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Age changes in lumbar intervertebral discs

Measurements of disc thickness, shape and degeneration, using the criteria described by Rolander (1966), were recorded from 204 post-mortem lumbar spines. The "true average disc height" increased with age as the discs "sink" into the vertebrae. These results add information to previous studies which indicate that the loss of transverse trabeculae of lumbar vertebrae is primarily responsible for the change in shape of both vertebrae and discs in the elderly. While the incidence of disc degeneration does increase in old age, the majority of the discs examined did not show evidence of any such change.

Lance Twomey
James Taylor[1]

Western Australian Institute of Technology, Shenton Park, W. Australia and [1]University of Western Australia, Nedlands, W. Australia

Old age is accompanied by decline in stature and spinal length, which has been attributed largely to a reduction in the height of invertebral discs (Vernon-Roberts & Pirie 1977). However, quantitative studies of age changes in the vertebral column indicate that there is a loss in the height of vertebrae and a change in the shape of the vertebral end-plate in old age, and that this is the major factor leading to the decline in stature (Ericksen 1974, 1975, Twomey et al. 1983). There are no studies showing a reduction in intervertebral disc height in old age in "normal" populations. Indeed, Nachemson et al. (1979), reporting on a relatively small number of lumbar discs, showed that old age and disc degeneration are not necessarily linked, and also that disc degeneration is not synonymous with disc thinning. In their study, the five most grossly degenerated discs showed no evidence of disc thinning.

We have studied the lumbar discs in cadavers covering a wide age range.

Table 1. Age, sex and mean antero-posterior diameter (mm) of the intervertebral discs of 204 cadavers studied.

No.	Mean (range) age	Sex	Diameter				
			L1–2	L2–3	L3–4	L4–5	L5–S1
9	(0–1.5)	MF	15	17	17	17	16
28	8 (1.5–12)	MF	26	28	28	29	26
17	16 (13–19)	M	39	39	39	40	39
6	14 (13–17)	F	34	36	36	36	35
24	25 (20–36)	M	40	40	40	40	38
24	23 (18–35)	F	35	36	37	37	35
24	47 (36–59)	M	39	40	40	40	39
24	49 (36–59)	F	35	36	37	37	36
24	68 (60+)	M	40	41	41	41	41
24	73 (60+)	F	38	40	40	40	38

Material and methods

A block including the whole lumbar vertebral column, extending from the upper border of T12 to the lower border of S2, was removed from each of 204 cadavers and used for a study of the dimensions and movements of the lumbar column. Each column was removed within 48 h, in most instances within 24 h.

Psoas major and the erector spinae muscles were dissected away from each specimen. The cadavers were divided into six age groups (Table 1).

Using dial vernier calipers (accurate to 0.05 mm) direct measurements of horizontal antero-posterior and transverse diameters were made in each intact disc, and anterior, mid-disc and posterior heights were recorded following mid-line sagittal sectioning of each specimen. Inter-trial tests of the dial vernier calipers showed a high correlation (r = 0.97) across all age groups. To avoid inaccuracy due to any local irregularities at the disc/vertebral interface, a "true average disc height" was calculated by dividing the area of the disc in median section by its antero-posterior diameter. A MOP Image Analyser was used to trace and measure the area of each disc in median section.

From the three linear measurements of disc height, an index of disc convexity was devised so as to demonstrate the disc-vertebral shape changes from the perspective of the intervertebral disc. The index was derived by dividing the mid-disc height by the sum of the anterior and posterior disc heights as measured on mid-line sagittal section (Figure 1).

Rolander's (1966) 4-point method of classification of disc by physical appearance was used on 140 specimens. This classification is as follows:

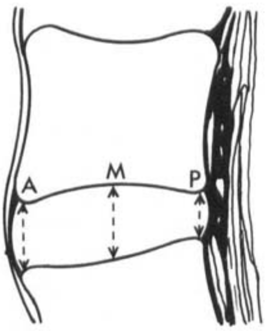

Figure 1. Intervertebral disc. Convexity index = M/A + P. M = mid-disc height, A = anterior height, P = posterior height.

0. Macroscopically normal discs, both nucleus and anulus are white and clearly distinct from each other.

1. Discs with normal appearance, although the nucleus is more fibrous. There is still a distinct boundary between nucleus and anulus.

2. Less distinct boundary between nucleus and anulus, colour change from white to yellowish-brown. There may be an isolated fissure in the anulus.

3. Frank disc degeneration with desiccation, multiple fissures in nucleus and anulus and disc thinning.

This classification provides a measure of "disc quality" and complements the data derived from direct measurement.

Results

Dimensions

Antero-posterior dimensions. The middle discs were consistently larger than the extreme lumbar discs (L1–2, L5–S1); they increased with age, 10 per cent in females and 2 per cent in males (Table 1). In all age groups the discs were larger in males than in females.

Disc height. There was a clear trend of increase in disc height for both sexes with increasing age (Table 2). A two-way analysis of variance (sex by age) with height as a co-variate showed sex differences at all levels, but only the L1–2 level showed an age by sex interaction requiring separate tests for the effect of age for males and females. The F tests for the remaining levels were taken directly from analysis of variance (ANOVA, Table 2). The ANOVA also showed a linear trend correlating disc thickness with stature for both sexes at each disc level ($p < 0.05$). The young adults of both sexes were taller on average than the old adults and thus the trend of increasing disc thickness with increasing age was strengthened.

Shape. There was an increase ($p < 0.025$) in seven of the ten disc convexity indices for both sexes in young adult life and old age (Table 3). These changes parallelled the changes noted in the vertebral concavity index (Twomey & Taylor 1983a) and emphasise that the disc-vertebral junction is one of the principal sites of age change after maturity.

Disc quality. The disc quality scores associated with sound healthy discs were universal in normal infants and children, while scores associated with disc ageing and disc degeneration were found with increasing freuqency through adult life to old age (Table 4). The lower disc levels showed the highest grades, particularly in the two oldest categories.

Table 2. "True average" disc height. Area median section/antero-posterior diameter. Mean (S.D.)

Disc	Sex	Age 20–35		60+
L1–2	M	9.2(1,0)	NS	9.2(1.3)
	F	6.1(2.5)	*	7.9(1.6)
L2–3	M	9.8(1.2)	**	10.9(1.9)
	F	8.0(1.3)		8.5(1.4)
L3–4	M	10.3(1.0)	NS	11.0(2.0)
	F	8.2(1.2)		8.5(2.3)
L4–5	M	11.3(1.3)	*	12.2(1.8)
	F	8.5(1.3)		9.2(1.8)
L5–S1	M	10.6(1.6)	*	11.2(2.9)
	F	8.1(1.2)		8.8(1.7)

NS not significant, * $p < 0.05$, ** $p < 0.01$.

Table 3. Disc Convexity Index. Mid-disc height/anterior + posterior disc heights. $t = -2.38$, $p < 0.025$.

Disc Level	Male 20–35	Male 60+	Female 18–35	Female 60+
L1–2	0.57	0.65	0.58	0.68
L2–3	0.60	0.66	0.61	0.63
L3–4	0.56	0.61	0.60	0.65
L4–5	0.58	0.56	0.54	0.54
L5–S1	0.43	0.53	0.49	0.48

Table 4. Classification of discs using the score devised by Rolander (1966).

Age	No.	Disc score	L1–2	L2–3	L3–4	L4–5	L5–S1
0–1.5	6	0	6	6	6	6	6
		1					
		2					
		3					
1.5–12	18	0	13	13	13	13	13
		1	5	5	5	5	5
		2					
		3					
13–20	13	0					
		1	13	13	13	12	12
		2				1	
		3					1
20–35	35	0					
		1	33	34	35	15	30
		2	1	1		1	4
		3	1	1		1	1
36–39	34	0					
		1	27	30	30	28	25
		2	2	3	2	2	6
		3	5	1	2	4	3
60+	34	0					
		1	17	17	16	10	12
		2	9	7	10	14	11
		3	8	10	8	10	11

Discussion

The general assumption that the loss in stature which occurs with increasing age (Stenhouse 1972) is due in large part to thinning of the intervertebral disc (Vernon-Roberts & Pirie 1977), is directly contradicted in this study. Average disc height is maintained or increased in old age (Table 2), confirming observations from previous studies that loss in vertebral height is the principal reason for loss in stature (Nachemson et al. 1979, Twomey 1981, Twomey & Taylor 1983b). The very small decline in anterior and posterior disc height (Twomey & Taylor 1983b) is more than counterbalanced by the increased disc convexity as the vertebral end-plate collapses. The discs can be considered to "sink" into the vertebrae (Figure 2); the collapse in the lumbar vertebral end-plates due to osteoporosis is the most obvious and widespread age change in the lumbar spine (Ericksen 1974 and 1975, Twomey et al. 1983).

The term "disc degeneration" is often imprecisely defined in the literature, where it may be used synonymously with disc thinning or the presence of osteophytes at joint margins which are often considered universal in old age (Lawrence 1969, Schmorl & Junghanns 1971, Vernon-Roberts & Pirie 1977). We distinguished between "normal" age change and "pathological" disc degeneration as expressed in Grades 2 and 3 of Rolander (1966); only the latter involves disc thinning and desiccation. This study clearly shows that elderly discs are not *usually* degenerated in these terms; old discs are usually neither "thin", nor desiccated. However, both grades may be associated with functional changes such as disc stiffness (Twomey & Taylor 1983a). The incidence of disc degeneration does increase in old age (Table 4), but 72 per cent of the elderly discs examined did not show any evidence of such change and were still normal by the above definition.

Possible causes of disc thinning could be (a) loss of disc material due to herniation or (b) loss of volume due to dehydration. It is most unlikely that the loss of disc substance by interspongious herniation or anular rupture has a significant influence on disc thickness, since the volumes lost appear insignificant (Taylor & Twomey 1983a, Twomey & Taylor 1983b). Despite an increasing incidence of microfractures in the vertebral end-plates of elderly subjects, the "stiffer" disc of old age does not prolapse readily into fractures of the vertebral end-plates. Similarly, a closer examination of Puschel's (1930) measurements shows that the greatest water loss in discs occurs during child-

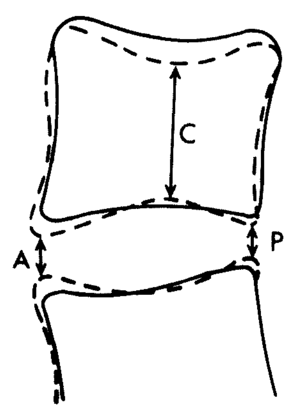

Figure 2. The changes in the shape of the anterior vertebral structures in old age. The young adult shape is indicated by the solid lines and the old adult shape is indicated by the dotted lines. The arrows indicate where there is a reduction in height. A = anterior disc height, P = posterior disc height, C = central vertebral height.

hood and adolescence. The water content of the anulus remains relatively constant throughout adult life, while that of the nucleus declines by only 6% from early adult life to old age. Furthermore, the total glycosaminoglycan content of the disc is maintained into old age, while the amount of collagen increases slightly (Adams & Muir 1976, Bushell et al. 1977). This supports a principal finding of the present study that average disc height is maintained in old age whereas "pathological" disc degeneration applies to a minority of elderly discs.

Puschel's view, that there is only a relatively small degree of dehydration during adult life, receives support from the work of Brown et al. (1957) who demonstrated only minimal bulging of all discs even under extreme compressive load. This evidence and that of the present study do not support the "underinflated tyre" simile as applied to intervertebral discs, and the term ought not be used to describe normal disc function in the elderly.

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