the process of narrowing down possible matches in the medico-legal context. The determination of sex can also help us understand the social and cultural context of human remains in archeological sites. Various parts of the skeleton have been shown to exhibit sexual dimorphism and have been used for many years to identify human remains. The accuracy of sex determination varies with the bones available for evaluation. The presence of only long bones gives a sex determination accuracy of 80–90% [1]. Human remains, however, are commonly fragmented when discovered with only parts of the skeleton intact. The use of carpal bones in this context have been studied only in recent times. Sulzmann et al. were the first researchers to describe a metric method for the potential use of carpal bones in sex determination [2]. The validity and applicability of this method on carpal bones was further evaluated by Mastrangelo et al. and was concluded to be of good accuracy [3]. The use of CT in the determination of sex from carpal bone measurement has never previously been evaluated. The accumulation of data for CT sex determination from bony remains may provide a non-invasive alternative to conventional evaluation, particularly in bio-archeological applications, where the preservation of the sample is of great importance. In forensic applications, the use of CT will allow the accurate measurement of bones in dismembered limbs while preserving the soft tissues. As the variations in bony dimensions between the sexes vary between different populations, a record specific to a given population is required in sex and biological profile determination. This is the first record of carpal bone volume in the Malaysian population. We aimed to evaluate the ability of carpal bone volumes derived from Multi Detector Computed Tomography (MDCT) in determining sex in the Malaysian population.

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2. Methods

2.1. Patients

This study was approved by the Institutional Medical Ethics Committee. The subjects were healthy adult volunteers recruited as part of an unrelated orthopaedic study of normal hands. Written consent was obtained prior to participation. There were 52 subjects comprising of 29 females and 23 males. The age of the participants ranged between 18 and 41 years. The exclusion criteria were the presence of skeletal immaturity, dysplasia, pathological or traumatic lesions, history of previous surgery of the hand and arm, degenerative or inflammatory arthritis and finally those aged younger than 18 years.

2.2. Image acquisition and analysis

CT scans of both hands were performed using a 16 slice CT scanner (SOMATOM sensation 16, Siemens Medical Solutions, Erlangen, Germany) without intravenous contrast media. The protocol used 120 Kv tube potential and effective tube current time product of 180 mAs, collimation 16×0.75 mm, slice width of 0.75 mm and pitch of 0.45. The right and left hands of the participants were scanned from distal radius and ulna to the mid metacarpal bones to include the carpal bones in the FOV. For image analysis, axial overlapping images of 0.75 mm were reconstructed using a bone (B70f) convolution kernel.

For analysis images were transferred to a Syngo Multimodality workplace computer workstation (Siemens Medical Solutions, Erlangen, Germany). The commercially available Siemens Medical Solutions software; SyngoMMWP, version VE36A was used. The available CT volume analysis tool was used, which enabled to measure volume of the tissue of interest with respect to density (Hounsfield Units [HU]).

A bone window (centre 700/width 4000 HU) was used. Using the CT volume analysis package of this software, regions of interest (ROIs) were manually drawn on each axial image of each individual carpal bone at a slice thickness of 0.75 mm. Following this, the system then evaluated the drawn volume within the limits of densities that were selected and a volume measurement was generated for each bone (see Fig. 1).

3. Results

A total of 52 CT scans of the hands were included, of which 55.8% were females. The subjects were aged between 18 and 41 years with the mean of 22.98. CT volume measurements were repeated by two investigators, twice. Non-parametric Wilcoxon Signed Rank tests revealed p-values of >0.05, indicating insignificant intra- and interobserver variability. A comparison of the bone volumes between the right and left hand using the Wilcoxon Signed-Rank Test showed that there was no significant difference between the right and left hand for any of the carpal bones (Table 1). Thus, each bone pair arising from the same subject was considered as two separate samples, increasing the sample size to 104.

Concerning gender differences, the carpal bones volumes were significantly higher in males (Mann-Whitney *U* test p values <0.001) (Table 2).

To determine the carpal bones most suitable to apply to the logistic regression model, ROC curves were performed and area under the curve (AUCs) obtained. The highest AUC was that for the trapezium, while the lowest was for triquetrum (Table 3). The ROC coordinates were used to determine the best cutoff point for each individual bone in predicting sex.

3.1. Calculation of predictive values, sensitivities and specificities for bone volume cut-offs

Using the cutoff points suggested from the ROC, the positive predictive value (PPV), negative predictive value (NPV), sensitivity,

Table 1
Comparison of the volumes (cm^3) of carpal bones between the right and the left hand.

Bone	Right hand, cm^3		Left hand, cm^3		p-value
	Mean ± SD	Range	Mean ± SD	Range	
Scaphoid	2.33 ± 0.64	1.38–3.85	2.33 ± 0.65	1.47–3.80	0.870
Lunate	1.65 ± 0.45	0.93–2.68	1.68 ± 0.49	0.95–3.06	0.403
Triquetrum	1.36 ± 0.33	0.93–2.12	1.35 ± 0.33	0.90–2.26	0.575
Pisiform	0.82 ± 0.26	0.27–1.34	0.81 ± 0.26	0.06–1.35	0.674
Trapezium	1.94 ± 0.54	1.18–3.39	1.93 ± 0.53	1.16–3.43	0.329
Trapezoid	1.26 ± 0.32	0.86–2.08	1.24 ± 0.32	0.85–2.09	0.164
Capitate	3.12 ± 0.78	2.02–4.89	3.14 ± 0.77	2.09–4.86	0.229
Hamate	2.52 ± 0.64	1.24–3.82	2.50 ± 0.65	1.33–3.96	0.420

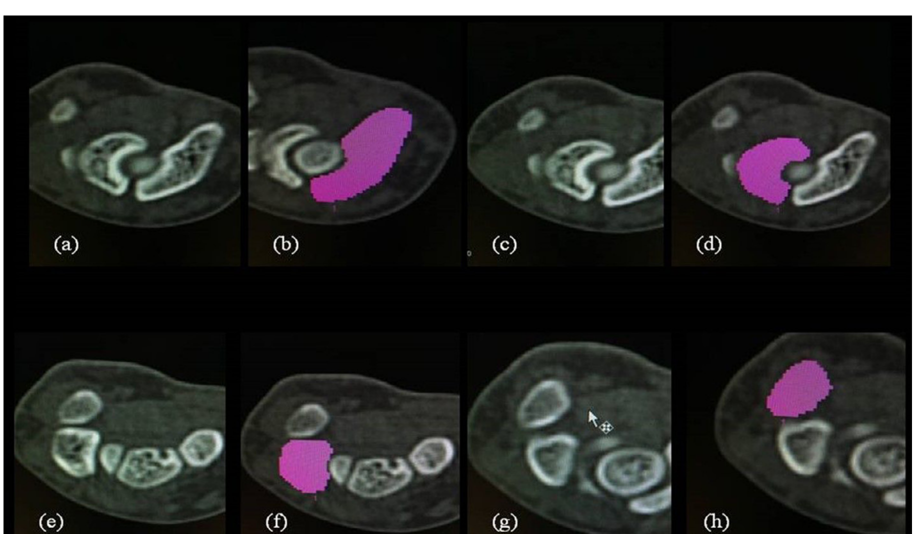

Fig. 1. Axial CT images of the proximal row of carpal bones (a & b) scaphoid, (c & d) lunate, (e & f) triquetrum and (g & h) pisiform with original images of the bones and after the ROI drawn.