Reciprocal Angulation of Vertebral Bodies in a Sagittal Plane: Approach to References for the Evaluation of Kyphosis and Lordosis

PEIRRE STAGNARA, JEAN CLAUDE DE MAUROY, GEORGES DRAN, GEORGES P. GONON, GIUSEPPE COSTANZO, JOANNES DIMNET, and ANNICK PASQUET

This report establishes a table of references for kyphosis and lordosis since, to the best of the authors' knowledge, no such table exists. A sample of healthy individuals was selected and, by means of roentgenographic study, the authors were able to define the reciprocal angulation of each vertebral body. The average values of the data obtained should provide a directly applicable table of references, but four years of work in this direction has shown that there is no simple answer. However, this study does establish an easily reproducible reference position, criteria sample selection, roentgenographic and clinical measuring processes, and a method to computerize the information obtained. [Key words: kyphosis, lordosis, quantitation, reciprocal relationship]

Sitting and supine positions are extremely variable, but we have noticed that each individual has a habitual standing posture. For subjects undergoing clinical and X-ray examinations at intervals of five to ten years, and where no growth or pathologic deformation factors are to be taken into account, the clinical and X-ray measurements of kyphoses and lordoses are remarkably constant to within a few degrees, provided the position is clearly stipulated.

This standing position, easily reproducible, is as follows: legs straight and trunk and shoulder-girdle in relaxed position (Figure 1).

The clinical measurements are taken relative to the vertical represented by a plumb line. (These measurements will not be given here.) In his thesis, Georges Dran studied the correlations between X-ray and clinical measurements, which are close enough to confirm each other.

For a lateral roentgenogram of the spine in the standing position defined above, the humeri must be moved forward without modifying kyphosis or lordosis. We found that having the hands resting on a horizontal support in front of the patient at pelvis level did not change the clinical measurements, whereas having the arms straight out in front or raised above the head changed kyphosis and lordosis considerably.

COMPOSING THE SAMPLE

For the first sample, we chose young adults with no known spinal pathology, aged from 20 to 29, inclusive-
This period of life appears to be probably the most stable; skeletal maturity has been reached and the vertebral modifications more frequent in older subjects have not yet appeared. Our study particularly concerns a group of 100 subjects from Lyons and Marseilles: 43 women and 57 men. A second check group of 37 subjects (19 women and 18 men) was made up of subjects from Rome who were selected by Giuseppe Costanzo.

**COMPUTERIZING THE INFORMATION**

**Digitalizer**

The measurements were established by treating each roentgenogram on a digitalizing table, with four points defining each vertebral body. The bottom edge of the film was used as a reference to the horizontal. The program fed into the computer gives all the reciprocal angulations defined above. We found the average value of each reciprocal angulation for each level, the standard deviations, and the upper and lower limits of the sample.

Thus, we were able to compose a table with two entries and 15 columns with the values rounded off to the nearest degree. Our first observation is that, even for this small sample, the differences from one person to the next are so great that average values cannot by any means be used as normative values (Table 1). Taking as an example the reciprocal angle of T11 with L3, the average value is -5° (lordosis 5°), but our sample includes all intermediate values between a lordosis of -30° and a kyphosis of +15°, giving a 45° range (the standard deviation at this level being 9°).

Consequently, the average values can be used for a certain number of cases studied statistically, but for individual cases, it is better to use the upper or lower limits of the sample in order to evaluate an excess or a deficit.

**EVALUATION OF MAXIMUM KYPHOSIS AND MAXIMUM LORDOSIS**

The sacrum basis is the lower limit of lordosis. The slope of the sacrum basis on the horizontal varies from 19° to 65°, the average of the sample being 41° and the standard deviation 35°.

Between the maximum lordotic curve and the maximum kyphotic curve, there is an intermediate vertebral body which is tilted most from the horizontal in the thoracolumbar region (Figure 2). This intermediate vertebral body can be found at five different levels, three of which are more common: L1 in 1/3 of cases, T12 in 1/5 of cases, and L2 in 1/5 of cases.

For each individual, there exists a maximum kyphotic curve, which in our study is measured according to the angle between the upper border of T4 at the top and the lower border of the intermediate vertebral body at the bottom. In the same way, there exists a maximum lordotic curve, measured between the upper border of the intermediate vertebral body at the top and the sacrum base at the bottom.

These maximum kyphosis and lordosis are the main object of this preliminary study. For maximum
<table>
<thead>
<tr>
<th>S</th>
<th>L5</th>
<th>L4</th>
<th>L3</th>
<th>L2</th>
<th>L1</th>
<th>T12</th>
<th>T11</th>
<th>T10</th>
<th>T9</th>
<th>T8</th>
<th>T7</th>
<th>T6</th>
<th>T5</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-35</td>
<td>0</td>
<td>-35</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>L5</td>
<td>-35</td>
<td>-27</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td>L4</td>
<td>-53</td>
<td>-27</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td>L3</td>
<td>-64</td>
<td>-36</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
<td>-16</td>
</tr>
<tr>
<td>T8</td>
<td>-81</td>
<td>-44</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
</tr>
<tr>
<td>T6</td>
<td>-62</td>
<td>-33</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
</tr>
<tr>
<td>T5</td>
<td>-61</td>
<td>-28</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
</tr>
<tr>
<td>T4</td>
<td>-51</td>
<td>-23</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 1. Reciprocal Angulation of Each Vertebral Body*  

* Table of references based on observation of 100 adults, aged 20-29 years (43 women, 57 men). Values to the left are minimums; values in parentheses are the means; values below are standard deviations. Positive values are kyphosis; negative values are lordosis.
lordotic curves, the values are between \(-32\)° and \(-84\)°; the average is \(-50°\), and the standard deviation is \(30°\). For the 43 women and 57 men making up the French sample, the average was not different according to sex. For maximum kyphotic curves, the values of the angles between T4 and the intermediate vertebral body can vary between \(+7°\) and \(+63°\), with an average of \(+37°\), and are the same for both men and women.

The standard deviations are considerable, and the
subjects furthest from the average value are far from being handicapped. For example, a male subject with a maximum kyphosis of 14° and a vital capacity of 6.6 l is an athlete with good performances in a number of different fields, and, at the other end of the scale, a male subject, with a maximum kyphosis of 63° and a vital capacity of 5.2 l is an excellent mountaineer. Faced with such great variations, the study of the distribution of individual deviations became imperative in order to see whether they could be plotted on a
Gaussian curve or whether they were irregular. The values of the sacrum slopes, the maximum lordotic and the kyphotic curves have been distributed in ten groups; each group brings together a certain number of cases of the sample represented by the histogram columns.

The sacrum base slopes between 18° and 66° have been spread over ten groups of 4.8° (average 41°) (Figure 3). For the 100 French men and women together, the distribution is relatively symmetric, but, if we divide the sexes, we observe for the 57 male subjects a deficit around 45°, whereas many of the 43 female subjects are close to 40°. The maximum lordotic curves between -32° and -84° have been distributed in ten groups of 5.2° (average 50°) (Figure 4). As far as the French subjects are concerned, the distribution is fairly irregular. There are a good number of cases between 45° and 70°. If we divide the sexes, the histograms are quite different. Female subjects are grouped around 50° to 60°, whereas male subjects form a compact block up to 75°.

The Italian check group shows one particularity: for 19 female subjects in the column from 58° to 63°, right in the middle of the histogram, there are no cases. The sample, however, is not sufficiently large for us to attribute any special significance to this fact other than its status as an illustration of the extreme variability of individual cases.

The maximum kyphotic curves between +7° and +62° have been divided into ten groups of 5.5° (average 37°) (Figure 5). As far as the 100 French subjects are concerned, there is a clear grouping of the values between 30° and 50°. Male and female subjects show practically the same distribution. The Italian check groups are less regular. In general, the Italian subjects have slightly more accentuated curves than the French, and this could be a Mediterranean characteristic, but a larger sample is necessary before any conclusions can be drawn.

Between kyphosis and lordosis, the intermediate vertebral body, the most tilted of the thoracolumbar region, shows a slope from the horizontal, varying according to the individual, from -32° to -5° (backward sloping), with an average value of -18°. The distribution in ten groups of 1.8° shows a greater irregularity in female subjects (Figure 6).

CORRELATIONS BETWEEN KYPHOSIS–LORDOSIS AND SACRAL BASE SLOPES

In 1951, A. Delmas, a French anatomist, described three types of spinal morphology: subjects with marked curves, subjects with slight curves, and intermediate types. With the "living" documents we brought together, it was possible to study the correlations of our three measurements (sacrum base, maximum kyphosis and maximum lordosis) for each individual case. The morphologic types appear much more varied than those described by Delmas.

The computer presents us with a "cloud of points" and allows ellipses covering the most characteristic groupings to be described. Given the differences in distribution between male and female subjects in the histograms studied, we have treated each sex separately. In order not to overload the present paper, we give only the documents concerning the 43 French women.

CORRELATIONS BETWEEN SACRAL BASE SLOPE AND MAXIMUM LORDOSIS

As one might have expected, this correlation is quite close and can be described in a long oblique ellipse. There is a marked correlation for the male subjects, a little less close for the female subjects (Figure 7).

CORRELATIONS BETWEEN MAXIMUM LORDOSIS AND MAXIMUM KYPHOSIS

One could expect a close correlation, since a considerable lordotic curve seems to call for a compensatory kyphotic curve as a corollary. Our documents show
widely disposed "clouds" for men and women, but in the latter group the search for characteristic grouping ellipses displayed two zones separated by a thinly inhabited area. This could suggest that, whatever the maximum lordosis, the maximum kyphosis can equally well be less marked, or more marked relative to an average value which we again observe as having little significance (Figure 8).

CORRELATIONS BETWEEN MAXIMUM KYPHOSIS AND SACRAL BASE SLOPE

Dispersion is even greater here. However, two zones of concentration are found. Rounder ellipses show considerable dispersion even within these zones (Figure 9).

Numerous other measurements are being studied, including morphology of the sacrum and height of discs and vertebral bodies. This will make the study of other correlations possible.

DISCUSSION

To the best of our knowledge, no table of reference for the reciprocal angulation of vertebral bodies in standing humans existed prior to this study. What we propose is a protocol for the X-ray examination of the subject in an easily reproducible standing position. In roentgenograms taken without these precautions, variations can occur, above all, in the lumbar area.

Our sample is a modest one. Our observations should be checked by extending the study under the same conditions. The geographic origin of the sample should be mentioned since it seems that this may be a factor of variation in spinal morphology.

There is very little difference between the sexes, the average values being superimposable. The lordotic appearance of feminine subjects, no doubt, is due to a more marked curve of the buttocks than we usually find in male subjects.

The span of a possible values of maximum kyphosis and lordosis in subjects with no spinal disease is considerable. The distribution of these values is often irregular within the extreme limits of the sample. It is therefore unreasonable to speak of normal kyphotic or lordotic curves. The average values are only indicative and not normative. The extreme values show the morphologic latitude of the human species.

For smaller segments, the deviations are far less marked. Consequently, for angular kyphosis and lordosis, the reciprocal angle table can be used as a reference.

Each subject has a unique spinal "physiognomy," just as he has a unique facial "physiognomy."

A study of larger samples should allow more complicated morphologic types than those proposed by Delmas to be distinguished. The functional values and pathologic predispositions of these different types remain to be studied. Where attenuated or accentuated kyphosis or lordosis are concerned, one should avoid using such adjectives as "excessive," "insufficient," or "pathologic" and, even more so, "abnormal."

Greek mythology offers us a significant legend. Procustus, a bandit, after having robbed his victims, laid them on his bed ("Procustus' bed" is a proverbial saying), considered as being of standard (mean), or normal length. Those who were too short were stretched to the "right" length, and those who were too tall were cut down to size (Figure 10). In orthopedics, let us avoid the Procustus complex, let us not be

Fig 9. Correlation between sacral base slopes and maximum kyphosis (43 French women).

"mean"-minded (in all senses of the word) without discernment.

SUMMARY

In order to establish a sagittal plane curve reference table for standing subjects examined laterally, we determined an easily reproducible standard posture. A sample of 100 healthy subjects from 20 to 29 years of age, was chosen (43 women, 57 men). The reciprocal angulations of each vertebral body in relation to the others were fed into a digitalizer and studied by computer. The study particularly concerns maximum kyphosis, maximum lordosis, sacral base slopes, and the tilt of intermediate vertebral bodies. The dispersion of the results is remarkably wide and, within the extreme values, the distribution is irregular. Individual correlations of these values are often dispersed, but certain groupings can appear, allowing an approach to spinal morphotypology. For considerable lengths, average values cannot be used as norms, given the wide span of values. Only the extreme limits are useful for the appreciation of curves as excessive, insufficient, or inverted.

REFERENCES

1. Delmas A: Types rachidiens de statique corporelle. Revue de Morphophysiologie humaine, 1951

Address reprint requests to

P. Stragnara
Centre De Readaptation Fonctionnelle Des Massues
92 Rue E. Locard Lyon 5
69322 Lyon Cedex 1
France

Accepted for publication March 10, 1981.