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GROWTH IN HEIGHT OF CHILDREN WITH SCOLIOSIS

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Treatment of scoliosis still presents considerable orthopaedic problems because our knowledge of the cause and development of the condition is so scanty. Even today as many as 80–90 per cent of all cases of structural scoliosis are of the idiopathic type.

It is, however, likely that progression of the condition requires the presence not only of the primary causal factor but also of other conditions such as growth and muscular imbalance.

It has long been known that growth in height is a *sine qua non* for the development of scoliosis and that most cases of vertebral body change cease to increase at the same time as growth of the spine ceases (Calvo 1957). The deformity also progresses most rapidly during the period of fast growth. James (1967) has shown that idiopathic structural scoliosis often makes its first structural appearance within three periods of life, periods during which growth in height is rapid, viz. 0–3 years (infantile scoliosis), 5–8 years (juvenile scoliosis) and after 10 years (adolescent scoliosis). The last group is the largest.

A search of the literature failed to reveal any more detailed studies of the relationship between growth in children with and without scoliosis. Duval-Beaupère (1971) and Duthie (1959, 1971) have studied the relationship between rate of growth and progression of structural scoliosis. Duval-Beaupère, however, did not notice any evident difference between growth pattern in scoliosis and in a normal population.

It was therefore decided to undertake an investigation of this point by comparing growth in height of a group of children with scoliosis,

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non-structural as well as structural, and in an age-matched group of children without scoliosis.

MATERIAL AND METHODS

Children with scoliosis

Included in the study were 1,616 children, 905 girls and 711 boys with scoliosis diagnosed over the years 1958–1967. The children were all residents of the city of Linköping and its environs. The age range was 6 to 19 years at the time of the first examination, 11.8 ± 3.0 (average ± s. d.) and 12.8 ± 2.3 for C-shaped and S-shaped cases in girls and 12.2 ± 2.9 and 13.0 ± 3.0 in boys, respectively.

All stages of scoliosis—both of structural and non-structural types—were included, ranging from very mild to occasional, extremely severe cases. All the cases were examined clinically. In standing position a plumb line was suspended from the spinal process of C VII to crena ani. The spinal processes were localized and marked on the skin. Scoliosis was defined as a deviation of 1 cm or more of the vertebral spinous processes from the line between vertebral process of the C VII and crena ani. The severity of scoliosis was measured and expressed in cm of deviation. In addition the child was investigated with regard to whether the deformity was completely corrected in sitting or lying position or by correcting a pelvic obliquity (non-structural scoliosis), or was permanent and withstood attempts at correction (structural scoliosis). A requirement for a case to be rated as structural scoliosis was also the presence of rotational deformity causing thoracic or lumbar deformity, observed with the patient in a forward-bending position.

The cases were subdivided into four main types:

Type 1. Left convex C-shaped curvature of the entire spine (66.2 per cent).
Type 2. Right convex C-shaped curvature of the entire spine (14.3 per cent).
Type 3. S-shaped scoliosis with right convexity proximally (12.6 per cent).
Type 4. S-shaped scoliosis with left convexity proximally (6.9 per cent).

The distribution of types of scoliosis among the sexes is demonstrated in Table 1. The severity of scoliosis expressed as maximal deviation in cm is presented in Tables 2 and 3.

Table 1. Distribution of cases among types and sexes (viewed from behind).

Sex	Type of scoliosis			
				
Boys	496	99	65	51
Girls	574	132	139	60

Table 2. Severity of C-shaped scoliosis.

Maximal deviation (cm)	Boys	Girls
1.0	261	325
1.5	267	289
2.0	53	70
2.5	9	14
> 2.5	5	8

Table 3. Severity of S-shaped scoliosis.

Maximal deviation (cm)	Boys	Girls
1.0	90	139
1.5	13	33
2.0	7	8
2.5	4	12
> 2.5	2	7

Roentgenograms were obtained in 598 of the cases. The clinical diagnosis of scoliosis according to the above was confirmed in all instances. In cases of S-shaped scoliosis, type and localization always agreed with the clinical finding. In 150 consecutive cases of clinically determined C-shaped scoliosis the diagnosis was confirmed except for seven children (4.7 per cent) where an S-shaped deformity was found roentgenographically. Left-right clinical localization always agreed with roentgenological examination. The height in standing position was recorded for all the children included in the study and used for the comparison of height between children with and without scoliosis.

In the C-shaped scoliosis 379 out of 595 boys and 521 out of 706 girls had non-structural scoliosis. In the S-shaped scoliosis 74 out of 116 boys and 161 out of 199 girls had structural scoliosis. 917 of the children were measured twice or more and the data of these cases were used for comparison of growth rates between children with and without scoliosis. No attempt was made to correct for the decrease in stature caused by the shortening of the trunk due to the scoliosis.

The method of clinical investigation provides a sufficiently accurate separation between children with and without scoliosis for the purpose of the present study. It does not, however, provide sufficient accuracy for the classification into more or less severe cases.

Control cases

Controls were schoolchildren from the city of Linköping who were matched with regard to age and year of birth to the children with scoliosis and who had been measured annually between the ages of 7 and 16. All these children came from the school most likely to represent a social cross section of the population of the city. The control cases were measured in September each year, whereas children with scoliosis were measured at the time of first examination, which was randomly spread over the year. Children already classified as having scoliosis were excluded from the control group. In order to investigate the reliability of the control sample in relation to the population at risk, two more schools in the city were included. In these children, altogether 247 (116 boys and 131 girls), the height had been measured at ages 7, 10, 11 and 13. There was full agreement between the controls and this additional sample. Moreover, data obtained from the population of Sweden (Karlberg et al. 1972) and Danish and Norwegian data (Andersen 1968, Skoleundersökning av barn i Oslo 1960) were studied for comparison (Figures 1 and 2).

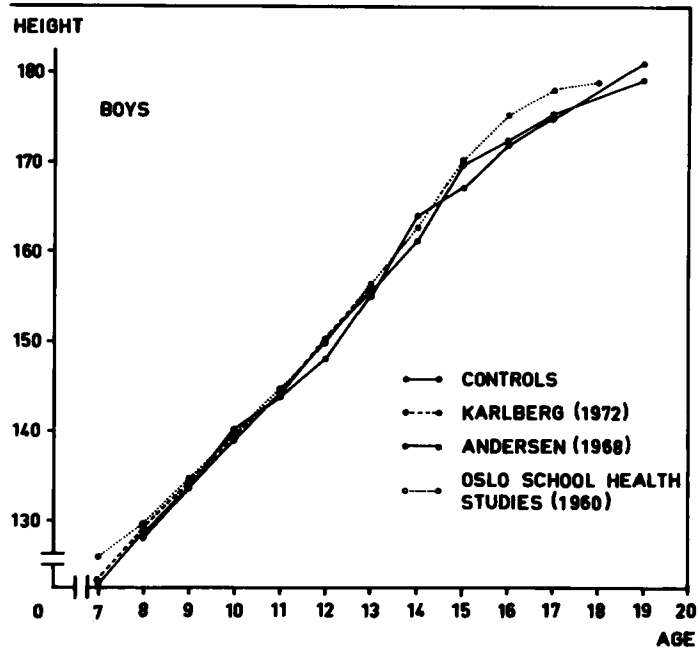

Figure 1. Controls in comparison to contemporary height studies: boys.

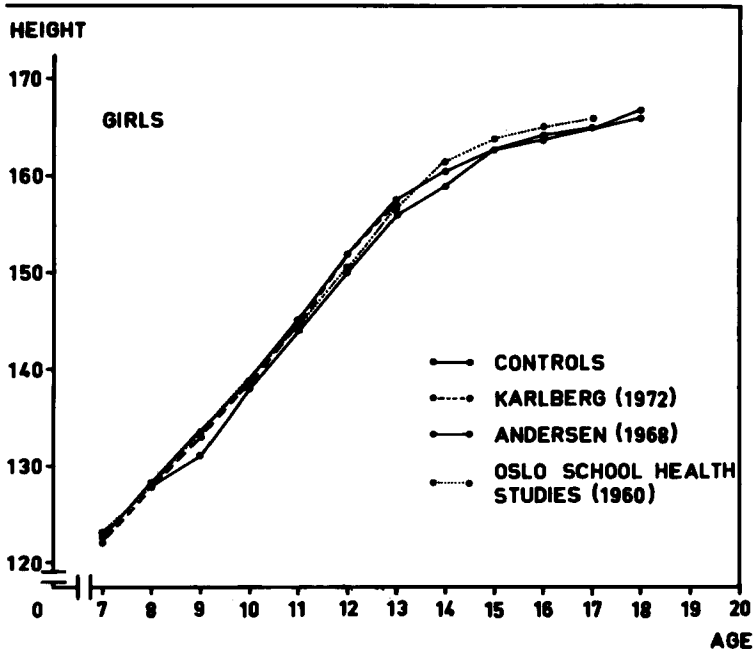

Figure 2. Controls in comparison to contemporary height studies: girls

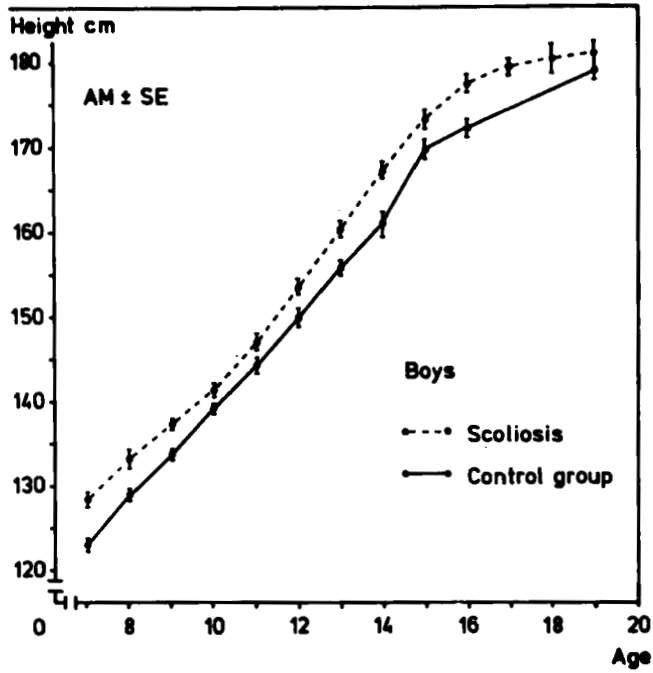

Figure 3. Comparison of height between boys with and without scoliosis.

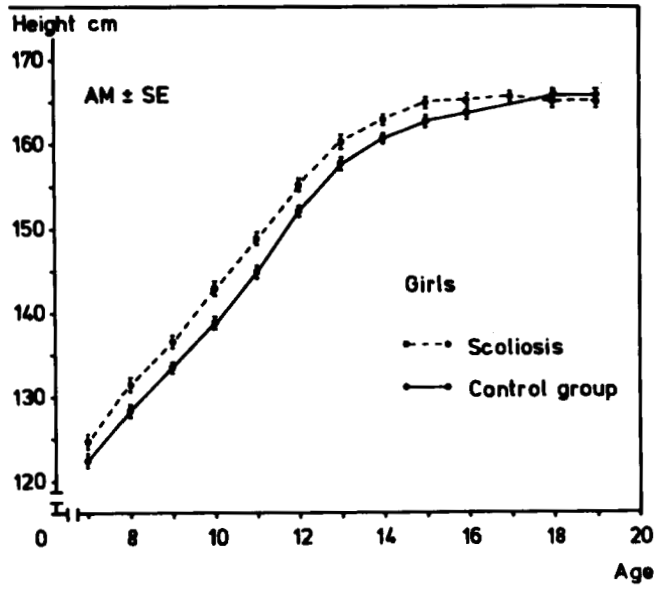

Figure 4. Comparison of height between girls with and without scoliosis.

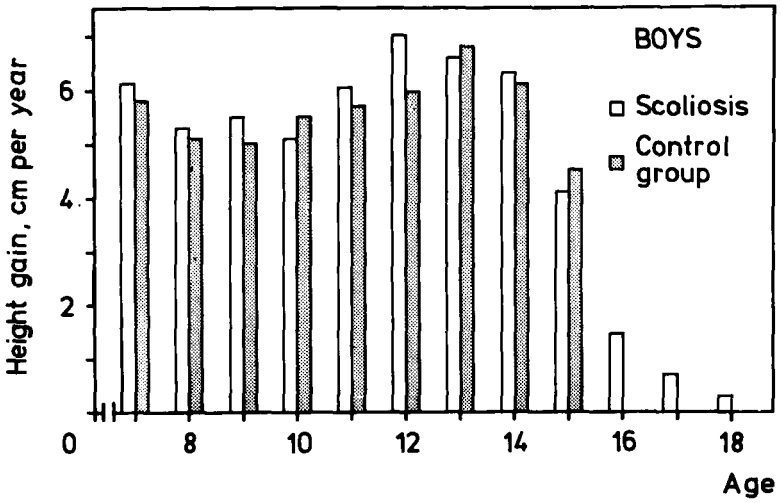

Figure 5. Annual growth in height of boys with and without scoliosis (No controls above 16 available).

In order to permit calculation of the height of adults as well, 150 girls aged 18 and 19, students of theoretical and vocational schools in the city, and 100 military servicemen aged 19, drawn from the same area, were included. The homogeneity of these data is demonstrated in Figures 1 and 2.

Standard statistical methods were applied to the data and differences with a probability level of 95 per cent or better are referred to as significant.

RESULTS

Children with scoliosis, non-structural as well as structural, were significantly taller than the control children, girls as well as boys, but in girls the difference evened out at the time of cessation of growth, i.e. at about 15. The same was found in boys, except that the difference was significant even at the age of 16 and possibly later (Figures 3 and 4, Table 4). The growth rates calculated on the longitudinal data are demonstrated in Figures 5 and 6 and in Tables 5 and 6. In boys as well as in girls in the controls there is a decreasing tendency in growth rate during the 8th and 9th years of life. However, this decrease does not occur or is at least significantly less pronounced in girls with scoliosis. The rapid growth immediately prior to puberty is less pronounced in girls with scoliosis. As a result the maximum difference in height between girls with and without scoliosis occurs at about the age of 10 (Figure 7) and after that slowly decreases.

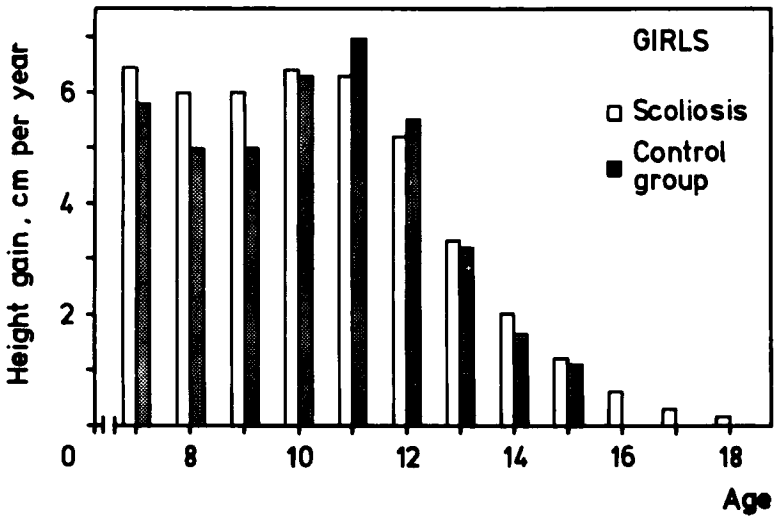

Figure 6. Annual growth in height of girls with and without scoliosis (No controls above 16 available).

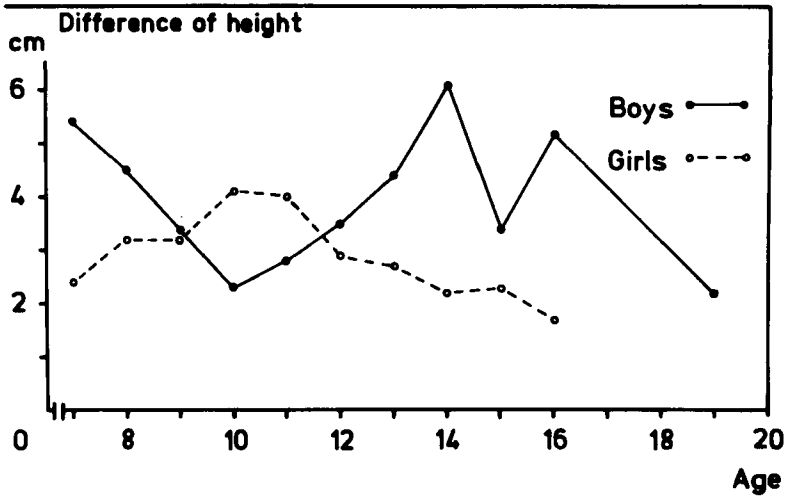

Figure 7. Difference in height between children with and without scoliosis.

In boys this pattern is less pronounced. There is a tendency towards a more rapid growth before the age of 13 in boys with scoliosis, and this results in a maximum difference between boys with and without scoliosis at about the age of 14 to 16 (Figure 7). It should, however,

Table 4. Comparison of height between children with and without scoliosis.

Age years	Boys						Girls					
	Scoliosis			Controls			Scoliosis			Controls		
	Mean	n	SD	Mean	n	SD	Mean	n	SD	Mean	n	SD
7 (6.5–7.5)	128.4	30	4.4	123.0	125	4.9	124.9	29	5.5	122.5	116	4.9
8 –	133.3	55	5.8	128.8	103	5.5	131.6	76	5.6	128.4	95	5.1
9 –	137.2	64	6.1	133.8	119	5.5	136.8	114	6.3	133.6	100	5.3
10 –	141.4	91	6.7	139.1	121	5.7	143.0	157	7.1	138.9	110	5.5
11 –	147.0	117	7.0	144.2	119	6.3	149.0	197	7.8	145.0	101	5.9
12 –	153.5	125	7.5	150.0	113	6.6	155.2	227	8.1	152.3	102	5.8
13 –	160.2	157	8.1	155.8	113	6.6	160.4	261	6.7	157.5	103	6.1
14 –	167.2	173	8.8	161.1	86	7.7	162.6	269	6.1	160.6	100	5.0
15 –	173.3	173	7.8	169.9	94	7.0	164.9	175	5.2	162.6	55	5.0
16 –	177.5	108	6.5	172.3	104	5.9	165.0	189	6.0	163.7	98	4.9
17 –	179.6	73	6.2				165.7	125	6.2			
18 –	180.0	45	10.7				165.0	51	5.8	165.8	98	6.0
19 –	181.3	19	6.3	179.1	98	6.2	165.0	18	5.5	165.7	57	6.1
20 –							164.6	8	6.1			

be noted that already at the time of diagnosis and first examination, the difference in boys with and without scoliosis is considerable.

Children with S-shaped, structural scoliosis could not be demonstrated to differ in height from children with non-structural C-shaped scoliosis (Tables 7 and 8).

DISCUSSION

It is generally accepted that structural scoliosis can only develop in the growing spine. This has been demonstrated by an increased frequency of diagnosis of scoliosis and the progression of the condition in periods of rapid growth and by the fact that structural scoliosis usually becomes stationary after the end of the period of growth. However, the difference between the pattern of growth in height of children with and without scoliosis in non-structural as well as structural cases demonstrated here is a novel observation.

It must be assumed that growth and height of a given individual are genetically governed. At any rate, it is generally accepted that the final height of a given individual is predetermined. But it is not known with certainty whether the time and rate of growth are under genetic control. According to Tanner (1961, 1962), however, both final body

Table 5. Comparison of growth rate between boys with and without scoliosis.

Age years	Growth rate (cm/year)							
	Scoliosis				Controls			
	Mean	n	SD	SE	Mean	n	SD	SE
7	6.1	31	1.2	0.2	5.8	100	1.5	0.2
8	5.3	39	1.7	0.3	5.2	100	1.4	0.1
9	5.5	44	1.8	0.3	5.0	100	1.3	0.1
10	5.1	72	1.5	0.2	5.5	100	1.8	0.2
11	6.1	86	2.2	0.2	5.7	100	1.7	0.2
12	7.0	86	2.8	0.3	6.0	100	1.9	0.2
13	6.6	115	2.3	0.2	6.8	65	2.3	0.3
14	6.3	115	2.7	0.3	6.1	60	2.1	0.3
15	4.1	87	2.4	0.3	4.5	28	2.0	0.4
16	1.6	59	1.6	0.2				
17	0.7	44	0.9	0.1				
18	0.3	24	0.5	0.1				
19	0.1	10	0.3	0.1				

Table 6. Comparison of growth rate between girls with and without scoliosis.

Age years	Growth rate (cm/year)							
	Scoliosis				Controls			
	Mean	n	SD	SE	Mean	n	SD	SE
7	6.4	27	1.2	0.2	5.8	98	1.3	0.1
8	6.0	73	1.7	0.2	5.1	100	1.4	0.1
9	6.1	98	1.9	0.2	5.0	100	1.4	0.1
10	6.4	138	2.2	0.2	6.3	100	2.1	0.2
11	6.4	171	2.2	0.2	7.0	100	2.1	0.2
12	5.2	192	2.1	0.3	5.5	100	2.1	0.2
13	3.3	212	2.2	0.2	3.2	95	2.0	0.2
14	2.0	223	1.6	0.1	1.6	70	1.4	0.2
15	1.2	190	1.4	0.1	1.1	47	1.1	0.2
16	0.6	129	0.8	0.1				
17	0.4	65	0.7	0.1				
18	0.2	26	0.5	0.1				

height and the shape of the growth curve are genetically governed but completely or partly independent of one another. The growth pattern may vary from one individual to another in a given population (Bayley 1956, Tanner et al. 1966). Some attain adult height, body weight and sexual maturity relatively early, whereas others grow slowly, are

Table 7. Comparison of height between boys with functional (C-shaped) and structural (S-shaped) scoliosis.

Age years	Functional C-shaped scoliosis			Structural S-shaped scoliosis		
	Mean	n	SD	Mean	n	SD
11	146.9	50	5.4	148.8	4	4.9
12	154.7	44	7.5			
13	160.9	89	9.7	161.5	18	6.9
14	166.2	73	8.0	166.9	12	7.2
15	174.2	77	8.1	172.6	23	7.8
16	176.4	46	6.8	176.8	17	6.2

Table 8. Comparison of height between girls with functional (C-shaped) and structural (S-shaped) scoliosis.

Age years	Functional C-shaped scoliosis			Structural S-shaped scoliosis		
	Mean	n	SD	Mean	n	SD
10	142.4	81	7.8			
11	149.3	70	7.9	150.0	19	6.1
12	154.9	59	7.3	155.2	12	6.8
13	160.8	114	6.1	160.0	51	7.1
14	163.4	93	6.7	162.5	26	5.5
15	164.7	62	5.8	165.4	34	6.0
16	165.4	42	6.9	164.9	19	6.1

relatively short in childhood, but grow more rapidly towards the end of their teens and may continue to grow for a few years after the former group has ceased to grow. The final adult height of both groups may then be equal.

The genetically predetermined height is, however, influenced by other conditions such as hormonal disturbances and environmental factors, especially socio-economic ones.

The investigation showed that children with different types of scoliosis, both boys and girls, above 7 years of age are significantly taller than normals during the growth period, but in this material this difference in height of children with scoliosis seems to diminish with increasing age. The annual growth in height before the age of 10 of the girls with scoliosis differed significantly from that of their controls.

The girls with scoliosis grew faster than their controls up to this age but slower afterwards. During the first few years after puberty the rate of growth was roughly the same for both groups, but then seemed to decrease earlier in the girls with scoliosis than in the controls.

In the boys the difference in annual growth was not so clear. The tendency, however, pointed towards a slower growth in the controls up to 12 years of age, though the difference was not statistically significant. Yet here, too, the boys with scoliosis were taller than their controls.

The scoliotic children of both sexes ceased to grow earlier than their controls. As this material was not corrected for the shortening of the trunk due to the scoliosis there might be a possibility that a progression of the scoliosis has negatively influenced the measured height.

This suggests that children growing quickly are more exposed to the risk of the condition than those growing more slowly. One might very well imagine that rapid growth might interfere with the posture of the trunk, which, together with other factors predisposing to scoliosis, may result in a disorder of the growth of the spine and a consequent development of a structural scoliosis. What argues against this growth pattern having anything to do with the primary cause of scoliosis or being one sign and scoliosis another of a clinical entity is that all types of scoliosis, both non-structural and structural, of the series showed a uniform growth pattern and that all differed significantly in this respect from the controls. The number of severe cases was, however, too small to demonstrate with certainty any difference between types of scoliosis.

Figure 7 gives the difference in height between the controls and the scoliotic boys and girls. At first sight the two curves seem to go in opposite directions, but on closer analysis it will be realized that both curves may perhaps be similar but with a phase lag, the boys showing a similar tendency, but 2–3 years later, which also is roughly the interval between puberty in boys and girls.

The declining part of the curve for 7- to 10-year-old boys may correspond to what one might expect in girls before 7–8 years of age. But this is only an assumption because the number of girls below 7 years was too small to allow any conclusion. On the other hand, the difference in growth between children with and without scoliosis was increased during puberty for both sexes and afterwards decreased up to adult age.

Figure 7 also demonstrates that the difference between the height of

scoliotic children and their controls varied considerably. This argues for the generally accepted assumption of a correlation between the period of rapid growth and the onset of or, at any rate, progression of scoliosis. Furthermore, these observations suggest that those children who grow quickly earlier in life than average are more inclined to develop scoliosis under otherwise equal conditions.

SUMMARY

Growth in height between the ages of 7 and 19 in individuals with scoliosis, both non-structural and structural, and living in Linköping or its environments was compared with that of sex- and age-matched controls. The loss in body height due to scoliosis *per se* was ignored. The true difference of growth in height was therefore greater than that recorded. The controls agreed in height with three other height measuring studies in Scandinavia.

Between the ages of 7 and 15 years the boys and the girls with scoliosis were taller than their controls. Growth in height seemed to cease 1–2 years earlier in the patients than in the controls. In adult age both groups seemed to be equally tall. Between the ages of 7 and 9 the patients with scoliosis grew faster than their controls. This suggests that the prepuberal growth phase occurs earlier in children with scoliosis.

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