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Threshold values for supine and standing Cobb angles and rib hump measurements: prognostic factors for scoliosis

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Abstract Seven parameters recorded at the first clinical examination of 326 growing scoliotic patients were correlated with the speed of progression of the scoliotic curve during a natural history survey period. The parameters were: age; bone age (according to Greulich and Pyle); pubertal and Risser stage; curve shape; rib hump, measured in forward bending in a sitting patient and supine and standing radiographic Cobb angles of the scoliotic curve. The speed of progression of the scoliotic curve was expressed as the annual increase in Cobb angle. It was quantified graphically after plotting the measurements taken from all the radiographic examinations made during the survey. The survey period ranged from 6 months to several years, depending on the rate of progression. It was 6 months only if the scoliotic curve demonstrated worsening of more than 3° at two successive examinations performed at least 3 months apart. The authors aimed to identify the minimum values of curve angle and rib hump, identified at first examination in 95–100% of patients whose parameters at follow-up were above these values (supine angle: 17°; standing angle: 24°; rib hump: 11 mm), therefore demonstrating curve worsening. Then, they analysed how the other parameters such as age, bone age, state of maturation and curve shape influenced these threshold values of rib hump and supine and standing angles. The authors present the threshold values for the whole sample according to the sexual state of maturation and also for each curve shape. They demonstrate that a combination of states of maturation, several measures of the scoliotic curve and curve shape provides the best basis for individual prognosis.

Key words Scoliosis · Curve progression · Prognostic · Threshold · Maturation

Introduction

Since the first publications by Collis and Ponseti and by Duriez [3, 5], many works have emphasized the fact that scoliotic curves can continue to increase during maturity. However, good treatment during growth only can aid in stopping the increase of the deformity. Consequently the tendency is to start treatment for scoliosis at a smaller and smaller angle. These treatments are easier but also longer than those undertaken at a later stage, and they can be only warranted if the scoliotic curve is increasing. Since only 2 out of every 1,000 patients with a minor degree of curvature will have a progressive scoliosis, the challenge is to identify these subjects [2, 14, 15, 17–19]. Hence, prognostic factors for the development of scoliosis must be found. Any such parameter, a qualitative one or a threshold of a quantitative one, must be present at the first examination for the vast majority (95–100%) of worsening scolioses and must be absent from all the stable scolioses. A combination of several parameters can produce increased reliability with lower thresholds for each parameter.

In a long-term follow up, Lonstein [13] identified a combination of prognostic factors for minor scoliosis – Cobb angle corrected for chronological age and Risser stages – from which the risk of progression could be calculated. The smallest Cobb angle involving a 95% risk of progression was 20° for children below 9 years old. Risser stage is a very late informant parameter during growth of scoliotic patients; Risser stage 0 affects scoliotic patients from 1 to 14 years. Consequently, using Risser stage as a maturation indicator can lead to loss of information. For this reason we also use the early informant parameters of bone age and sexual state of maturation [6, 7, 16].

Research of prognostic factors requires longitudinal studies of the history of each scoliosis, as this is the only means of demonstrating an increase in the deformity. Retrospective studies generally suffer from incomplete data on the parameters measured at first examination or from lack of quantification of the worsening of the deformity. Such studies have established the relationship of both Cobb angle and age with subsequent worsening of the curve [4]. In 1989, on a polycentric and retrospective investigation, we demonstrated the relationship between several clinical and radiological parameters recorded during the first examination of a patient with worsening scoliosis [11, 12], but we were not able to find a threshold of these parameters that would reliably predict worsening. Prospective studies must be of limited duration because of the ethical requirement for treatment, consequently they run a risk of wrong assessment of worsening.

We used a semi-longitudinal approach to study the relationship between the parameters measured during the first examination and development of the scoliotic curve, measured as the annual rate of progression of Cobb angle in 262 growing scoliotic patients selected on account of having a supine Cobb angle and rib hump measurement below 30° and 30 mm, respectively, at first examination. The incidence of scoliotic progression was 95% in those patients for whom the supine Cobb angle was greater than 17°, or the rib hump was above 11 mm at first examination. These threshold values can therefore be used for individual prognoses [8].

The present study employs the same approach. Its purpose is to determine a similar threshold for the standing Cobb angle and to determine how the parameters of curve shape, age, bone age and state of maturation influence these thresholds.

Materials and methods

Seven parameters were recorded at the first examination of 326 growing idiopathic scoliotic subjects and were correlated with the rate of progression of the scoliotic curve established during a natural history survey period.

Initial parameters

Supine and standing angle. This was measured according to the Cobb method.

Rib hump. This was measured with a spirit level with the subject bending forward in a sitting position with the pelvis supported by an assistant.

State of maturation. The subjects were assigned to one of six states:

State I: no external sexual sign of puberty
State II: just the first external sexual signs of puberty
State III: from the first external sexual signs of puberty to menarche
State IV: menarche to Risser test of iliac epiphysis French state 1 (first appearance of iliac epiphysis ossification)
State V: positive Risser test from French state 1 to 3 (complete progression of iliac epiphysis ossification)
State VI: Risser test from French state 4 to 5 (from outset to completion of iliac epiphysis ossification fusion with the iliac crest)

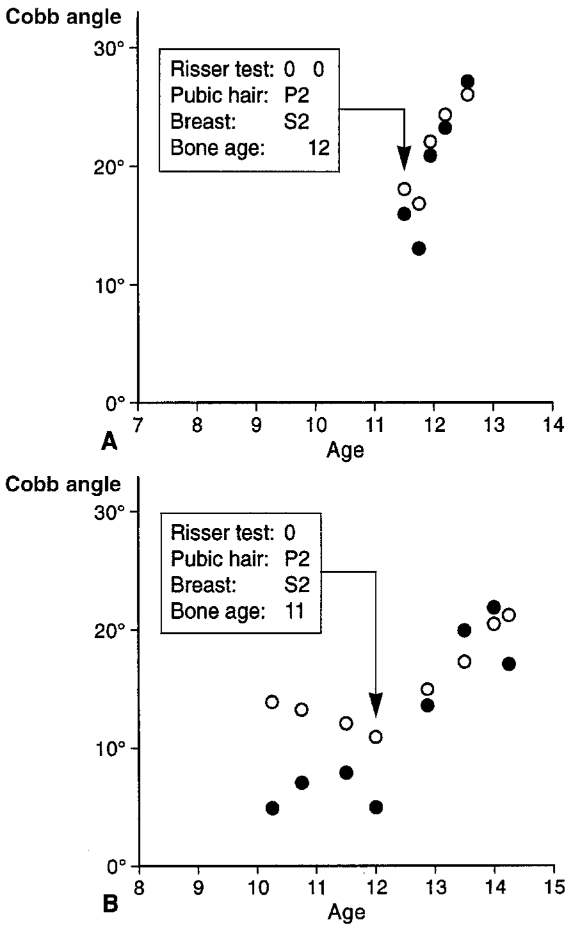


Fig. 1 A, B Graphical estimation of the evolution rate of two scoliosis curves (● thoracic Cobb angle, ○ lumbar Cobb angle). **A** A short natural history follow-up, on account of fast worsening. **B** A longer natural history follow-up, on account of start of puberty and low rate of progression

Chronological age.

Bone age. This was established according to the Greulich and Pyle atlas.

Curve shape. The curve was classified into one of five shapes: thoracic, thoraco-lumbar, lumbar, double major and triple major. Classification into single, double or triple curve was based on the number of humps: one, two or three.

Rate of scoliosis progression. The rate of scoliosis progression was expressed as the annual increase in Cobb angle. It was estimated graphically from a minimum of three measurements of Cobb angle taken during successive examinations made more than 3 months apart during the natural course of a survey period. If the first sexual signs of puberty occurred during the survey period, a minimum of three successive examinations were made in the new state of maturation (Fig. 1 B). Both supine and standing radiographs were made only for the first examination. During the natural history survey, the radiographic survey was made only in the supine position. The patients were not treated during the survey period. The data of all curve angles were plotted on a graph as described previously [7, 9, 10]. Because the reliability of Cobb angle measurement in a supine position is 3° [1], treatment was started only if the supine curve increased by more than 3° at each of the successive examinations. When the difference between two successive measurements of supine Cobb angle was smaller than 3°, the natural history survey was continued until successive points on the graph demonstrated evidence of a slow but regular progression. Consequently, and as stated elsewhere [8, 9], the rate of curve progression requires more time to be quantified graphically when the progression is small. Thus, the survey of the natural history of the patients varied from 9 months to 3 years, depending on whether the progression rate was greater than 12° or less than 2° per year (Fig. 1). When successive measures of Cobb angle, plotted over 3 years, remained within a horizontal "cloud", we concluded that it was a non-progressive scoliosis. Two of these long follow-ups were regressive and were classified as "non-evolutive scoliosis".

Since the computerized data analysis required only one Cobb measurement and one rib hump measurement for each patient, only one measurement of the supine and standing curves and one rib hump measurement were retained for double and treble major scolioses. These were the measurement for the main structural curve, selected by comparison of rib hump measurements. For this comparison, the lumbar rib hump measurement was multiplied by two. Computerized data analysis also required that measurements of the thoracic and lumbar rib hump may be of equal significance, consequently the measurement of hump for all lumbar curves were multiplied by two. The interpretation of the results took this point into account: the threshold of lumbar hump was divided by two after the statistical analysis.

Table 1 Regression coefficients of the quantitative parameters – supine angle, standing angle, rib hump measurement – with the rate of scoliosis progression

	Supine Cobb angle	Standing Cobb angle	Rib hump measurement
Progression rate (°/year)	0.68665	0.68212	0.56301

Table 2 Regression coefficients between age, bone age and the state of maturation at first examination

	Age	Maturation state
Bone age	0.58580	0.64071
Maturation state	0.74262	

Analysis of the data

We demonstrated in our previous studies that both initial Cobb angle in supine or standing position and initial rib hump measurements correlate with the rate of scoliosis progression [9, 12]. The rate of scoliosis progression is not, however, correlated with age, bone age or state of maturation. All these correlations were verified in the sample before the subjects were assigned between evolutive and non-evolutive scoliosis groups (Tables 1, 2).

Parameters for each subject of each of the two groups were then plotted on successive graphs, with the values for each subject represented by a distinctive conventional sign indicating whether or not this curve was evolutive. For each subject, two of the initial quantitative parameters were plotted: supine Cobb angle, standing Cobb angle or rib hump measurement (ordinate) versus age, bone age or state of maturation (abciss). These procedures were repeated for each qualitative subgroup of curve shape.

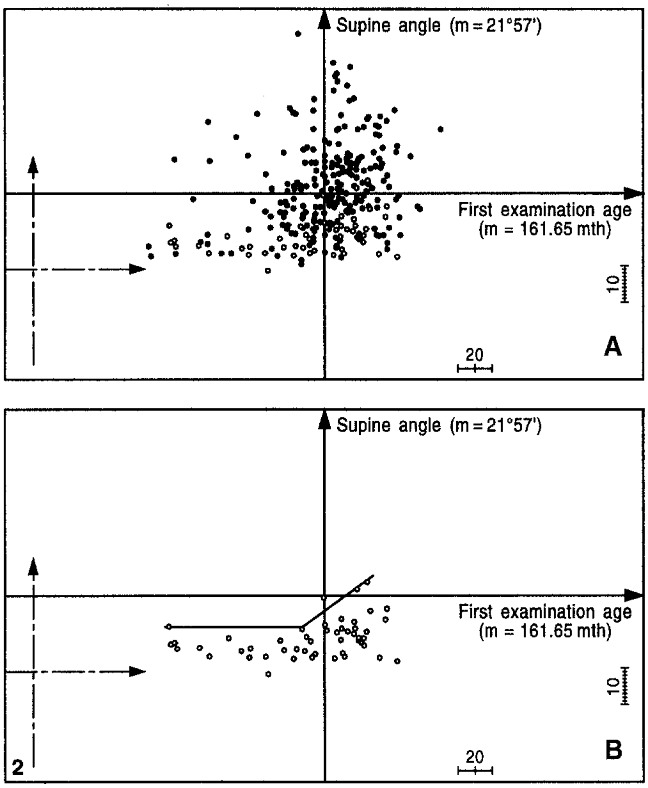
Results

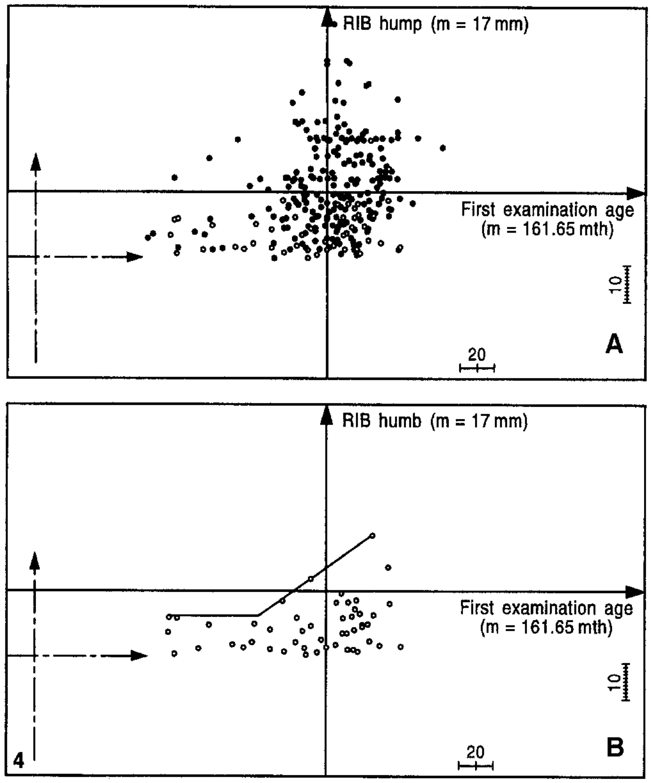
Table 3 shows the mean values of the parameters that describe the sample.

Figures 2, 3, 4 (A & B) where age is taken into account, demonstrate that the evolutive scolioses (●) are very scattered and most of them lie above the line, while the non-evolutive scoliosis cases (A) (○) are clustered together below

Table 3 Mean values of the parameters that describe the sample and mean rate of progression of the scoliosis according to the shape of the scoliotic curve

	Thoracic		Thoraco-lumbar		Lumbar		Double-major		Treble-major		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
No. of patients	61		69		39		125		32		326	
Age	159.9	29.8	161.2	28.9	164.0	21.9	162.7	14.0	161.7	23.6	161.9	24.5
Bone age	155.0	30.2	161.3	25.2	163.0	21.9	159.0	29.5	164.2	27.3	159.9	27.7
Supine Cobb angle	27.8	18.7	15.4	10.9	13.3	7.7	27.8	13.4	26.4	12.6	21.6	14.5
Standing Cobb angle	34.5	22.0	22.1	14.3	19.7	10.3	29.0	15.7	31.6	15.3	27.8	17.0
Rib hump measurement (mm)	21.2	18.1	8.7	7.2	13.2	10.5	20.4	12.5	18.5	9.2	17.0	13.2
Progression (°/year)	8.7	7.6	3.7	3.8	3.8	4.0	6.8	5.7	9.1	8.3	6.4	6.2





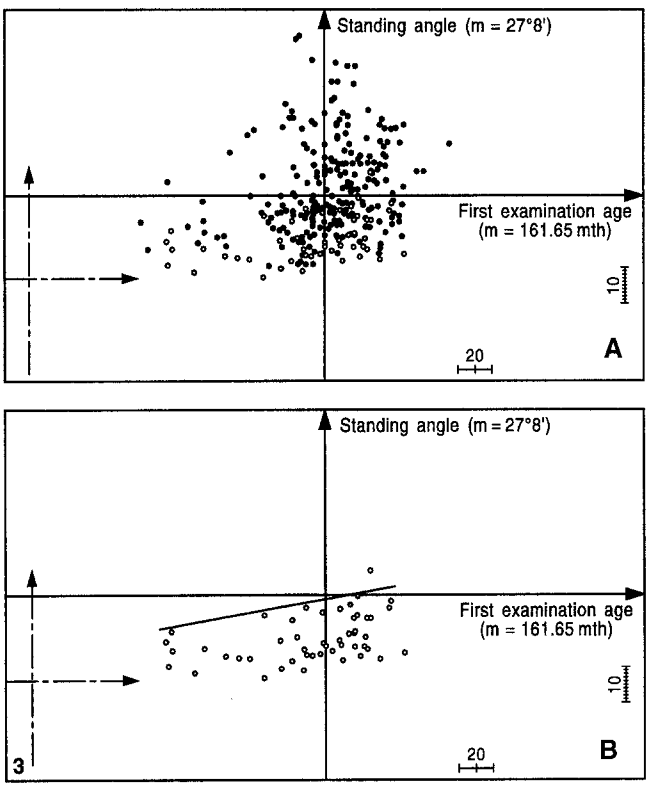


Fig. 2–4 When age and curve measurement data at first examination were taken into account, the supine angle, standing angle and rib hump values of non-evolutive scoliosis cases (○) are clustered together under the line, while the evolutive scolioses (●) are very scattered (**A** all the scolioses; **B** only non-evolutive scolioses). The line represents the threshold values of the supine Cobb angle, standing Cobb angle and rib hump measurement above which, for each age, the scoliosis will surely progress, but below which no conclusion or prognosis is possible

Table 4 Threshold values for supine and standing Cobb angle and rib hump measurement for all the samples according to state of maturation, calculated from analysis of the graphs relating to age, bone age and maturation state (see Materials and methods for explanation of states I–VI)

Maturation state	Supine Cobb angle (°)	Standing Cobb angle (°)	Rib hump measurement (mm)
State I	10	16	8
State II	10	16	10
State III	12	16	13
State IV	12	20	13
State V	19	24	17
State VI	21	25	17

the line. For this population, the lines represent the thresholds of the supine angle, standing angle or rib hump above which, for each age, scoliosis will surely progress, but below which no conclusion or prognosis is possible. This line provides thresholds for the supine angle, standing angle and rib hump measurement, whatever the shape of the scoliotic curve.

Table 5 Threshold values for supine and standing Cobb angle and rib hump measurement for each curve shape (thoracic, thoraco-lumbar, lumbar, double major) according to state of maturation, calculated from analysis of all the graphs related to age, bone age and state of maturation

	Thoracic		
	Supine Cobb angle (°)	Standing Cobb angle (°)	Rib hump (mm)
State I	13	12	6
State II	17	20	11
State III	17	20	11
State IV	17	20	11
State V	17	20	11
State VI	21	22	11
	Thoraco-lumbar		
	Supine Cobb angle (°)	Standing Cobb angle (°)	Rib hump (mm)
State I	9	20	8
State II	10	20	8
State III	12	20	8
State IV	12	20	8
State V	12	20	8
State VI	15	23	14
	Lumbar		
	Supine Cobb angle (°)	Standing Cobb angle (°)	Rib hump (mm)
State I	4	12	5
State II	9	13	7
State III	13	13	7
State IV	13	13	7
State V	15	24	8
State VI	15	24	8
	Double major		
	Supine Cobb angle (°)	Standing Cobb angle (°)	Rib hump (mm)
State I	5	10	8
State II	6	10	8
State III	12	14	8
State IV	12	23	20
State V	23	27	20
State VI	25	35	30

Because of the correlation between age, bone age and state of maturation, the threshold values established for each of these three parameters were similar. Since the higher levels of correlation were with state of maturation (Table 2) we suggest using only the thresholds of supine and standing Cobb angle and rib hump measurement related to these states of maturation (Table 4).

Since the mean rate of scoliosis progression decreases from treble curves to lumbar curves, taking into account scoliotic curve shape, bone age and state of maturation should provide lower thresholds for the less evolutive curve shapes. These thresholds are shown in Table 5.

Discussion and conclusion

Our subjects were children seen at R. Poincaré Hospital after their scoliosis was detected. Consequently it is not representative of a scoliotic population as an epidemiological study would be, which would include more minor scolioses and more non-evolutive scolioses. Children below four years of age are not represented, and the conclusions cannot therefore be applied to them. The accuracy with which the upper boundary of the cluster of points is defined depends on sample size. Consequently the results require confirmation by study of a greater sample. Moreover, the division of the sample in subsample of scoliosis shape, decreases each sample and consequently leads to an increase in the risk of error and reduces the accuracy of the thresholds for each curve shape. Nevertheless, analysis of the results demonstrated differences between curve shapes, with lower thresholds for lumbar curves and higher thresholds for double major curves. This study also indicates a particularly poor prognosis for triple major scolioses. Mean progression rate was the highest for this curve shape and only one case did not worsen.

The graphs show that many cases of scoliosis with supine or standing Cobb angle or rib hump measurement below the threshold values demonstrated worsening progression; consequently no prognosis can be made on the basis of these parameters, and monitoring is necessary, especially if the child is going through puberty, in which case check-ups should be every 3 months. If, on first examination, the parameters of a scoliotic patient exceed all of the three thresholds (supine and standing Cobb angle and rib hump measurement) the risk of worsening is much larger: the scoliosis will probably progress linearly as previously described [7, 10].

The thresholds were established for a population containing mainly girls. Since boys start puberty 2 bone-years later than girls, the threshold for pubertal boys should be read using their sexual maturation state.

The question is whether all three thresholds (supine Cobb angle, standing Cobb angle and rib hump measurements) must be reached before deciding on an evolutive prognosis. This does not appear to be so, since a scoliosis which has a parameter below the threshold at first examination may progress. We also know that for the same value of one of the three parameters, the values of the other parameters may vary greatly.

In conclusion, a combination of state of maturation, several measures of the scoliotic curve and curve shape provides the best basis for individual prognosis.

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