Time of fusion of epiphyses at the elbow and wrist joints in girls of Northwest India

Daisy Sahni, Indar Jit*, Sanjeev

Department of Anatomy and Forensic Medicine, Postgraduate Institute of Medical Education and Research, Chandigarh, India

Received 14 April 1994; revision received 1 November 1994; accepted 1 December 1994

Abstract

A radiological examination of both elbows and wrists of 149 Northwest Indian schoolgirls between the ages of 11 and 19 years, of middle socio-economic status, was undertaken to determine the time of fusion of the epiphyses with the metaphyses of the medial epicondyle of the humerus, the proximal end of the radius and the distal ends of both radius and ulna. The data were subjected to discriminant function tests as well as sensitivity and specificity tests. If the epiphysis of the medial epicondyle of the humerus or that of the head of the radius has not fused with metaphysis completely, the age of the girl would be < 16 years. However, the age of the girl should be > 16 years if the distal epiphyses of the radius and the ulna show complete fusion with their respective metaphyses. Discriminant function tests show that 91.95% of girls can be correctly classified as being above or below the age of 16 years.

Keywords: Skeletal ageing; Epiphyseal union; Radius and ulna; Medial epicondyle humerus

1. Introduction

A large number of cases of crime against young girls take place in this part of the country. In cases of alleged rape, when the sexual intercourse has taken place with the consent of the girl, to make it a cognisable, criminal offence it has to be proved that the girl was <16 years of age. In such cases the age is usually estimated by noting the degree of fusion of the epiphyses with the metaphyses of the long bones

* Corresponding author.
at the elbow and wrist joints. Because of the lack of relevant data, in many such cases the medical experts are not in a position to certify the age of the girl with the result that the accused gets the benefit of doubt and is set free. When estimating the age, most of the medical specialists depend on the description given in the textbooks of anatomy published in the western countries. It has been emphasised that the findings in those countries are not necessarily applicable to Indians. According to several workers [1-3], in India the union of epiphyses with metaphyses takes place 2–3 years earlier than in the western countries.

2. Materials and methods

For the purpose of this paper, a radiological examination of both elbows and wrists of 149 girls (students) between the ages of 11 and 19 years was made. The subjects were of middle socio-economic status [4] and were residents of the Chandigarh zone of Northwest India. All of them were Punjabis in origin and therefore belonged to the same ethnic group. The age of each subject was noted from the admission register of the school and only those cases were accepted in which the parents confirmed the age. In case of doubt, the subject was excluded. The subjects included in the study were healthy. Over and underweight [4] girls were also excluded from this study. Radiological pictures of the elbows (anteroposterior) and wrists (posteroanterior) of both sides were taken and degree of fusion of various relevant epiphyses was recorded. The epiphyses included were:

1. the medial epicondyle of the humerus $x_1$;
2. the upper end of the radius $x_2$;
3. the lower end of the radius $x_3$; and
4. the lower end of the ulna $x_4$.

As the values of left and right variables were the same, data pertaining to the bones of the right side only were analysed statistically. The results were subjected to discriminant function as well as sensitivity and specificity tests.

2.1. Degree of fusion

Fusion of the epiphyses was classified as +3, which constituted complete 100% fusion, and 0 where there was no fusion at all. In between these two extremes the degree of partial fusion of epiphyses was further divided into +1 and +2; the former indicated the stage of commencement of fusion as shown by fusion of less than half of the contact area, while the latter depicted partial but not complete fusion when the fusion involved more than half of the contact area. Another stage of fusion classified as +2.5 was defined between +3 and +2, where there was almost a complete fusion of the epiphysis but a slight notch was still visible in the X-rays at the site where the epiphysial disc existed.

3. Results

3.1. Elbow — medial epicondyle of the humerus

The degree of fusion of the medial epicondyle of the humerus and the percentage of cases exhibiting this are given in Table 1. In 3 out of 13 subjects in the age group
<table>
<thead>
<tr>
<th>Age groups (years)</th>
<th>No. of cases</th>
<th>Medial epicondyle of humerus</th>
<th>Upper end of the radius</th>
<th>Lower end of the radius</th>
<th>Lower end of the ulna</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12</td>
<td>12</td>
<td>-</td>
<td>12</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>12-12.99</td>
<td>13</td>
<td>10</td>
<td>11</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>13-13.99</td>
<td>22</td>
<td>13</td>
<td>9</td>
<td>12</td>
<td>22</td>
</tr>
<tr>
<td>14-14.99</td>
<td>28</td>
<td>8</td>
<td>4</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>15-15.99</td>
<td>18</td>
<td>3</td>
<td>16</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>16-16.99</td>
<td>20</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>17-17.99</td>
<td>16</td>
<td>-</td>
<td>16</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>≥19</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>5</td>
</tr>
</tbody>
</table>
12–12.99 years, the medial epicondyle was seen to have fused partially (+2) with the metaphysis. Complete fusion was present for the first time in the next age group, 13–13.99 years, when it was seen in eight out of 22 instances (36%). The percentage of cases exhibiting complete fusion went on increasing with age until it was 100% in the age group 16–16.99 years, when there was complete fusion in all the 20 humeri examined.

It may thus be concluded that in the case where the medial epicondyle has not completely fused with metaphysis, the age of the girl should be < 16 years.

3.2. Elbow — upper end of the radius

As indicated in Table 1, the upper end of the radius exhibited 'commencement of fusion' (+1) in two out of 13 instances in the age group 12–12.99 years. The youngest subject exhibiting complete fusion was seen in the age group 13–13.99 years, where this degree of fusion was present in nine out of 22 instances (41%). In the next higher age group (14–14.99 years) there was a sudden increase in the percentage of complete fusion, which reached 82%. Complete fusion in 100% of instances, however, was seen in the age group 16–16.99 years.

It may, therefore, be stated with confidence that in the case where the epiphysis of the upper end of the radius has not completely fused with the metaphysis, the age of the girl should be < 16 years.

3.3. Wrist — lower end of the radius

It is evident from Table 1 that the lower end of the radius shows partial fusion with the metaphysis in the age group 14–14.99 years, when seven out of 28 (25%) girls exhibited commencement of fusion (+1 in Fig. 1), five had partial (incomplete) fusion (+2 in Fig. 2) and there was no fusion at all in the remaining 16 subjects. In the age group 16–16.99 years, complete fusion was seen for the first time in four (20%) girls and a notch (+2.5) was noted in three (15%) subjects (Fig. 3). In the age group 18–18.99 years the majority of girls, 11 out of 15 (73%), exhibited complete fusion and all the girls in the age group ≥ 19 years exhibited complete fusion of this epiphysis (Fig. 4).

This means that if complete fusion of the epiphysis is present at the lower end of the radius, the girl should be aged > 16 years.

Fig. 1. X-ray of the wrist joint of a girl of 14 years and one month, exhibiting non-fusion of the epiphysis at the lower end of the ulna. The epiphysis of the lower end of the radius shows commencement of fusion (+1).

Fig. 2. X-ray of the wrist joint of a girl of 14 years and 10 months, exhibiting partial (incomplete) fusion (+2) of the epiphysis at the lower end of the radius.

Fig. 3. X-ray of the wrist joint of a girl of 16 years and 5 months exhibiting an almost complete fusion of the distal epiphysis of the radius. However, a notch (marked —) is still visible on the lower end of the radius proximal to the base of styloid process. The degree of fusion is +2.5.

Fig. 4. X-ray of the wrist joint of a girl of 18 years and 2 months exhibiting complete fusion (+3) of the epiphysis of the lower ends of the radius and ulna.
3.4. Wrist — lower end of the ulna

The degree of fusion of the lower end of the ulna and the percentage of cases exhibiting this is given in Table 1. It is seen from this table that the lower end of the ulna started fusing with the metaphysis in the age group 14–14.99 years, when out of 28 subjects four (14%) exhibited 'commencement of fusion' (+1) while partial fusion (+2) was seen in 10 subjects (36%). There was no fusion at all in 14 (50%) instances. Complete fusion was seen for the first time in the age group 16–16.99 years when five out of 20 (25%) instances exhibited this degree of fusion. The percentage of girls exhibiting complete fusion steadily increased with age until it was 80% (12 out of 15) in the age group 18–18.99 years and 100% in the age group ≥ 19 years.

This shows that a girl who has a complete fusion of this epiphysis would be aged > 16 years.

3.5. Discriminant analysis

Since no single variable was completely satisfactory to classify the subject as above or below 16 years of age, multivariate discriminant analysis was applied to include all the four variables simultaneously to see if we could get better results. The multivariate discriminate constants arrived at were:

\[ Y = -1.694 - 0.1354(x_1) - 0.0048(x_2) + 1.007(x_3) + 0.6780(x_4), \]

where \( Y \) stands for a discriminant score.

The discriminant score of each subject was calculated according to the formula mentioned above and the subject was assigned to group 1 (< 16 years) if the discriminant score was negative or zero and to group 2 (> 16 years) if the score was positive. The results showed that 91.95% of the subjects could be correctly classified whether above or below the age of 16 years.

Calculated group membership of subjects after applying the discriminant analysis was:

<table>
<thead>
<tr>
<th>Actual age group</th>
<th>&lt;16</th>
<th>&gt;16</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;16</td>
<td>84</td>
<td>10</td>
<td>94</td>
</tr>
<tr>
<td>&gt;16</td>
<td>2</td>
<td>53</td>
<td>55</td>
</tr>
<tr>
<td>Total</td>
<td>86</td>
<td>63</td>
<td>149</td>
</tr>
</tbody>
</table>

Sensitivity and specificity for the discriminant analysis were: sensitivity, 89.4%; specificity, 96.4%; false positives, 10.6%; false negatives, 3.6%.

4. Discussion

One of the best methods of estimating the age of an individual is to find out the degree of fusion of the epiphyses with the metaphyses. This method is accepted in
the law courts and is very extensively followed by the medical officers. In spite of the fact that considerable work has been done in India on the times of fusion of various epiphyses, the anatomists and radiologists continue to depend upon the figures given in the textbooks of anatomy and radiology written by Western authors [5]. It appears that the information provided by some workers in India [6,7] is not sufficient. From the point of view of an offence committed under section 375 of the Indian Penal Code, it is necessary to find out if the age of the girl is below or above 16 years. Hepworth [8] made a radiological examination of the ends of the long bones of the limbs and the bases of the first metacarpals in 63 Punjabi individuals aged 8–18 years and recorded the age of fusion of the epiphyses. Unfortunately, he did not give the sex of the subjects, although he did state that the epiphyses unite with the shaft 'somewhat' earlier in girls than in the boys. The term 'somewhat' seems to be vague and does not help us in fixing the time of fusion of the epiphysis with the metaphysis in case of girls. He also concluded that in India the fusion of the epiphyses with the metaphyses takes place 2.5–3 years earlier than the corresponding fusion in the English and American subjects.

4.1. Medial epicondyle of the humerus

All the previous workers who studied the time of fusion of the medial epicondyle in the North Indian girls have stated that complete fusion occurred in all subjects at the age of 16 years [2,3,9]. Basu and Basu [10], however, recorded the latest time of fusion in this epiphysis as 17 years. A table in their paper shows that at the age of 16 years, all the 20 girls had complete fusion of this epiphysis, although at the age of 17 years one out of 12 girls did not exhibit this fusion. However, in the present material, although the earliest complete fusion was seen at 13 years and 1 month, all girls in the age group of 16–16.99 years exhibited complete fusion. A girl exhibiting complete fusion of the medial epicondyle will be 13 years of age or above it. This point, therefore, is not helpful for the purpose of this paper. On the contrary if the fusion of the epiphysis is incomplete or has not occurred at all, the girl is < 16 years of age.

4.2. Upper end of the radius

Most of the previous workers in India [9–11] who radiologically examined the elbow joints of the Indian girls have found that complete fusion of the proximal (head) epiphysis of the radius with the metaphysis takes place by the age of 16 years in 100% of instances. The present observations also tally with their findings. In the present investigations the earliest complete fusion of the head of the radius was seen at the age of 13 years and 5.5 months; this is in agreement with the observations made by Lall and Townsend [9] in Uttar Pradesh girls. However, in Bengali girls the earliest fusion has been seen at the age of ~12 years [10,11].

4.3. Lower ends of radius and ulna

Galstaun [11] took radiographs of the wrists of 215 Bengali girls between the ages of 12 and 20 years and came to the conclusion that although the epiphyses at the lower ends of radius and ulna may sometimes completely fuse with their respective
metaphysis at an earlier age (12 years in the case of the radius and 14 years in the case of the ulna), complete fusion in all instances had occurred by the age of 19 years.

Basu and Basu [10] found the earliest complete fusion of these epiphyses at 12 years but fusion in 100% of instances was found by the age of 18 years. Bajaj, Bhardwaj and Bhardwaj [3] gave merely the mean ages of fusion of these epiphyses as 16.4 ± 1.5 years for the radius and 15.8 ± 1.7 years for the ulna. Lall and Townsend [9] found a few cases of complete fusion of these epiphyses at 14—15 years.

On the whole, the observations of these workers do not help us in fixing the ages of the girls, whether below or above 16 years. The present investigation, however, shows that in the case of normal, healthy girls, who are residents of the Chandigarh zone of Northwest India, the earliest age at which complete fusion of the epiphyses with the metaphyses at the distal ends of the radius and ulna takes place is 16 years. A girl exhibiting complete fusion of any of these two epiphyses should be 16 years of age or above it. However, in the case where the fusion is partial the girl should be <19 years.

As some asymmetry in the union of the epiphysis with the metaphysis has been recorded [12], in the present investigation elbows and wrists of both sides were X-rayed but no asymmetry could be detected.

Discriminant function analysis, using degrees of fusion in the medial epicondyle of the humerus, the upper end of the radius, and the lower ends of the radius and the ulna indicated that ~92% girls could be assigned correctly to the groups above and below 16 years of age. The sensitivity and specificity of these variables were also very high.

To find out whether the age of a Northwest Indian girl is below or above 16 years, a radiological examination of the both elbows and wrists should be made. If the epiphysis of the medial epicondyle of the humerus or that of the head of the radius has not fused with its respective metaphysis, the girl will be below 16 years of age. If the distal epiphyses of the radius and the ulna have completely fused with the metaphyses, the age of the girl would be >16 years.

Acknowledgements

The authors are grateful to Doctor Padam Singh, Director of the Institute for Research in Medical Statistics (Indian Council of Medical Research) for statistical analysis of the data. He conducted the discriminant analysis as well as the sensitivity and specificity tests. They are also grateful to the students of the Government Higher Secondary School, Sector 14 (Panjab University), Chandigarh for helping us in this project and to Mr. M.L. Sharma of this department for skiagrams and photographs.

References


