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Schmorl's nodes (intravertebral herniations of intervertebral disc tissue) in two historic British populations

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INTRODUCTION

The human vertebral column may be affected by herniation of intervertebral disc tissue into the vertebral bodies, forming ectopic deposits of nucleus pulposus material. These are called Schmorl's nodes (Fig. 1) after G. Schmorl whose extensive work included descriptions of the lesion (Schmorl & Junghanns, 1971). Schmorl's nodes are most frequent in the lumbar and lower thoracic regions (Resnick & Niwayama, 1978).

Collins (1949) indicated the sequence of events liable to follow the formation of Schmorl's nodes. The displacement of disc substance may produce narrowing of the space between vertebral bodies with consequent diminution of spinal movements. Forward tilting of the vertebral bodies may occur, with the production of abnormal stresses leading to arthropathies such as marginal osteophytosis, ankylosis of adjacent vertebrae and osteoarthritis of apophyseal joints. According to Resnick & Niwayama (1978), the occurrence of multiple Schmorl's nodes in early life may lead to Scheuermann's disease (juvenile kyphosis).

The aetiology of Schmorl's nodes is largely unknown. Occasionally their development is associated with specific diseases which produce weakening of the subchondral bone and resultant disruption of the cartilaginous endplate, for example, hyperparathyroidism and metastatic deposits in the vertebral column (Schmorl & Junghanns, 1971; Resnick & Niwayama, 1978). In some cases, their occurrence can be linked with trauma such as vertebral fractures (Schmorl & Junghanns, 1971). However, the majority of Schmorl's nodes are of unknown cause ('idiopathic'). It is possible that comparative studies of populations of different ethnic and/or temporal origins may help to clarify the cause of these lesions.

Whilst often undetectable in radiographs of the living (Schmorl & Junghanns, 1971), Schmorl's nodes are readily identified in dried bone because they produce characteristic deformations on the superior and/or inferior surfaces of vertebral bodies (Fig. 2). The present report describes the occurrence of Schmorl's nodes in two adult historic British populations. The vertebral sequence Thoracic 8 – Sacral 1 (TV8–SVI) was selected for examination in this study for two reasons: (1) within this region there are specific anatomical features enabling precise identification of individual vertebrae, a cogent factor when confronted with cases where the remains were incomplete or partially damaged; (2) Schmorl's nodes occur most frequently in this zone.

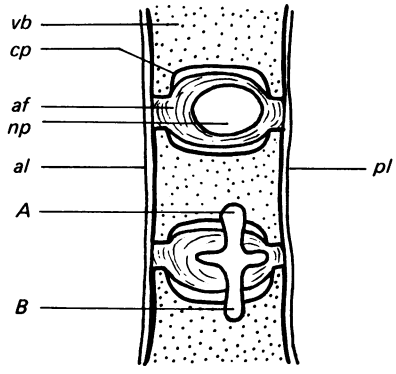

Fig. 1. Diagrammatic illustration showing production of Schmorl's nodes. *af*, annulus fibrosus; *al*, anterior longitudinal ligament; *cp*, cartilaginous endplate; *np*, nucleus pulposus; *pl*, posterior longitudinal ligament; *vb*, vertebral body. *A*, upward herniation of nucleus pulposus producing a node on the inferior surface of the vertebral body above; *B*, downward nuclear herniation producing a node on the superior surface of the vertebral body below.

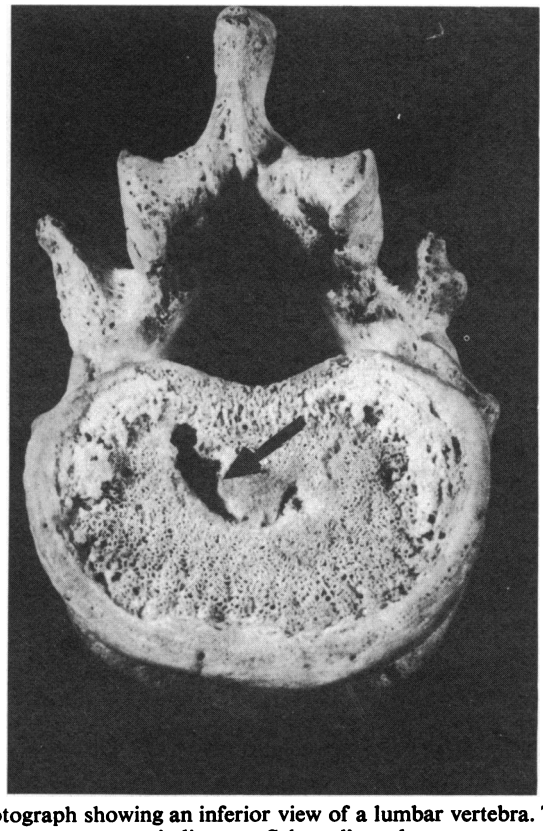

Fig. 2. Photograph showing an inferior view of a lumbar vertebra. The arrow indicates a Schmorl's node.

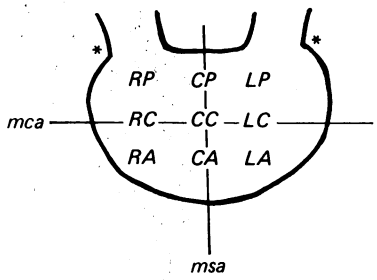

Fig. 3. Diagram used for recording the position of Schmorl's nodes on the vertebral surface. *, the lateral attachments of the pedicles to the edge of the vertebral body; *msa*, midsagittal axis, defined by a line running through the midpoint between * and *; *mca*, midcoronal axis, defined by a line perpendicular to the midsagittal axis, through the midpoint on the midsagittal axis. The upper case letters indicate the nine possible locations for nodes: *RA* Right quadrant, anterior to the midcoronal axis. *RP* Right quadrant, posterior to the midcoronal axis. *LA* Left quadrant, anterior to the midcoronal axis. *LP* Left quadrant, posterior to the midcoronal axis. *RC* On the midcoronal axis, to the right of the midsagittal axis. *LC* On the midcoronal axis, to the left of the midsagittal axis. *CA* On the midsagittal axis, anterior to the midcoronal axis. *CP* On the midsaggital axis, posterior to the midcoronal axis. *CC* On intersection of the midcoronal and midsagittal axes.

MATERIALS AND METHODS

Population groups

The sample representing the chronologically earlier population comprised remains excavated from a thirteenth to sixteenth century cemetery associated with a Carmelite Friary in Aberdeen. For this sample, age at death and sex were estimated using conventional osteological methods (Krogman, 1973). These remains yielded 24 individuals in which the vertebral sequence TV8–SVI was complete (n = 7) or nearly complete (n = 17). These individuals comprised 18 males and 6 females. The age range was from about 19 years to over 45 years.

The chronologically later series represented a London population of the eighteenth to nineteenth centuries. Their skeletons were housed in the crypt of St Bride's Church and age at death and sex were documented for this group. These remains yielded 53 adult individuals in which the vertebral sequence TV8–SV1 was complete (n = 14) or nearly complete (n = 39). These individuals comprised 28 males and 25 females. The age range was from 21 to 77 years.

For convenience, the two populations are designated simply as 'Aberdeen' and 'London' throughout this report.

Assessment of Schmorl's nodes

For each skeleton, the presence or absence of Schmorl's nodes was noted for each available superior and inferior vertebral body surface within the TV8–SV1 sequence. Whenever a node was found, its position on the vertebral surface was recorded on a diagram where the surface was divided into four quadrants by two lines passing through the centre of the surface, one in the sagittal plane and the other in the coronal plane. Using this diagram, a Schmorl's node was assigned to one of nine possible positions (Fig. 3).

RESULTS

None of the individuals showed evidence of pathological conditions known to be associated with Schmorl's nodes. Table 1 shows the number of individuals showing

Table 1. *Number of individuals affected with Schmorl's nodes*

	Aberdeen males	Aberdeen females	London males	London females
Number of individuals	18	6	28	25
Number of individuals with Schmorl's nodes	13	4	21	5
% of individuals with Schmorl's nodes	72	67	75	20

$\chi^2 = 8{\cdot}48$; $P < 0{\cdot}05$.

Table 2. *Number of vertebral surfaces affected with Schmorl's nodes*

	Aberdeen: number of affected surfaces/total number of surfaces	London: number of affected surfaces/total number of surfaces
Males and females	141/399	88/866
Males	107/298	80/435
Females	34/101	8/431

osteological evidence of Schmorl's nodes. High incidence rates were found in Aberdeen males, Aberdeen females and London males (72, 67 and 75 %, respectively). A significantly lower frequency was seen in London females where only 20 % of individuals were affected.

The incidence of node-affected vertebral surfaces in the two groups is shown in Table 2.

The incidence of node-affected surfaces was significantly greater in the Aberdeen material than in the London material when the sexes were combined ($\chi^2 = 99{\cdot}23$, $P < 0{\cdot}001$). Considering the sexes separately, Aberdeen males had significantly more node-bearing surfaces than London males ($\chi^2 = 20{\cdot}96$, $P < 0{\cdot}001$) and, similarly, Aberdeen females had significantly more affected surfaces than London females ($\chi^2 = 103{\cdot}84$, $P < 0{\cdot}001$). In the London group, a significant sex difference was found in the frequency of affected surfaces, with males showing a greater incidence than females ($\chi^2 = 64{\cdot}11$, $P < 0{\cdot}001$). In contrast, in the Aberdeen group, there was no significant sex difference in the occurrence of node-bearing vertebral surfaces. Comparison of Tables 1 and 2 demonstrates that although similarly high proportions of node-bearing individuals occurred among Aberdeen males, Aberdeen females and London males, the number of affected vertebral surfaces was distinctly lower in London males, indicating that the extent of the lesion was less severe in individuals of the latter group. London females showed not only low incidence rates but also mild severity in terms of fewer affected surfaces per individual as shown by a mere 2 % of affected vertebral surfaces.

The question of severity of Schmorl's nodes in individual skeletons was investigated further by considering separately those individuals with complete TV8–SV1 columns (Table 3).

This confirmed the greater severity of the lesion in the Aberdeen group where the majority of the individuals (6/7) had over 25 % of their vertebral surfaces affected with Schmorl's nodes. This contrasted sharply with the London group where over half the individuals had nodes on less than 5 % of their surfaces.

Table 3. *Proportion of node-affected vertebral surfaces in skeletons with complete TV8–SV1 columns*

Node-affected surfaces (%)	Aberdeen ($n = 7$)		London ($n = 14$)	
	Males ($n = 5$)	Females ($n = 2$)	Males ($n = 8$)	Females ($n = 6$)
$\leqslant 5$	—	—	4	6
6–25	1	—	2	—
26–50	2	1	1	—
51–75	1	1	1	—
> 75	1	—	—	—

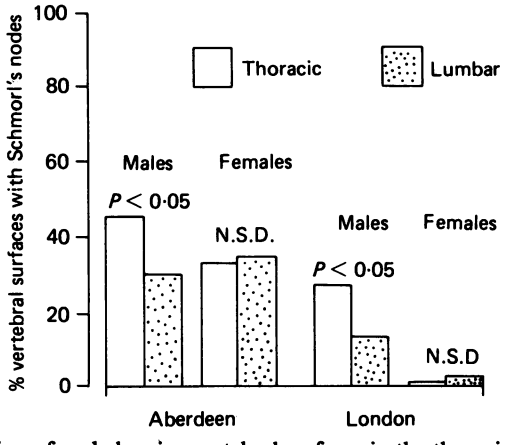

Fig. 4. The proportion of node-bearing vertebral surfaces in the thoracic and lumbar regions of Aberdeen and London males and females. *P* denotes significance of difference between groups calculated by the χ-square test; N.S.D. indicates no significant difference between groups according to the χ-square test.

Table 4 shows the incidence of Schmorl's nodes associated with specific vertebral surfaces.

These data showed that the frequency of nodes declined markedly below the level of the superior border of LV4, i.e. below the third lumbar disc space. However, applying the χ-square test, no statistically significant differences in incidence were found among the surfaces. The superior and inferior surfaces of the vertebral bodies did not differ significantly in frequency of Schmorl's nodes in either sex or either locality or in all the data combined.

There was, however, a significant sex difference in the distribution of Schmorl's nodes within the thoracic and lumbosacral portions of the column, irrespective of geographical provenance (Fig. 4). In the males, the thoracic region contained a significantly greater proportion of affected vertebrae than the lumbosacral region (Aberdeen: $\chi^2 = 4{\cdot}44$, $P < 0{\cdot}05$; London: $\chi^2 = 4{\cdot}48$, $P < 0{\cdot}05$). In the females, however, nodes were more evenly distributed along the column. Neither the Aberdeen nor the London females showed a significant difference in node frequency between the thoracic and lumbar zones.

The observed positions of Schmorl's nodes on the vertebrae are illustrated in Figure 5. The vast majority of nodes occurred on, or posterior to, the midcoronal

Table 4. *Frequencies of Schmorl's nodes on individual vertebral surfaces*

Vertebral surface	Number of surfaces affected/number of surfaces observed: Aberdeen Males	Aberdeen Females	London Males	London Females
TV8				
S*	3/14	2/4	4/20	0/23
I†	6/14	0/4	8/20	0/20
TV9				
S	5/12	1/4	4/19	0/20
I	7/14	0/4	8/20	0/20
TV10				
S	7/14	0/4	3/20	0/21
I	8/15	1/4	8/20	1/21
TV11				
S	5/13	1/3	3/21	1/19
I	7/13	3/4	8/23	1/20
TV12				
S	7/13	3/4	2/20	0/19
I	6/15	2/4	4/19	0/19
LV1				
S	5/13	1/5	2/17	0/23
I	5/14	2/6	3/18	1/23
LV2				
S	8/14	3/6	5/24	1/22
I	6/16	3/6	3/22	0/23
LV3				
S	9/17	3/6	4/20	0/20
I	7/17	2/6	5/20	0/21
LV4				
S	4/15	3/6	4/22	2/20
I	1/14	1/6	2/22	0/19
LV5				
S	1/16	1/6	0/23	1/20
I	0/15	1/6	0/23	0/20
SV1				
S	0/10	1/3	0/22	0/18

* S, superior surface; † I, inferior surface.

axis in both groups (Aberdeen: 99 %; London: 97 %). Furthermore, in both groups, over 60 % of the lesions were confined to the midsagittal axis on, and posterior to, its intersection with the midcoronal axis.

In both groups, the nodes often occurred on two or more sequential vertebral surfaces to form discrete series of remarkably similar shape and position (Fig. 6). Out of 38 node series observed, 20 (i.e. 53 %) occurred in this peculiar replicated form.

In the London group, there was no significant correlation between age and the proportion of node-affected vertebral surfaces. In the Aberdeen group, correlation analysis was precluded by lack of documentation of age. However, the material was divided into two broad categories, namely, under 30 years and over 30 years. No significant difference was found between these two groups.

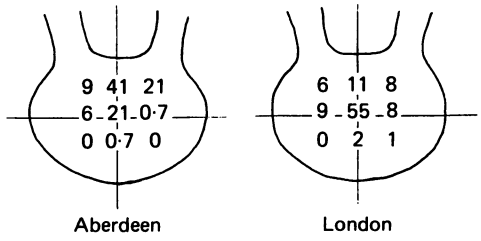

Fig. 5. The location of Schmorl's nodes on the vertebral surface. The numerals denote the percentage of nodes occupying each of the nine positions described in Figure 3.

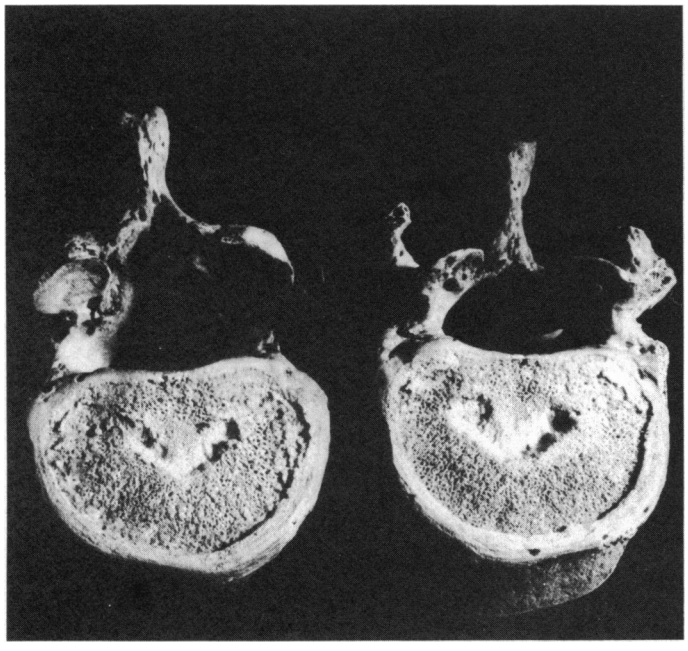

Fig. 6. Photograph showing Schmorl's nodes on two sequential vertebral surfaces. Note the virtually identical shape, size and position of the nodes.

DISCUSSION

This study reports the occurrence of Schmorl's nodes in the thoracolumbosacral (TV8–SV1) vertebral columns of adult skeletal remains derived from two historic British populations, one from thirteenth to sixteenth century Aberdeen and the other from eighteenth to nineteenth century London.

High incidences are found in Aberdeen males, Aberdeen females and London males (72, 67 and 75%, respectively). A significantly lower proportion of London females are affected (20%). Hilton, Ball & Benn (1976) reported a high incidence (76%) in a modern cadaveric population derived from Manchester. Batts (1939) found a relatively low incidence (20%) in a cadaveric group in Ann Arbor, Michigan. However, these studies did not specify the incidence according to sex. An intermediate rate of 38% was reported by Schmorl & Junghanns (1971) in a modern cadaveric population from Germany, with similar incidences in males and females (39·9 and 34·3%, respectively).

The lesions are more severe in Aberdeen than in London, in terms of the proportion of affected vertebral surfaces in the skeletons. Aberdeen males and females had 37 and 34% affected surfaces, respectively whilst significantly fewer node-bearing surfaces were found in London males (19%) and London females (2%). In London, females had significantly fewer affected surfaces than males, whereas in Aberdeen the sexes did not differ significantly in this respect. McWhirr, Viner & Wells (1982) found that Schmorl's nodes affected 12 and 9% of male and female vertebral surfaces (TV4–LV5), respectively, in a Romano–British population excavated at Cirencester. Compared to the present study, these rates are rather low, except for the London females in whom the lesion is particularly scarce.

Thus although methodological differences may preclude precise comparisons, it appears that different populations exhibit considerable variation in the incidence and severity of Schmorl's nodes.

No statistically significant differences in node frequency are associated with any specific vertebral surface. McWhirr *et al.* (1982) recorded maximal incidence on the inferior surface of TV11, but gave no statistical confirmation. In the present work, upper and lower vertebral surfaces exhibit similar incidences of Schmorl's nodes. Reporting on a series of routine autopsies in San Diego, Resnick & Niwayama (1978) claimed that the lesion favours the lower vertebral surface but presented no quantitative data.

In the present material, the distribution of Schmorl's nodes within the column is markedly different in the sexes, regardless of geographical origin. In males, the lesions are significantly more frequent in the thoracic than in the lumbosacral portion, whereas in females they are spread evenly along the thoracolumbosacral column. No mention of this sex difference has been found in previous reports.

The Schmorl's nodes found in the present study are considered to be of the idiopathic type in view of the absence of evidence of any condition known to induce the lesions. However, the findings of this investigation may contain clues to the aetiology of Schmorl's nodes. Firstly certain hypothetical causal factors are not supported by this study. For example, Dent's (1955) implication of osteoporosis is contradicted by the lack of relationship between age and incidence of Schmorl's nodes. The same objection applies to the association with degenerative disc disease by Hilton *et al.* (1976).

Owsley & Bradtmiller (1983) have suggested that stresses associated with pregnancy and childbirth may induce Schmorl's nodes. If reproductive history were a major causal factor, it is perplexing to find such marked differences between Aberdeen and London females. A definitive test of this hypothesis would require a study based on subjects with documented obstetrical history.

Abnormalities of the vertebral blood vessels have been invoked in the genesis of Schmorl's nodes. In the fetus, the intervertebral discs are well supplied with blood vessels. These subsequently degenerate so that the normal adult intervertebral disc is virtually avascular. According to Schmorl & Junghanns (1971), anomalies in this process could result in the persistence of vascular channels in the cartilaginous endplate. The presence of such channels would weaken the endplate and thereby facilitate the herniation of the nucleus pulposus into the subchondral bone. In post mortem adult lumbar columns, Nachemson, Lewin, Maroudas & Freeman (1970) and Maroudas, Stockwell, Nachemson & Urban (1975) found that vascular channels perforating the subchondral bone and penetrating the cartilaginous endplate occurred mainly in the central region of the vertebral surface. This site corresponds

closely with the localisation of Schmorl's nodes in the present study. The role of residual vascular channels might be clarified by quantitative studies on their degree of concurrence with Schmorl's nodes.

Some authors have suggested that Schmorl's nodes may form at foci of endplate weakness arising from incomplete resorption of the notochord (Schmorl & Junghanns, 1971; Resnick & Niwayama, 1978; McWhirr *et al.* 1982). The present study supports the notochordal remnant hypothesis by virtue of the clustering of Schmorl's nodes in the central/central-posterior part of the vertebral surface, since this locality represents the site originally occupied by notochord (Williams & Warwick, 1980). Furthermore, the tendency for node sequences to assume not only the same position, but also the same shape, is suggestive of flawed notochordal regression. The fact that ageing did not bring about an increased frequency of Schmorl's nodes may reflect the inability of the nucleus pulposus to herniate through weak spots in the endplate once it has lost its youthful elastic turgor (Resnick & Niwayama, 1978).

It has been suggested that trauma and strenuous activity, particularly during adolescence, may contribute to the formation of Schmorl's nodes (Schmorl & Junghanns, 1971; McWhirr *et al.* 1982). When considering skeletal remains, it is difficult to assess such factors in the absence of information on the life style of the populations concerned. Such information was not available for this study. It might have helped to explain the marked differences between Aberdeen and London females, particularly in view of Brugsch's (1957) claim that housework is the most common cause of Schmorl's nodes in females.

The observed sex differences in the regional distribution of Schmorl's nodes is puzzling and requires further investigation. It may reflect sex related differences in prenatal axial skeleton development. Williams & Warwick (1980) recorded that ossification of the centra commences in the lower thoracic region and extends cranially and caudally along the column. However, in a study of unsexed fetuses Bagnall, Harris & Jones (1977) reported that the centra begin to ossify in both the lower thoracic and upper lumbar regions. Further work on fetal series of known sex may disclose developmental differences that might be related to the different male and female nodal distribution patterns. Alternatively, sex differences in node distribution may be associated with different stress patterns arising from sex differences in skeletal structure and/or physical activity.

SUMMARY

The herniation of the nucleus pulposus into the vertebral body produces ectopic deposits of disc material which are known as Schmorl's nodes. This prolapsed disc tissue leaves characteristic deformations on the surface of the vertebral body and hence the incidence of this lesion can be studied in skeletal remains. This report describes the occurrence of Schmorl's nodes in TV8–SV1 in two historic adult British populations, one from Aberdeen and the other from London.

In the Aberdeen group, both males and females showed a high incidence rate and severity of Schmorl's nodes. In the London group, the males had a similarly high affliction whereas the females were nearly free of the condition. The lesion had no significant predilection for any one particular vertebral surface. However, in males in both localities, the frequency of Schmorl's nodes was significantly higher in the thoracic region than in the lumbosacral region. In contrast, both groups of females showed similar node frequency in these two zones. The majority of Schmorl's nodes

were localised in the central and central-posterior regions of the vertebral surface. When nodes occurred on successive vertebral surfaces, they often formed sequences showing similar shape and position.

The aetiology of Schmorl's nodes is unclear. Various hypothetical causal factors were appraised in relation to the findings of this study. It was suggested that anomalies in vascular and/or notochordal regression may be related to the development of the lesion.

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