STATURE AND ITS COMPONENTS IN ADOLESCENT IDIOPATHIC SCOLIOSIS

CEPHALO-CAUDAL DISPROPORTION IN THE TRUNK OF GIRLS

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Stature and its components were examined in 143 girls aged 11 to 15 years with adolescent idiopathic scoliosis. Correction was made for loss of height due to the lateral spinal curvature, and the findings were compared with those from 202 healthy girls of similar age. Using three components of stature (suprapelvic, pelvic and subischial heights) we were able to show that the relatively greater stature of girls with adolescent idiopathic scoliosis was due to changes in the pelvis and lower limbs but not significantly in the spine.

Suprapelvic height was reduced relative to subischial height; this probably represents the growth pattern of predominantly ectomorphic individuals, reflecting the physique of many of these girls. Pelvic height was disproportionately increased, and this is considered to be a true rather than an apparent difference. Cephalo-caudal disproportion involving two segments suggests a common mechanism of causation which is unlikely to be secondary to the scoliosis. These physical features may in some way be associated with a predisposition to progression of the scoliosis.

Between birth and skeletal maturity there is normally a change in the proportion of trunk length to leg length. In the prepubertal child trunk length, usually measured as sitting height, becomes a smaller proportion of total height because of greater leg growth. The adolescent growth spurt has two main components, an earlier spurt in leg growth and a later one of trunk growth which overlap. The spinal component of growth, particularly in boys, is greater and increases the proportion of trunk length in the final adult stature (Hejinian and Hatt 1929; Tupman 1962; Anderson, Hwang and Green 1965; Tanner 1978).

The adolescent growth spurt in sitting height in boys is generally considered to be due to androgens. In contrast, in adolescent girls growth hormone is as much responsible for the increase in sitting height as it is for leg growth (Tanner *et al.* 1976; Burns *et al.* 1981). This sex difference in the hormonal control of trunk growth is relevant to the findings reported in this paper and may in some way be linked to the predilection of girls to develop progressive scoliosis during adolescence (Sizonenko 1978; Skogland and Miller 1980).

It is generally considered that rapid growth of the trunk is one factor in the development and progression of adolescent idiopathic scoliosis (Risser and Ferguson 1936). However, few papers have used longitudinal data to analyse the velocity of growth in relation to progression of the spinal deformity (Duthie 1959, 1971; Duval-Beaupère 1970, 1971; Willner 1974a; Dickson and Sevitt 1982).

In contrast, several papers use cross-sectional data to examine stature in children with juvenile and adolescent idiopathic scoliosis (Willner 1974a, 1974b, 1975a; Nordwall and Willner 1975; Burwell, Dangerfield and Vernon 1977; Burić and Momčilović 1982; Leong *et al.* 1982). The findings have been generally consistent and have shown that, after correcting for loss of height due to lateral spinal curvature, stature was significantly greater in scoliotic patients than in controls (but see Drummond and Rogala 1980). The method used to correct for loss of trunk height was that of Bjure and his colleagues (Bjure, Grimby and Nachemson 1968; Bjure and Nachemson 1973). Overall, the stature of scoliotic girls was about 5 cm greater than that of healthy girls of similar age, suggesting a significantly different growth pattern (Willner 1975b). The increased height was found in a longitudinal study to be present before the onset of the scoliosis (Willner 1974a).

Two recent school screening studies using uncorrected height found no evidence that children with structural scoliosis were taller than controls (Drummond and Rogala 1980; Taylor and Slinger 1980). In a third school screening study, Dickson and Sevitt (1982) measured the height of boys and girls with idiopathic scoliosis and suggested that increased stature was

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related to the progression rather than to the presence of scoliosis.

A few workers have examined whether the increase of stature of scoliotic girls was in the spine, or the lower limbs, or in both (Willner 1975b; Burić and Momčilović 1982). Again, the findings were consistent and showed no evidence of disproportion between trunk and lower limbs (but see Leong *et al.* 1982). A ratio method involving measurements of trunk height and leg length has been used to evaluate early spinal fusion in the growing child (Risser *et al.* 1973).

In this paper we examine height in terms of its components and report a cephalo-caudal skeletal disproportion in the trunks of girls with adolescent idiopathic scoliosis. A preliminary report of these findings has been published (Nicolopoulos, Burwell and Webb 1984).

MATERIAL AND METHODS

Patients. The patients were a consecutive series of 143 girls, aged 11 to 15 years, diagnosed as having adolescent idiopathic scoliosis (AIS) and attending Harlow Wood Orthopaedic Hospital during the years 1973 to 1981. This was in the period before school screening was started in Nottinghamshire. The average angle of spinal curvature was 39° (range 6° to 86°). Most patients were examined for this study during their first attendance and before treatment had been started, but 11 of the girls had worn a Milwaukee or Boston brace for less than three months and 23 had worn a brace for more than three months. None had had a surgical operation. The wearing of a brace was shown not to influence the findings, and data from all patients were analysed.

Radiographs. Anteroposterior spinal radiographs taken at or near the first clinical examination were measured by one observer (RGB), for all spinal curve angles, using Cobb's method (1948). For each patient either the major structural curve or the larger curve in double spinal curves was used for correcting stature. No correction was made for the spinal curves of 10° or less seen in six girls. The bone ages of the patients were not assessed. The spinal curve angles in each age group were as follows: 11 years, 34.4° ± 15.7°; 12 years, 40.3° ± 18.0°; 13 years, 40.2° ± 18.7°; 14 years, 39.0° ± 16.2°; and 15 years, 38.2° ± 18.5° (mean and standard deviation).

Measurements. Each girl was measured by one observer (RGB) using Holtain equipment for: standing height, sitting height, total lower limb lengths (left and right) and bi-iliac width using the methods described in Burwell *et al.* (1978).

Calculations. These were made to give figures for suprapelvic height, pelvic height and subischial height as reported in Merriam *et al.* (1983) (Fig. 1). Subischial height was standing height minus sitting height. Standing height, sitting height and suprapelvic height were each corrected for loss of height due to lateral spinal curvature using the formula of Bjure and Nachemson (1973) ($\log y = 0.011x - 0.177$, where y is trunk height loss and x is

Fig. 1

Diagram to show the measurements made on each child and from them the heights obtained by calculation.

the angle of lateral spinal curvature). Lower limb length was the average of both lower limbs measured by a tape from anterior superior iliac spine to medial malleolus.

Standard deviation score (SDS). This was calculated for standing height and for sitting height using Tanner's figures (1978); and for suprapelvic height, pelvic height and subischial height using figures from our control series. The standard deviation score (SDS) of a body measurement such as stature was obtained from the formula:

$$\text{SDS of stature} = \frac{\text{stature of child} - \text{mean stature at given age}}{\text{standard deviation at given age}}$$

The use of standard deviation scores enabled data from different age groups to be pooled for statistical analysis (Burwell, Vernon and Dangerfield 1980).

Controls. The controls were 202 healthy girls aged 11 to 15 years. All had clinically straight spines and had been included in a previous study (Burwell *et al.* 1983). All measurements were again made by the same single observer (RGB).

Error study. A group of 20 healthy boys and girls aged 11 to 14 years were examined twice by one observer (RGB). The error for each measurement was as follows: suprapelvic height ± 3.1 mm, pelvic height ± 4.1 mm and subischial height ± 2.9 mm (standard deviation of measurement differences/√2). The mean error for each skeletal region was: suprapelvic height 0.45%; pelvic height 7.34%; and subischial height 0.50%. The error for stature and sitting height is given elsewhere (Burwell *et al.* 1980).

The data were analysed by a computer using several statistical methods.

RESULTS

Measurements (Table I)

Standing height: that of the girls with AIS was significantly greater than that of the control girls for each age group from 12 to 15 years.

Table I. Measurements of girls with adolescent idiopathic scoliosis (AIS) compared with those of control girls (mean $\pm$ 1 standard deviation in centimetres, height corrected for scoliosis)

Age (years)	Group	Number	Standing height	P	Sitting height	P	Lower limb length	P
11	Control	23	146.2 $\pm$ 5.2	NS	77.4 $\pm$ 3.3	NS	75.6 $\pm$ 3.3	NS
	AIS	11	147.3 $\pm$ 9.3		78.8 $\pm$ 4.7		75.7 $\pm$ 5.6	
	Difference		+ 0.75%		+ 1.81%		+ 0.13%	
12	Control	49	152.0 $\pm$ 6.9	**	79.8 $\pm$ 3.9	**	79.1 $\pm$ 4.2	***
	AIS	24	156.9 $\pm$ 6.4		82.4 $\pm$ 3.0		83.0 $\pm$ 5.3	
	Difference		+ 3.22%		+ 3.26%		+ 4.93%	
13	Control	46	157.2 $\pm$ 6.6	*	82.8 $\pm$ 3.5	NS	81.6 $\pm$ 4.1	**
	AIS	36	160.6 $\pm$ 9.0		84.2 $\pm$ 4.6		84.9 $\pm$ 5.5	
	Difference		+ 2.16%		+ 1.69%		+ 4.04%	
14	Control	38	159.7 $\pm$ 6.0	**	84.4 $\pm$ 3.5	**	82.6 $\pm$ 4.2	**
	AIS	47	163.6 $\pm$ 6.7		86.7 $\pm$ 3.4		85.8 $\pm$ 5.1	
	Difference		+ 2.44%		+ 2.73%		+ 3.87%	
15	Control	46	159.5 $\pm$ 8.3	*	84.9 $\pm$ 3.5	NS	82.0 $\pm$ 4.6	**
	AIS	25	163.9 $\pm$ 7.3		86.7 $\pm$ 5.7		85.3 $\pm$ 3.5	
	Difference		+ 2.76%		+ 2.12%		+ 4.02%	

P, probability of statistical significance (Student's *t*-test): *0.01 < *P* < 0.05; **0.001 < *P* < 0.01; ****P* < 0.001; NS, not significant.

$$\text{Difference \%} = \frac{\text{mean (AIS)} - \text{mean (control)} \times 100}{\text{mean (control)}}$$

Sitting height: that of the girls with AIS was significantly greater than that of the controls for two age groups (12 years and 14 years).

Lower limb length: that of the girls with AIS was significantly greater than that of the controls for each age group from 12 to 15 years.

Bi-iliac width: that of the girls with AIS was not significantly different from that of the controls except at 14 and 15 years when it was significantly greater (0.001 < *P* < 0.01 and 0.02 < *P* < 0.05 respectively).

Calculations (Table II, Figs 2 and 3)

Suprapelvic height: that of the girls with AIS was not significantly different from that of the controls for any age group from 11 to 15 years.

Pelvic height: that of the girls with AIS was greater than

that of the controls at a very highly significant level, for each age group from 12 to 14 years, and still significant at 15 years.

Subischial height: that of the girls with AIS was significantly greater than that of the controls for two age groups (12 and 15 years).

Skeletal proportions

Relative contribution of different components of stature to the increased height of girls with adolescent idiopathic scoliosis (Table III). The girls with AIS showed an increase of about 2% to 3% over the controls for stature, sitting height and subischial height. Suprapelvic height showed an increase of up to 1.1 cm (1.6%). Pelvic height was increased up to 1.7 cm, with a 25% increase over the controls. Hence, the stature increase in girls with AIS is

Table II. Calculated results for girls with adolescent idiopathic scoliosis compared with those for control girls (mean $\pm$ 1 standard deviation in centimetres, height corrected for scoliosis)

Age (years)	Group	Number	Suprapelvic height	P	Pelvic height	P	Subischial height	P
11	Control	23	70.6 $\pm$ 3.0	NS	6.8 $\pm$ 1.6	NS	68.8 $\pm$ 2.9	NS
	AIS	11	71.7 $\pm$ 4.3		7.2 $\pm$ 0.9		68.5 $\pm$ 5.2	
	Difference		+ 1.56%		+ 5.88%		- 0.44%	
12	Control	49	72.9 $\pm$ 3.6	NS	6.8 $\pm$ 1.5	***	72.3 $\pm$ 3.8	*
	AIS	24	73.9 $\pm$ 3.0		8.5 $\pm$ 1.7		74.5 $\pm$ 4.6	
	Difference		+ 1.37%		+ 25.00%		+ 3.04%	
13	Control	46	75.6 $\pm$ 3.4	NS	7.2 $\pm$ 1.7	***	74.4 $\pm$ 3.8	NS
	AIS	36	75.7 $\pm$ 4.4		8.5 $\pm$ 1.5		76.4 $\pm$ 5.4	
	Difference		+ 0.13%		+ 18.06%		+ 2.69%	
14	Control	38	77.1 $\pm$ 3.2	NS	7.2 $\pm$ 1.3	***	75.4 $\pm$ 3.9	NS
	AIS	47	77.9 $\pm$ 3.4		8.8 $\pm$ 1.6		76.9 $\pm$ 4.8	
	Difference		+ 1.04%		+ 22.22%		+ 1.99%	
15	Control	46	77.9 $\pm$ 3.6	NS	7.0 $\pm$ 1.6	*	75.3 $\pm$ 4.2	*
	AIS	25	78.7 $\pm$ 4.9		8.0 $\pm$ 2.0		77.3 $\pm$ 3.3	
	Difference		+ 1.03%		+ 14.29%		+ 2.66%	

See footnotes to Table I

Fig. 2

Fig. 3

Figure 2—Suprapelvic height in girls with adolescent idiopathic scoliosis (AIS) and healthy girls (mean ± 2 standard errors). There is no statistically significant difference between the scoliotic and healthy girls at any age (NS, not significant). Figure 3—Pelvic height in girls with adolescent idiopathic scoliosis (AIS) and healthy girls (mean ± 2 standard errors). There is a very highly significant difference between the scoliotic and the healthy girls at 12, 13 and 14 years of age (***, $P < 0.001$) with a less significant difference at 15 years (*, $0.02 < P < 0.05$; NS, not significant).

contributed to mainly by increases in pelvic and subischial heights (together 78%) and less so by suprapelvic height (22%).

Proportion of sitting height to leg length. This was studied, using the sitting height/stature centile chart of

Table III. Summary of the differences in results for girls with adolescent idiopathic scoliosis (AIS) and those for age-matched control girls

Component of stature	Maximum mean absolute increase AIS over control	Increase of components per cent
Standing height	Up to 4.9 cm (12 years)	3.2
Sitting height	Up to 2.6 cm (12 years)	3.3
Suprapelvic height	Up to 1.1 cm (11 to 15 years)	1.6
Pelvic height	Up to 1.7 cm (12 years)	25
Subischial height	Up to 2.2 cm (12 years)	3.0

Tanner (1978). Girls aged 12 to 15 years with AIS mainly fell within the 3rd to 97th centiles, but there was an apparent excess of girls below the 50th centile; controls were evenly distributed on this chart. The ratio of sitting height to subischial height did not reveal a significant difference between girls with AIS and the control girls except at 13 years (Mann-Whitney test). There is therefore little or no evidence to suggest any relative disproportion between trunk length and leg length in girls with AIS.

Proportion of suprapelvic height to leg length (Table IV). The ratios of suprapelvic height to subischial height were calculated and showed that in scoliotic girls, as against the controls, suprapelvic height was significantly *decreased* in relation to subischial height in each age group from 12 to 15 years. The significance of the ratios of suprapelvic height to bi-iliac width are also given in Table IV.

This finding was confirmed by calculating, for each girl with AIS, suprapelvic height recorded as a standard deviation score (SDS) *minus* the subischial height SDS (Tanner and Whitehouse 1982); this calculation gives a measure of relative spinal shortening and the mean difference for each age group was: 11 years, +0.5 SD; 12 years, -0.4 SD; 13 years, -0.6 SD; 14 years, -0.1 SD; and 15 years, -0.3 SD. Thus in girls with AIS suprapelvic height was about one-half a standard deviation less than the standard deviation for subischial height. There was no correlation between suprapelvic height SDS and pelvic height SDS.

Proportion of pelvic height to other skeletal measurements (Table IV). Ratios were calculated for each of the follow-

Table IV. The significance of the ratios of suprapelvic height and pelvic height to some other skeletal measurements in girls with AIS compared with controls (Mann-Whitney test)

Age (years)	Ratio of suprapelvic height to		Ratio of pelvic height to		
	Subischial height	Bi-iliac width	Suprapelvic height	Subischial height	Bi-iliac width
11	NS	NS	NS	NS	NS
12	Decreased**	NS	Increased***	Increased***	Increased***
13	Decreased***	NS	Increased***	Increased**	Increased***
14	Decreased*	Decreased*	Increased***	Increased***	Increased***
15	Decreased**	Decreased*	Increased*	Increased*	Increased*

Decreased and increased refer to the girls with AIS compared with controls

Probability of statistical significance: * $0.01 < P < 0.05$; ** $0.001 < P < 0.01$; *** $P < 0.001$; NS, not significant

Fig. 4

Pelvic height (expressed as standard deviation scores ± 2 standard errors) for girls with AIS, and healthy control groups of tall girls and short girls (see text).

ing pairs of measurements: pelvic height to suprapelvic height, pelvic height to subischial height and pelvic height to bi-iliac width. The results show that in scoliotic girls compared with controls, pelvic height was significantly increased relative to each of the other measurements for the age groups from 12 to 15 years.

Comparison of pelvic height in scoliotic girls with that in tall control girls (Fig. 4). Most girls with AIS in each age group were about 3 to 5 cm taller than the controls (Table I). In order to examine whether the increased pelvic height of the scoliotic girls was due merely to increased stature, the standard deviation score for pelvic height was calculated for each of the 143 girls with AIS and for 48 control girls whose stature was on or above the 75th centile. The average standing height of these tall control girls was 6 to 7 cm greater than that of the controls of similar age and they were significantly taller than the scoliotic girls. Despite this, as shown in Figure 4, the pelvic height of the girls with AIS was greater than that of the tall control girls, the difference being statistically very highly significant ($P < 0.001$, Mann-Whitney test, two-tailed probability). Figure 4 also compares the pelvic height of the 48 tall control girls with that of 65 short control girls (height on or below the 25th centile), the difference being very significant ($0.001 < P < 0.01$). The pelvic height SDS was not significantly different in 23 girls who had worn a brace for three months or more from that of girls who had not worn a brace.

These results show that pelvic height in healthy girls is a function of stature; that the increased pelvic height in scoliotic girls is not due solely to their increased stature; and that this difference is not due to wearing a brace.

DISCUSSION

Our findings confirm earlier work which showed that girls with adolescent idiopathic scoliosis were taller than controls of similar age. This difference was found to be consistent for standing height and less consistent for sitting height and for subischial height.

The proportion of sitting height to subischial height was again shown not to differ between the groups. How-

ever, when stature was separated into other components (suprapelvic height, pelvic height and subischial height), a dual cephalo-caudal disproportion was revealed in the trunk of the scoliotic girls.

Suprapelvic height. Suprapelvic height is a better indicator of the length of the spine than is sitting height (or stem length) which includes the pelvis; we have reported observations on this for healthy children (Nicolopoulos, Burwell and Webb 1985). The present findings show that suprapelvic height was similar in girls with AIS and controls. This confirms the work of Skogland and Miller (1981) who made radiological measurements of the thoracolumbar spine and found scoliotic spines to be 1% longer than control spines, though this was not statistically significant.

The close similarity of our findings (Table III) with those of Skogland and Miller suggests that the radiological method of Bjure and Nachemson (1973) gives a reasonably accurate correction of spinal length (Taylor and Slinger 1980). Moreover, the value of this method as we have used it has been confirmed by Hodgett (1985). A caveat is, of course, that these methods of correction for loss of height use only two-dimensional measurements of a three-dimensional deformity (Roaf 1980). This problem may be resolved in the future by the measurement of images produced by nuclear magnetic resonance or ultrasound.

In girls with adolescent idiopathic scoliosis there is the paradox that suprapelvic height is "normal" (or more correctly, not detectably abnormal) despite the fact that their stature is significantly greater than that of control girls. Moreover, in the scoliotic girls, suprapelvic height was reduced in relation to subischial height when this ratio was compared with that of controls.

The growth pattern of predominantly ectomorphic individuals is of trunk shortening relative to leg length (Tanner and Whitehouse 1982). This is probably the physique of many girls who develop AIS, a hypothesis which is supported by the finding that in girls with AIS, despite their increased stature, bi-iliac width is not significantly different from controls at 12 to 13 years. Although it is generally agreed that scoliotic girls are commonly "tall and lean", we know of no formal appraisal of their physique, though some information is available for healthy girls (Tanner and Whitehouse 1982).

What then, is the connection between a relatively short spine and selection from the population which leads to the development of AIS in some children? Previous work on this has used stature (Willner 1975a; Dickson and Sevvitt 1982) and the ratio of vertebral body height to width (Skogland and Miller 1981; Glasbey 1983; Taylor and Twomey 1984). The latter indicates increased slenderness compared with controls and may merely reflect the vertebral shape of predominantly ectomorphic subjects. Dickson *et al.* (1984) have suggested that the susceptibility of a small number of young adolescent girls to develop AIS is linked to an age-related

pattern of sagittal spinal curves and especially the observation that kyphosis is least pronounced at 10 to 12 years (Willner and Johnson 1983). This Swedish report has been confirmed in Britain (Lowden, Burwell and Webb 1985) but, in contrast, healthy Japanese children are reported to show an increased kyphosis at 11 to 12 years (Suzuki *et al.* 1981).

These clinical and radiological features of ectomorphy need evaluation against both severity of the spinal curve at diagnosis and its subsequent fate. Preliminary findings from our series suggests that the severity of the spinal curve in 13-year-old scoliotic girls was directly related to relative spinal shortening when this was taken as suprapelvic height SDS *minus* subischial height SDS.

Such "ectomorphic" skeletal proportions are similar qualitatively, but not quantitatively, to "eunuchoid" proportions in which legs are long relative to trunk (Tanner and Whitehouse 1982). This growth pattern is associated with low androgenic hormones. Both are seen in Klinefelter's syndrome which is associated with scoliosis (Smith 1976). In rabbits there is evidence of a genetic factor influencing the linearity of the spine; this may be the equivalent of the linearity of ectomorphy in man (Tanner and Sawin 1953).

Pelvic height. We report elsewhere that in healthy children pelvic height was significantly greater in girls than boys in each age group from 10 to 13 years (Nicolopoulos *et al.* 1985). The relatively greater pelvic height in girls with AIS is similar to that recently reported in male patients with low back pain (Merriam *et al.* 1983). The method we used to calculate pelvic height showed both a true and an apparent increase; for the reasons given in Merriam *et al.* (1983), we conclude that a true pelvic height increase is, in general, a skeletal feature of girls with adolescent idiopathic scoliosis. This conclusion explains (wholly or in part) the observed decrease in the ratio of trunk height/sacral height (S1) calculated from radiographs for girls with adolescent idiopathic scoliosis measured longitudinally between 10 and 16 years of age (Raso, personal communication).

We shall consider two possible causes for this true increase in relative pelvic height: firstly, early skeletal maturation (Burwell *et al.* 1973; Nordwall and Willner 1975; Low *et al.* 1978; but see Drummond and Rogala 1980) and, secondly, an abnormality of control of pelvic growth. We reject the first possibility, because in children who are maturing early the spine should be lengthened relative to subischial height—and this is opposite to the growth pattern found in scoliotic girls.

The second possibility, an abnormality of control of pelvic growth, has two aspects: blood-borne factors and skeletal tissue responses. Firstly, hormonal change could lengthen the pelvic component of the appendicular skeleton as it may do in "eunuchoid" skeletal proportions. This possibility suggests some further investigations: a search for increased pelvic height in Klinefelter's syn-

drome, and further hormonal studies in scoliotic girls, particularly on testosterone and other plasma steroids and their receptors in iliac and spinal tissues (Smith and Walker 1977; Skogland and Miller 1980; Saartok *et al.* 1984). Secondly, either genetic or environmental factors or both could act directly or indirectly on skeletal primordia in early embryonic life and alter tissue responses to blood-borne factors later in life (Burwell *et al.* 1977; Harrison and Burwell 1981). According to this latter hypothesis, the particular region of the skeleton affected would be influenced by the cephalo-caudal progression of development of the trunk (Scammon and Calkins 1929; Knott and Meredith 1937); between fetal and adult life, the normal spine shows a relative decrease in the thoracic region caused by more rapid growth in the lumbar region (Schultz 1924). Whether this greater caudal rate of growth also involves the height of the pelvis is unknown, though it seems likely. Hence girls with AIS could have an abnormality of mechanisms *intrinsic* to the skeleton which determine skeletal proportions in the trunk; equally this dual disproportion could result from hormonal change; or these two mechanisms could act together.

Viewed in this way, the cephalo-caudal disproportion of two segments of the trunk suggests the possibility of a mechanism of causation common to both segments. It is unlikely to be secondary to the scoliosis. A general hypothesis to explain this pattern of skeletal disproportion in girls with AIS would be a disturbance of the mechanisms which control the two main components (trunk growth and leg growth) of the adolescent growth spurt.

Skeletal disproportions. The view of Somerville (1952) and of Roaf (1966a, 1966b, 1980) that a basic defect in scoliosis is relative lengthening of the anterior components of the spine compared with the posterior elements, has been confirmed by other workers (Deane and Duthie 1973; Deacon, Flood and Dickson 1984). It is not possible to determine whether this skeletal disproportion is linked to an initiating defect in the growing axial skeleton or is merely secondary to the deformity (Roaf 1966b, 1980; Dangerfield, Burwell and Vernon 1980; Dickson *et al.* 1984).

A second type of skeletal disproportion in AIS is asymmetry between the right and the left sides of the body. This has been detected as asymmetry of the upper arm (Dangerfield *et al.* 1980; Burwell, Dangerfield and Vernon 1981) and as facial asymmetry (Mehta 1981). The upper arm difference may be secondary to the scoliosis or be part of a basic disorder of symmetry, the most obvious feature of which is the scoliosis (Burwell *et al.* 1984).

A third type of skeletal disproportion, outlined here, involves dual cephalo-caudal changes in the trunk. We argue that these segmental changes suggest a common mechanism and are not secondary to the scoliosis. They support the hypothesis that at the time of diagnosis of

AIS in girls there is a complex and basic disorder of skeletal proportions.

The association between constitution and particular diseases is well known. In adolescent idiopathic scoliosis it is possible that some physical features involving disproportion of the skeleton initiate the deformity, but it seems more likely that these features are associated with a predisposition to its progression. Further work is needed to evaluate this concept of susceptibility to AIS in girls, with growth and hormonal studies and including case controls. The results could have both preventative and therapeutic importance.

Since this paper was submitted for publication, Archer and Dickson have published findings from a cross-sectional and longitudinal study of uncorrected standing height for 96 girls aged 10 to 15 years, referred after school screening and observed for one year. The increase of stature for girls having lateral spinal curves of 15° or more, they suggest, is in the spine and due to an uncoiling effect of the normal kyphosis (Archer and Dickson 1985).

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