J. Anat. (1984), 138, 2, pp. 281–286
With 3 figures
Printed in Great Britain

Sexual dimorphism in human vertebral body shape

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(*Accepted* 30 *June* 1983)

INTRODUCTION

Sexual dimorphism in vertebral body shape, as seen in lateral radiographs, has been demonstrated in adolescent vertebrae (thoracic 12–lumbar 3) by Brandner (1970). Female vertebrae are more 'slender' in the sagittal plane than male vertebrae. In the same age group, the growth related deformity of idiopathic scoliosis becomes a progressive curvature six times more frequently in girls than in boys (Drummond, Rogala & Gurr, 1979; Lancet editorial, 1981). Progression of scoliosis is related to the rate of growth in stature and is measured by the increase in lateral curvature in the thoracic or lumbar vertebral column (Burwell, 1971).

This study compares sex differences in growth in length of the thoracolumbar vertebral column and growth in transverse diameter of the thoracic and lumbar vertebral bodies. It is argued that increased slenderness of vertebral bodies, as occasioned by greater height or lesser width, tends to reduce the stability of the vertebral column in the coronal plane.

MATERIALS AND METHODS

Study 1

As part of an anthropometric measurement study of school and university students in Perth, Western Australia, an anthropometer was used to measure 'thoracolumbar spine length' from the upper margin of the spinous process of the first thoracic vertebra to the lower margin of the spinous process of the fourth lumbar vertebra in a standard erect posture.

Measurements were made on 1427 subjects (Table 1) between 9.30 am and 3.30 pm and the time of each measurement was recorded. A control study of diurnal loss in sitting height was also performed in 20 volunteers aged 8–43 years. Cross sectional data were grouped by age and sex.

Study 2

From the extensive files of the scoliosis clinics at the Royal Perth Hospital and Princess Margaret Hospital, Perth, 166 radiographs were obtained of normal spines and of spines with postural or idiopathic curves less than 10 degrees (Table 2*a*). Films were taken at a tube-film distance of 7 feet to minimise distortion and magnification error. Mid-vertebral height and minimum transverse diameter of the sixth and ninth thoracic vertebrae were measured on anteroposterior radiographs to the nearest 0·5 mm. Heights were checked on lateral radiographs, taking account of minor differences in magnification error, to confirm the accuracy of the height measurements. The index of height/transverse diameter was calculated for each

Table 1. *Anthropometric measurement of thoracolumbar spine length (mm)*

Age (years)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Males	27	43	48	57	47	50	57	59	70	57	56	42	35	40	10
Females	34	55	48	44	51	56	61	74	66	73	62	46	23	22	14

Totals: Males 698
Females 729
1427

Table 2(*a*). *Indices of height/transverse diameter for T6 and T9*

Age range (years)	Sex	Number of cases	Index: height/transverse diameter T6	T9
2–8	M	22	0·51 ± 0·03*	0·52 ± 0·03
	F	14	0·50 ± 0·03	0·52 ± 0·03
			(No significant difference)	
9–12	M	20	0·57 ± 0·05	0·57 ± 0·05
	F	25	0·63 ± 0·05	0·62 ± 0·04
			$P < 0.001$	$P < 0.001$
13–16	M	26	0·63 ± 0·06	0·60 ± 0·06
	F	28	0·74 ± 0·07	0·72 ± 0·08
			$P < 0.001$	$P < 0.001$
17–25	M	12	0·69 ± 0·04	0·68 ± 0·05
	F	19	0·79 ± 0·06	0·76 ± 0·05
			$P < 0.001$	$P < 0.001$
		Total 166		

* Mean ± standard deviation; M, male; F, female.

Table 2(*b*). *Indices of height/transverse diameter for L1, L3 and L5*

Age range (years)	Sex	Number of cases	Index: height/transverse diameter L1	L3	L5
2–8	M	16	0·48 ± 0·03*	0·45 ± 0·04	0·39 ± 0·04
	F	8	0·48 ± 0·06	0·46 ± 0·06	0·41 ± 0·08
				(No significant difference)	
9–12	M	7	0·50 ± 0·03	0·47 ± 0·02	0·40 ± 0·02
	F	6	0·58 ± 0·05	0·53 ± 0·04	0·47 ± 0·08
			$P < 0.001$	$P < 0.001$	$P < 0.001$
13–19	M	17	0·61 ± 0·04	0·57 ± 0·05	0·47 ± 0·05
	F	11	0·67 ± 0·07	0·63 ± 0·05	0·49 ± 0·04
			$P < 0.005$	$P < 0.001$	$P < 0.05$
20–35	M	23	0·60 ± 0·05	0·58 ± 0·05	0·46 ± 0·05
	F	17	0·71 ± 0·07	0·67 ± 0·08	0·53 ± 0·06
			$P < 0.001$	$P < 0.001$	$P < 0.001$
		Total 105			

* Mean ± standard deviation; M, male; F, female.

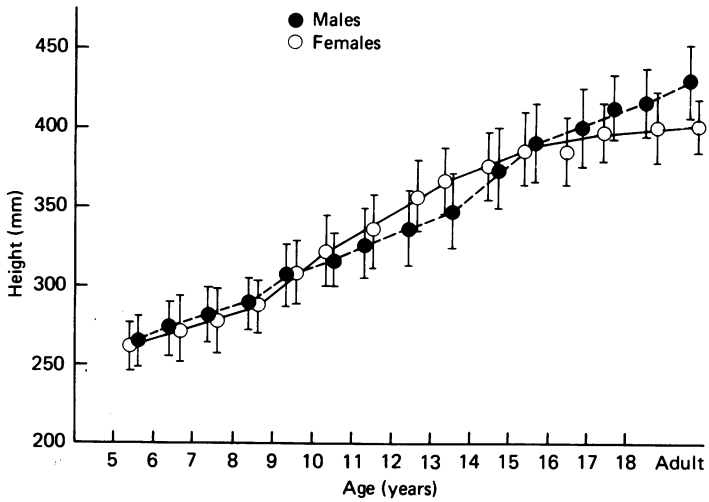

Fig. 1. Thoracolumbar spine length.

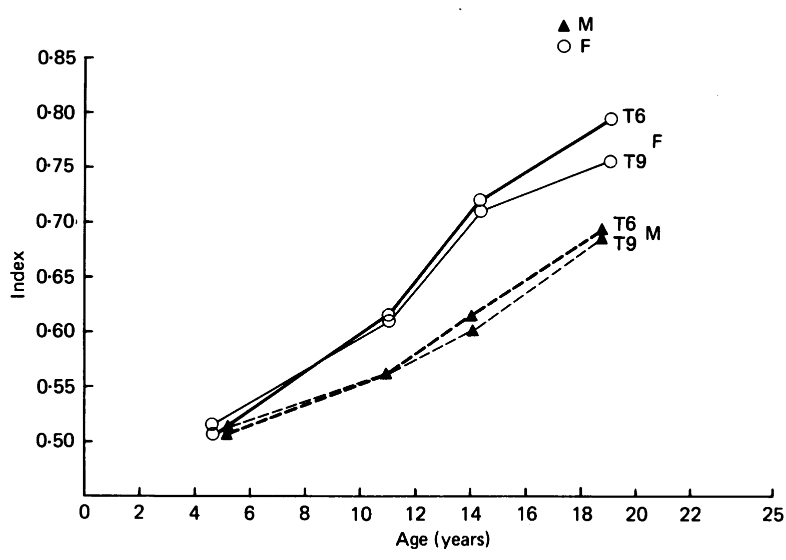

Fig. 2. Thoracic vertebrae: index of height/transverse diameter.

vertebra and data for indices were arranged in four age groups: 2–8, 9–12, 13–16 and 17–25 years. Mean indices for males and females were plotted with age.

Study 3

Lumbar spines without apparent pathology were obtained at post mortem from 105 subjects in the age range 2–35 years (Table 2*b*). Transverse diameters of lumbar vertebrae were measured at the 'waist' in the intact specimen and mid-line height was measured following median sagittal section. Both were measured to the nearest 0·1 mm using Vernier calipers (Twomey, 1981). Indices of height/transverse diameter were calculated for each vertebra and grouped by age and sex.

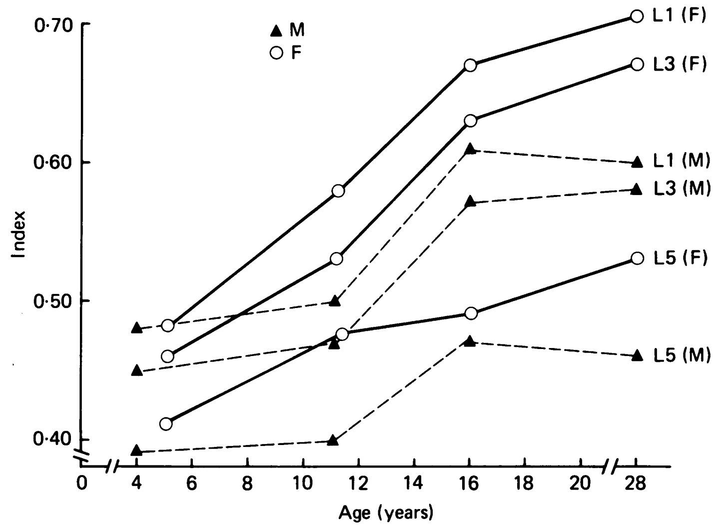

Fig. 3. Lumbar vertebrae: index of height/transverse diameter.

RESULTS

Study 1

The control study for diurnal loss in sitting height showed an average loss of 12 ± 4 mm in the 12 hours after rising. Approximately half of this loss occurred in the first hour after rising. Since time of measurement was always at least 2 hours after rising and male and female measurements in all age groups were randomly scattered throughout the day, there could be no bias accountable to the time of measurement.

At each annual stage from 5·5 to 9·5 years, mean values for spine length were almost identical in males and females, but from 9·5 to 12·5 years, growth increments were 61 % greater in females than in males. The growth spurt of 3–4 years which began at 8·5 years in females did not appear until 13·5 years in males (Fig. 1).

A two-way analysis of variance, with spine length from 7 to 13 years as the dependent variable, and sex and age as the independent variables, showed a highly significant two-way interaction ($P < 0{\cdot}001$) between sex and age. Thus, between 7 and 13 years, growth differed significantly in males and females.

A similar analysis of variance at 12 and 13 years only showed that spine length was significantly greater in females than in males ($P < 0{\cdot}001$).

Studies 2 *and* 3

All age groups over the age of 8 years showed sexual dimorphism in thoracic and lumbar vertebral body shape (Figs. 2, 3). Female vertebrae were more 'slender' (i.e. relatively taller and thinner) in the coronal plane. Using the unpaired Student's *t* test to compare male and female height/transverse diameter indices, differences were statistically significant for all vertebrae measured in all groups over the age of 8 years (Table 2).

Until the age of 13 years, these changes in the height/transverse diameter index resulted from both greater growth in vertebral height in females and greater growth in transverse diameter in males (Table 3). After 13 years, while vertebral height in-

Table 3. *Vertebral dimensions (mean values in mm)*

Vertebral level	Age (years)	Height (mm) M	%	F	%	Transverse diameter (mm) M	%	F	%
T6	5	11·9	—	11·5	—	23·8	—	22·5	—
	13	16·5	37	16·3	42	26·7	12	24·1	7
	Adult	20·5	24	19·2	18	30·2	13	24·5	2
T9	5	12·9	—	13·0	—	25·5	—	24·5	—
	13	17·7	37	19·2	48	29·9	17	27·9	14
	Adult	22·5	27	21·4	12	33·5	12	28·7	3
L1	5	14·8	—	13·3	—	30·1	—	29·6	—
	13	21·6	42	22·8	65	37·8	26	33·8	15
	Adult	25·3	21	24·9	13	42·2	12	36·1	7
L3	5	15·1	—	14·2	—	32·8	—	32·3	—
	13	21·0	39	21·6	52	41·6	27	37·5	16
	Adult	25·7	22	25·6	19	44·3	7	39·2	5
L5	5	14·5	—	14·0	—	35·8	—	35·3	—
	13	19·7	36	21·5	54	47·8	30	43·1	22
	Adult	24·1	22	24·1	12	52·2	9	46·6	8

M, male; F, female; %, % increment.

creased more rapidly in males than in females, the difference in the index was maintained or increased because transverse diameter continued to grow more rapidly in males than in females.

DISCUSSION

Three studies, using different measurement techniques, all support the view that the female thoracolumbar spine grows in length more than does the male spine from 9 to 13 years of age. Throughout the age range from 8 years to maturity, the transverse diameters of thoracic and lumbar vertebrae (T6–L5) increase more in males than in females. These sex differences in spinal growth produce a more slender thoracolumbar spine in females than in males, as seen in the coronal plane.

The spurt in vertical growth of female vertebrae begins almost 5 years before that in male vertebrae, and the female growth spurt is at least in part pre-pubertal in its timing. On the other hand the first breast changes of puberty may be seen as early as 8 years of age (Tanner, 1976). Tanner reviews the complex interplay between genetic, hormonal and environmental factors which are responsible for the timing of the growth spurt. In males, the first observable change at puberty is testicular enlargement, from 9·5 years onwards. Testicular enlargement and testosterone secretion increase in parallel, testosterone secretion producing increases in both muscle bulk and strength. Horizontal vertebral growth is in part dependent on mechanical influences such as muscle activity (Taylor, 1975; Feik & Storey, 1983; Twomey, Taylor & Furniss, 1983). The vertebral column, subjected to these different influences, appears to respond by earlier vertical growth in females and greater horizontal growth in males.

The stability of the laterally curved, axially loaded column of mild scoliosis, which is very common in both sexes (Drummond *et al.* 1979), depends on many factors which include vertebral shape and muscle support. Other things being equal, an axially loaded long slender column is more likely to buckle than a short thick column.

The susceptibility to buckling of a column is expressed by the ratio 1/kz, where 1 = effective length of the column, and kz = radius of gyration (Timoshenko, 1955). There is some evidence that scoliosis is more likely to progress in long slender vertebral columns than in relatively short wide columns (Schultz & Cisewski, 1978; Taylor & Slinger, 1980). It is suggested that the sexual dimorphism demonstrated in this study is one factor in the greater prevalence of progressive scoliosis in adolescent females.

SUMMARY

This study demonstrates that the earlier growth spurt in vertebral height in females and the greater growth in vertebral transverse diameter in males, both give rise to sexual dimorphism in vertebral shape, female vertebral bodies being significantly more slender than male vertebral bodies from the age of 8 years onwards. The possible relationship of this difference to sex differences in scoliosis prevalence is discussed.

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