Does Humeral Head Diameter Correlate with Humerus Length?

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INTRODUCTION: Bone strength and quality are being assessed for clinical and research purposes by making measurements on routine anterior-posterior (AP) radiographs of the proximal humerus [4]. Cortical index (CI) is the most common measurement employed in clinical settings and is defined as the difference between the outer and inner diameters divided by the outer diameter[4]. Mean combined cortical thickness (MCCT) has a stronger correlation with bone strength and is defined as the outer diameter minus the inner diameter[5]. These two variables are important for surgeons to evaluate radiographs of the fractured humerus and non-fractured side to make decisions regarding surgical fixation, assess bone quality and fracture strength, and potential complications of shoulder arthroplasty and fracture fixation[4, 5]. However, there is no agreement as to where measurements of CI and MCCT should be made. Tingart et al proposed fitting the proximal edge of a 2-cm rectangle at the point on the humerus where the endosteum became parallel and measuring CI and MCCT and the proximal and distal portions of the rectangle[5]. Mather et al proposed a similar method but to fit the rectangle at the location where the outer cortical margins become parallel [2]. Recently, a circle-fit method (CFM) to the humeral head to establish diaphyseal locations to measure CI and MCCT was found to provide minimal inter-observer variations when compared to the Tingart and Mather methods [3]. However, in that recent paper, only the upper half of the humerus bones were used. It is unknown whether humeral head diameter or the locations along the humeral shaft for the Tingart (Tingart distance) or Mather (Mather distance) measurements scales proportionally with humeral length. Answering this question is a logical next step in this area of research. Determining if these variables scale proportionally with bone length is important because then the measurements of CI and MCCT could be made at the same percentage of total humeral length regardless of the size of the bone. Accordingly, we asked: 1) Does humeral head diameter, Tingart distance, and Mather distance correlate with humerus length? If so, 2) What is the location of humeral head diameter, Tingart distance, and Mather distance as a percentage of bone length?

METHODS: With Institutional Review Board approval, this study used AP localizers taken from full length 1.25 mm sliced CT scans from 19 deidentified fresh-frozen cadaveric specimens. Images were imported into an open source medical image viewer (Horos, www.horosproject.org). A circle was fit to the humeral head[3] and the diameter of the humeral head recorded followed by the length of the humerus. Next, a 2-cm long rectangle was placed where the proximal endosteum becomes parallel, as done with the Tingart method. The length from the top of the humeral head to the first Tingart location was then recorded (Tingart distance). Another 2-cm long rectangle was then placed where the proximal outer cortical margins become parallel as done with the Mather method. The length from the top of the humeral head to the first Mather location was then recorded (Mather distance). The humeral head diameter, Tingart distance, and Mather distance were then determined as a percentage of the total humeral length. The humeral head diameter, Tingart distance, and Mather distance were then plotted against humeral length and the coefficient of determination (R^2) determined for the three variables. Computations were performed with software (JMP, www.jmp.com).

RESULTS: Of the 19 specimens, there were 15 left and 4 right humeri, age 37.5 ± 20.5 years, and mean length of 32.0 ± 2.6 cm. The humeral head diameter had a moderate correlation to humeral length (R^2 = 0.5644, [p=0.0002}) while the Tingart distance had a weak correlation (R^2 = 0.2731, [p=0.0217]) and very little correlation with the Mather distance (R^2 = 0.1817, [p=0.0688]) (**Figure 1**). The mean humeral head diameter was 4.9 ± 0.3 cm or 15.5 ± 0.9% of the humeral length. The mean Tingart distance was 8.7 ± 1.5 cm or 27.0 ± 4% of the humeral length. The mean Mather distance was 7.4 ± 1.3 cm or 23.2 ± 3.8% of the humeral length.

DISCUSSION: The most important finding of this study is that the humeral head diameter reliably correlates with 15.5 % of the humerus length. This has a stronger correlation and therefore less variance between specimens than the Tingart or Mather methods. The correlation of the humeral head diameter to humerus length in the present study of 19 specimens was R^2 = 0.5644 which is comparable to analysis of 2,754 humeri throughout the Holocene in which the correlation of head diameter to humerus length was R^2 = 0.5516 [1]. Future studies should compare CI and MCCT taken at normalized locations distal to the circle fit diameter of the humeral head to ultimate fracture load to develop an algorithm for proximal humerus fracture fixation and arthroplasty.

SIGNIFICANCE/CLINICAL RELEVANCE: Measurements of CI and MCCT should be assessed from locations based on a circle fit to the humeral head as this produces a reliable location of percentage humeral length across specimens. Reliably normalizing locations of CI and MCCT measurements between specimens will lead to greater correlation to fracture load, which will help develop an algorithm for proximal humerus fracture fixation and arthroplasty.

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IMAGES AND TABLES:

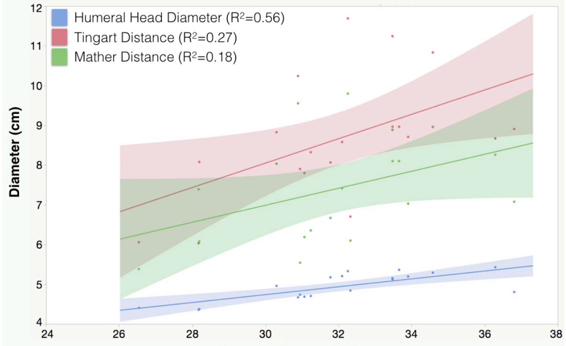

Figure 1: Plot of humeral head diameter (blue), Tingart distance (red), and Mather distance (green) to humeral length. Dark lines represent the best fit line while shaded areas represent 95% confidence intervals. Humeral head diameter had a better correlation (R^2 = 0.5644) compared to the Tingart distance (R^2 = 0.2731) and Mather distance (R^2 = 0.1817).

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