Scanty data is available on variations of heights of processes at the proximal end of ulna. This study aimed to obtain radiographic data for heights of olecranon (OH) and coronoid (CH) process and to test the sexual dimorphism, in a trial to devise a new formula for fragmentary bone sex assessing in two different populations. The study included 116 lateral radiographs of normal elbow of 83 adults, of 2 groups of populations. The first group included 66 radiographs of normal elbows for 33 volunteer Egyptian subjects (17 females and 16 males), whereas the second group included 50 radiographs of normal elbow of Saudi subjects (25 females and 25 males). The OH and CH were obtained. Statistical analysis with respect to values in males and females indicated an extremely statistically significant differences for the CH and OH/CH ratio (OH/CH %) (p<0.0001). No significant side differences in the measurements were identified in the available 33 pairs of radiographs. The current data indicated that the proximal ulna is a good bone from which to determine sex and that bone dimensions are population specific. The new devised formula (OH/CH ratio) could be used for the determination of sex in unidentified skeletal remains. Moreover, this formula can aid in surgical reconstruction or repair of these parts of bones.


**INTRODUCTION**

The ulna is the stabilizing bone of the forearm (1). Its proximal end is a massive hook which is concave forwards. This end has two prominent projections; the olecranon and the coronoid process. The olecranon is more proximal and is bent forwards at its summit like a beak while, the coronoid process projects anteriorly distal to the olecranon (2). The coronoid process acts as a bony buttress to prevent posterior dislocation (3). Occasionaly it is fractured in posterior dislocation of the elbow as a result of the indirect violence of a fall on the hand (4). Despite the evidenced role of coronoid tip fractures in the elbow instability (5), the orthopedic literature, however, contains very little information on the osseous anatomy of the coronoid process or the proximal ulna (6). Morphological differences have been shown to exist within gender and racial groups (7). Therefore, every population should have its specific measurements to achieve accurate sex determination. These differences become evident only after the end of puberty, when the skeleton has completed its growth (8). In a study examining gender differences in long bone anatomy, Mall et al. (9) reported that ulna length is shorter in women, but detailed
differences in the anatomy of the proximal ulna were not described. Using dry and adult ulnae, Purkait (10) suggested a method to assess sex specifically from the proximal ulna. He revealed that the olecranon-coronoid angle is a best single parameter, yielding 85% accuracy. Although this method was designed to specifically use the proximal ulna, determination of the angle is complicated and requires the ulna to be nearly intact making the method difficult to use with fragmentary elements (11).

Radiographs have long been the hallmark of elbow imaging and continue to be the initial imaging study of choice (12). The radiological assessment provides a clinically relevant and intra-operatively accessible measure of the bony processes that could be reliably applied by the operating surgeon to optimize fixation of comminuted fractures (13). The objective of this study was to determine the radiological sexual dimorphism of the olecranon and coronoid process, in a trial to devise a new formula for fragmentary bone sex assessing. The study also aimed to determine radiographic standard values of the heights as well as side-to-side correlation of these bones. It also tested whether the bone dimensions and sexual dimorphism are population specific.

Materials and Methods

116 lateral radiographs of normal elbow of 83 adults were studied. The study comprised radiographs taken from two separate groups of populations. The first group included 66 radiographs of normal elbow for 33 healthy Egyptian subjects (17 females and 16 males), all of whom were volunteers. All enrolled subjects consented to participate in the study after explanation of the aim and the procedures of the work. Their average age was 30 years (range: 23-55) and 38 years (range: 22-62) for females and males respectively. Individuals who had trauma history, fractures or metabolic disorders were excluded from the study. Images of the two elbows in each subject were taken. The X-rays were obtained in TechnoScan Centers, Zagazig, Egypt. The second group included 50 radiographs of normal elbow of Saudi subjects (25 females and 25 males). The images were obtained for various reasons such as soft tissue injuries, muscle pain and contralateral comparison following elbow injury. The radiographs were excluded if pathology affecting the anatomy of the elbow was present or if the lateral radiograph was deemed unacceptable. The ages ranged from 22 to 65 years, mean age was 35 years. Image of one side for each subject was available. They were 29 right and 21 left elbows. They were explored in the radio-diagnostic department of Al-Majmaah, King Khalid Hospital, Saudi Arabia. The selected radiographs were evaluated by the authors of the study together with an experienced radiologist and orthopedic surgeon. The following measurements were investigated in each radiograph:

i- Coronoid height (CH), defined as the distance from the tip of the coronoid process to the posterior subcutaneous border of ulna (Fig. 1).

ii- Olecranon height (OH), defined as the distance from the tip of the olecranon process to the angle of the olecranon at the posterior subcutaneous border of ulna, extending parallel to line of coronoid height (Fig. 1). In cases of obtuse angle, the line was extending to a line, tangent to the posterior subcutaneous border of ulna (Fig. 2).

The ratios of OH/CH were obtained from the previous measurements. The collected data were then reported and discussed. Simple statistical analysis (14) including mean, standard deviation (SD) and t-test was done to assess any gender differences existed. In order to ascertain whether bilateral asymmetry exits, the available 33 pairs of radiographs of the first group were subjected to a paired t-test.
RESULTS

Replication of measurements was satisfactory for the same observer over time and between the observers. All values had excellent intra-observer and inter-observer reliability. All measurements were found to have negligible intra-observer and inter-observer error. Statistical comparison of measured values in males and females in this study indicated an extremely statistically significant differences for the CH and OH/CH ratio (OH/CH %) (p<0.0001). Meanwhile, the OH was slightly higher in males than in females, but this difference was not statistically significant (p=0.0989). Table 1 summarizes the values in males and females. With study of each group separately, CH was greater in males than in females in both groups. The difference was extremely statistically significant (P-value =0.0015 in the first group and <0.0001 in the second group). In males of the first group, CH ranged from 29mm to 50mm with mean of 33.44±5.59mm, while in females, it ranged from 23mm to 43mm with mean of 29.12±4.95mm. In the second group males, CH ranged from 31mm to 51 mm with mean of 38.76±5.33mm, while in females, it ranged from 27mm to 33mm with mean of 30.72±2.19mm (Table 2 & Fig. 3). On the other hand, OH showed a slight increase in males than in females. This difference was considered to be not statistically significant in both groups (in the first group, P-value equals 0.5090 and in the second group, it equals 0.0539). The mean in males was 22.91±3.71mm (range: 19-34mm) and in females it was 22.32±3.42mm (range: 18-32mm) in the first group. While in the second group, its mean in males was 23.96±3.35mm (range: 19-34mm) while in females it was 22.44±1.89mm (range: 19-27mm) (Table 3 & Fig. 3). Comparing the measurements in the proximal ulna of the right and left elbows in the available sample of the first group (No. 33 subjects), no significant side differences were identified. Mean value of OH in right ulna was 22.70±3.57 mm, whereas in the left ulna it was 22.52±3.57 mm. In the right ulna, CH mean was 31.27±5.74 mm and in left ulna, it was 31.15±5.68 mm (Table 4).

The OH/CH% showed an extremely statistically significant difference between males and females in both groups. In males of the first group, it ranged from 66% to 72% with a mean of 68.78%±1.96%, while in females it ranged from 70% to 84% with a mean of 77.12%±3.44%. In the second group, the ratio in males ranged from 51% to 69% with a mean of 62.63%±5.11%, while in females it ranged from 69% to 79% with a mean of 73.12%±2.79% (Table 5, Fig. 4).

| TABLE 1. Statistical analysis of the investigated OH, CH and calculated ratios (%) of OH/CH in males and females |
| --- | --- | --- | --- | --- | --- |
| No. | Mean | SD | Range | No. | Mean | SD | Range |
| OH (mm) | Males | 57 | 23.37 | ±3.56 | 19-34 | 59 | 22.37 | ±2.85 | 18-32 | 0.598 | -0.19 to 2.18 | =0.0989 |
| CH (mm) | Males | 57 | 35.77 | ±6.05 | 29-51 | 59 | 29.80 | ±4.07 | 23-43 | 0.954 | 4.09 to 7.87 | <0.0001 |
| OH/CH (%) | Males | 57 | 65.88 | ±5.11 | 51-72 | 59 | 75.42 | ±3.73 | 69-84 | 0.829 | -11.19 to -7.90 | <0.0001 |

OH=Olecranon height, CH=Coronoid height, SD=Standard deviation, CI=Confidence interval, SE=Standard error of difference
TABLE 2. Statistical analysis of the investigated CH

<table>
<thead>
<tr>
<th>No.</th>
<th>Males</th>
<th>Females</th>
<th>SE</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH (mm) in First group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>33.44 ±5.59</td>
<td>29-50</td>
<td>1.298</td>
<td>1.73 to 6.91</td>
<td>&lt;0.0015</td>
</tr>
<tr>
<td>25</td>
<td>8.76 ±5.33</td>
<td>31-51</td>
<td>1.152</td>
<td>5.72 to 10.36</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

CH=Coronoid height, SD=Standard deviation, CI=Confidence interval, SE=Standard error of difference

TABLE 3. Statistical analysis of the investigated OH

<table>
<thead>
<tr>
<th>No.</th>
<th>Males</th>
<th>Females</th>
<th>SE</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OH (mm) in First group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>22.91 ±3.71</td>
<td>19-34</td>
<td>0.877</td>
<td>-1.17 to 2.34</td>
<td>0.5090</td>
</tr>
<tr>
<td>25</td>
<td>23.96 ±3.55</td>
<td>19-34</td>
<td>0.769</td>
<td>-0.03 to 3.07</td>
<td>0.0539</td>
</tr>
</tbody>
</table>

OH=Olecranon height, SD=Standard deviation, CI=Confidence interval, SE=Standard error of difference

TABLE 4. Statistical analysis of the calculated values of OH and CH of right and left ulnae in the first group

<table>
<thead>
<tr>
<th>No.</th>
<th>Right ulna</th>
<th>Left ulna</th>
<th>SE</th>
<th>95% CI</th>
<th>P-value</th>
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<tbody>
<tr>
<td></td>
<td>OH (mm)</td>
<td>CH (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>22.70 ±3.57</td>
<td>31.27 ±5.74</td>
<td>0.092</td>
<td>-0.01 to 0.37</td>
<td>0.0564</td>
</tr>
<tr>
<td>33</td>
<td>22.52 ±3.57</td>
<td>31.15 ±5.68</td>
<td>0.095</td>
<td>-0.07 to 0.31</td>
<td>0.2108</td>
</tr>
</tbody>
</table>

CH=Coronoid height, OH=Olecranon height, SD=Standard deviation, CI=Confidence interval, SE=Standard error of difference

TABLE 5. Statistical analysis of the calculated ratios (%) of OH/CH.

<table>
<thead>
<tr>
<th>No.</th>
<th>Males</th>
<th>Females</th>
<th>SE</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OH/CH (%) in First group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>68.78 ±1.96</td>
<td>66-72</td>
<td>0.695</td>
<td>-9.72 to -6.95</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>25</td>
<td>62.63 ±5.11</td>
<td>51-69</td>
<td>1.169</td>
<td>-12.85 to -8.14</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

CH=Coronoid height, OH=Olecranon height, SD=Standard deviation, CI=Confidence interval, SE=Standard error of difference.
**Fig. 1.** Lateral radiographic view of an adult female elbow. It shows the olecranon height (OH) and the coronoid height (CH). The line of olecranon height (OH) extends from the tip of olecranon process to the posterior subcutaneous border of ulna. The line of coronoid height (CH) extends from the tip of coronoid process to the posterior subcutaneous border of ulna, parallel to the previous line.

**Fig. 2.** Lateral radiographic view of an adult male elbow. It shows the olecranon height (OH) and the coronoid height (CH). The angle of the olecranon at the subcutaneous posterior border of the ulna is obtuse. The line of olecranon height (OH) extends from the tip of olecranon process to a tangent (red line) to the posterior subcutaneous border of ulna.

**Fig. 3.** Diagram showing the mean values (mm) of olecranon height (OH) and coronoid height (CH) in both groups of populations.

**Fig. 4.** Diagram showing the ratio (%) of olecranon height (OH) / coronoid height (CH) in both groups.
DISCUSSION

Few studies have defined any osseous measurements of the two processes at the proximal ulna. The current study detected a presence of significant difference in the CH between male and female specimens, with a mean of 35.77 mm and 29.80 mm, respectively. These results are nearly consistent with that reported by Rafehi et al. (15) who performed the same measurement but called it «ulnar height». They stated that the mean ulnar height for male specimens was 37.7±2.5 mm, whereas the mean height for female specimens was 33.3±1.75 mm. Similar sexual differences were reported by Matzon et al. (6) in a cadaveric study. They stated that the CH measured 15 mm in males and 13 mm in females. The differences in the values between their study and the current investigation are attributed to the used method for measurement. Their measurement was done from its tip to its base defined by the trough of the trochlear notch and the slope change of the distal coronoid process. In this measuring, difficulties arise in determining the coronoid base. In the current study, the CH was defined from the tip of coronoid process till the posterior subcutaneous border of the ulna. This border represents the most important bony landmark for all dorsal surgical approaches and the guideline for open reduction, internal fixation of displaced comminuted fractures of the proximal ulna (16). The anatomic landmarks for determining CH are necessary for proper classification of coronoid fractures (6).

In addition to CH, this study also evaluated the OH. Whilst CH showed extremely significant differences between males and females, OH did not show such gender differences. Its mean was 23.37±3.56 mm (range: 19-34 mm) in males and 22.37±2.85 mm (range: 18-32 mm) in females. These values were lesser than a mean of 26.2±2.01mm (range: 21-29 mm) reported by Wadia et al. (13). They did not mention presence of any gender difference in their study that included 33 males and 67 females. The difference in the values of the previous study and the current one might be due to methods used in measurements. In this study, OH was defined as the distance from the tip of the olecranon process extending to a line, tangent to the posterior subcutaneous border of ulna whether this line coincides with olecranon angle or not. Other factors such as the effects of magnification errors might have a role in such differences. These errors normally occur with any radiograph depending on the distance between the patient and the X-ray tube (13). The more projection of coronoid process in male than in females, in the current study, might explain the larger olecranon - coronoid angle of male noticed in other studies (10, 17).

In an attempt to avoid magnification errors of radiography, we converted the OH and CH data into ratios (or percentages). This standardizes the measurements, irrespective of the magnification power and also gives a formula for the surgeon to estimate height of a fractured process from the measurement of the other intact one. The OH/CH ratio (%) showed extremely statistically significant difference between males and females. Its mean in males was 65.88±5.11 %, while in females it was 75.42±3.73%.

Many studies have showed that there is a variation in the degree of sexual dimorphism among different populations (18-21). The current study also revealed a significant degree of sexual dimorphism in both groups of population samples. However, there were some differences in the size of the individual bony elements. For example, the mean values of the bony processes were slightly higher in Saudi than in Egyptians. Similar previous findings showed higher mean values in upper limb bones of Germen population than those of Greek population (21). The sexual dimorphism revealed in the current study was attributed mainly to the sexual differences in the height of the olecranon. Males had more OH values than females. Accordingly, OH/CH ratio was lower in males than in females. The ratio was the lowest in Saudi males (mean: 62.63%) and much higher in Egyptian females (mean: 77.12%). Many factors contribute in the development of
sexual dimorphism in a population e.g. genetic, environmental, mechanical and occupational factors; however, the most important is believed to be its genetic composition (19, 21). Although Egyptians and Saudi have the same life style, characters and geographic proximity, they expressed slight differences in the sexual dimorphism and dimensions of the examined bones. Therefore, the standards developed on one population should not be used for others, unless there is evidence that they have common traits in their skeletal biology (22, 23).

There was no statically difference between the investigated values of the right and left ulna. These findings allow the values of one side to be used as a standard for other one, in case of its surgical reconstruction or repair. Similar findings in Greek population were reported, in regard to measurements of the maximum length and epiphyseal width of the ulna (21). In contrary to the current results, Auerbach and Ruff (24) documented greater right-biases in upper limb bone dimensions. According to Trinkaus et al. (25), bilateral asymmetry is best observed in the diaphyses and especially their circumference or other cross-section characteristics.

CONCLUSIONS

The proximal ulna is a good bone to determine sex and the bone dimensions of its proximal part are population specific. The new devised formula, OH/CH% could be used for the determination of sex in unidentified skeletal remains from Egypt and Saudi Arabia. Moreover, this formula can aid in surgical reconstruction or repair of these parts of bones. No significant side differences were identified in the examined bones, so that one side can be used as a standard for the other. A preoperative radiograph of the contralateral elbow may be of great value for surgical assessment and management of the lesions of olecranon and coronoid process of ulna.

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Competing Interests

The authors declare that they have no conflict of interest.

REFERENCES


اختلافات الارتفاع الإشعاعي والأزوج الجنسي في الناتئين العظميين للنهاية القريبة من الزند

عبد النعم عوض حاجزي و محمد بن عثمان الرايكي

قسم التشريح و علم الأجنة - كلية الطب جامعة الزقازيق - مصر

قسم التشريح و علم الأجنة - كلية الطب جامعة المجمعة - المملكة العربية السعودية

قسم طب الأسرة والمجتمع - كلية الطب جامعة الملك سعود - المجمعة المملكة العربية السعودية

بيانات هزيلة هي المتاحة عن الاختلافات الموجودة في ارتفاعات نتوء النهاية القريبة لعظم الزند للناتئين الناجي والكوع، تهدف هذه الدراسة لتوفر بيانات بالتصوير الإشعاعي لهذه الناتئين، إضافة لفحص الأزوج الجنسي بهما، في محاولة لتشخيص الأندام من خلال فحص العظام المزجأة، وفي هذه الدراسة تم فحص عدد إجمالي 116 من الصور الإشعاعية الجناحية للكوع الطبيعي لمجموعتين مختلفتين من السكان، المجموعة الأولى اشتملت على 66 صورة للكوع طبيعي لعدد 23 متطوع مصري، في حين ضمت المجموعة الأخرى عدد 50 صورة كوع طبيعي لأشخاص سعوديين (25 من الذكور، ومثلهم من الإناث)، وتم أخذ القياسات، ومن ثم إجراء التحليل الإحصائي لها، حيث قدر النتائج على اختلافات جنسية ذات دلالة إحصائية عالية بين الذكور والإناث في الناتئين الناجي والكوع، بالنسبة للمجموعة للكوع/الناتئي الناجي في كلا المجموعتين، ومن ناحية أخرى لم يتم الحصول على اختلافات تذكر في القياسات بين الكوع الأيمن والأيسر في الأشخاص المتطوعين، ومن هذه النتائج يتبين أن النهاية القريبة للزنيد تمثل مثال جيد للعظام التي يمكن من خلالها تحديد الجنس، وأن حجم القياسات تختلف باختلاف السكان، وعلى يمكنا استخدام الصيغة المقتطعة في نسبة المنوية للكوع/الناتئي الناجي في تحديد الجنس من بقايا العظام الهيكلية مجهولة الهوية، علاوة على إمكانية استخدام البيانات المتاحة من الدراسة في بناء وإصلاح هذه الأجزاء من العظام.