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High stature and body mass might affect the occurrence of Schmorl's nodes

Dawid Trzciński, Anna Myszka, Janusz Piontek

Department of Human Evolutionary Biology, Institute of Anthropology,
Adam Mickiewicz University in Poznań, Poland

ABSTRACT: Schmorl's nodes are vertical herniation of intervertebral discs into the body of neighbouring vertebral endplate. Notwithstanding extensive studies, no consensus has been reached in the subject of their possible etiology. It is hypothesized that physical stress, trauma and high axial loading are the key factors in the occurrence of this pathology. The main objective of the current work is to reevaluate the relationship between stature and body mass and Schmorl's nodes. For this purpose, skeletal samples from Lithuania (44 males and 19 females) and Poland (97 males and 60 females) were used. The study confirmed that Schmorl's nodes are age-independent, and more frequent in males (12.63% on the superior and 19.32% on the inferior surface of vertebrae) than in females (6.23% and 12.29% respectively). Obtained results also suggest that high stature (e.g. Spearmann correlation for superior: R=0.20 p=0.017, and inferior: R=0.31 p=0.000 surface of vertebrae) and body mass (R=0.25, p=0.002 and R=0.32, p<0.001, respectively) are factors that increase the risk of Schmorl's nodes. Authors hypothesize that the afore-mentioned body size traits alter loadings acting on intervertebral discs, and rigidity of the spine.

KEY WORDS: spine pathology, vertebrae, body mass, skeletal sample

Introduction

Schmorl's nodes (SN) are frequently observed spine pathologies involving vertical herniation of intervertebral discs (nucleus pulposus) into the body of neighbouring vertebral endplate (Fig. 1). They mostly occur in young age, when turgor is usually higher (Resnick and Niwayama 1978). Their incidence is often used for interpretation of past human health and activity.

Schmorl's nodes are subject of interest not only in medical studies, but they also became examined in other fields, like bioarchaeology or physical anthropology (Üstündağ 2009). Notwithstanding such extensive studies, no consensus has been reached in the subject of their possible etiology (Üstündağ 2009).

Schmorl's nodes are commonly treated as a trace and indicator of physical stress and trauma (Stirland and Waldron 1997; Šlaus 2000; Üstündağ 2009;

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Fig. 1. Schmorl's nodes on superior surfaces of lumbar vertebrae. Credit: B. Iwanek

Jiménez-Brobeil et al. 2010; Novak and Šlaus 2011; Novak et al. 2012). Those changes are also related to high axial loading (Wagner et al. 2000; Baranto et al. 2006; Nagashima et al. 2013). In the past several years, new hypotheses about SN etiology have been proposed. It is possible that that immune system plays a key role in the formation of SN (Zhang et al. 2010). Another etiological factor might be the lower level of sex hormones in females (Wang and Griffith 2011).

In many studies, correlations of SN with other pathologies, related to physical loading, might be observed (Hilton et al. 1976; Williams et al. 2007; Faccia and Williams 2008; Woo and Pak 2014). There also exist discrepancy in terms of relationships between age and SN occurrence (Saluja et al. 1986; Jankauskas 1992; Šlaus 2000; Williams et al. 2007; Dar et al. 2009; Novak and Šlaus 2011; Plomp et al. 2012; Navitainuck et al. 2013; Sonne-Holm et al. 2013).

Another interesting hypothesis is proposed by Plomp et al. (2012, 2015), who claimed that shape and size of vertebral body, size of neural foramen, and shape of the superior articular facets and pedicles are correlated not only with the mere presence, but also with severity of SN (Plomp et al. 2012, 2015).

Such diverse results provoke further search for etiology of this specific disc herniation, especially including both environmental and genetical conditions. Such human body features as stature and body mass fit into these categories, and may influence the process of SN formation. Longer spine, larger body mass and general robustness may increase axial loading on the vertebral column (Han et al. 2103), which can result in SN. The hypothesis concerning body size influence on SN formation was examined by Sonne-Holm and coworkers (2013). The researchers found no correlation between SN and stature, body mass, BMI indicator or high physical load (Sonne-Holm et al. 2013). Plomp et al. (2015) investigated the influence of stature on Schmorl's nodes. They did not find differences in body height between individuals who did or did not display pathological changes (Plomp et al. 2015).

The main aim of the current work is to determine whether greater stature and body mass increase the risk of Schmorl's nodes, and to reavaluate the results obtained by Sonne-Holm et al. (Sonne-Holm et al. 2013) and Plomp et al. (Plomp et al. 2015), through application of a different methodological approach. The secondary objective is to investigate differences in the prevalence of SN between the upper and the lower vertebral body surfaces.

Materials and methods

Subjects used for this study were 220 human remains from Medieval and Early Modern period cemeteries from Lithuania and Poland. Sample consisted of only those skeletons for which sex could be univocally estimated, and which had at least one present vertebrae from both thoracic and lumbar area, and at least one well preserved femoral bone. Males are represented by 141 individuals, whereas females by 79.

Lithuanian samples come from several archeological sites. Most samples were found in Vilnius at Liejyklos st. (10 males, 3 females) and Subačiaus st. (25 males, 15 females), while the rest in rural areas: Rukliai (2 males, 1 female), Karmėlava (2 males), Ramoniškiai (1 male), Šiauliai (1 male), Dapkūnai (4 males), and Tauragnai (2 males), which amounts to the total of 44 males and 19 females.

Polish material comprises individuals from Łekno (48 males, 18 females) and Słaboszewo (49 males, 42 females) cemeteries, 97 males and 60 females in total.

Sex determination was performed using skull and pelvic traits, according to methods suggested by Buikstra and Ubelaker (1994). In order to estimate age, Todd's (1920) and Lovejoy et al. (1985) standards for pubic symphysis and auricular surface were used. Age groups frequencies are presented in Table 1.

For stature estimation, the formulas by Trotter and Gleser (1952) were used, based on the fact that they are the most

Table 1. Age and sex distribution of study samples

Age group	Lithuanian populations				Polish populations				All populations			
	Males		Females		Males		Females		Males		Females	
	N	%	N	%	N	%	N	%	N	%	N	%
18–29	9	20.45	7	36.84	18	18.56	18	30.00	27	19.15	25	31.65
30–39	14	31.82	3	15.79	23	23.71	24	40.00	37	26.24	27	34.18
40–49	9	20.45	4	21.05	26	26.80	13	21.67	35	24.82	17	21.52
50+	12	27.27	5	26.32	30	30.93	5	8.33	42	29.79	10	12.66
All	44	100	19	100	97	100	60	100	141	100	79	100

N – number of specimen in the sample.

Table 2. Formulas used to estimate stature and body mass

Authors	Formula
Stature	
Trotter & Gleser (1952)	ST = 2.38*(M1) + 61.41 (Males) ST = 2.47*(M1) + 54.10 (Females)
Body mass	
Ruff et al. (1991)	BM = [2.741*(F18) – 54.9]* 0.9 (Males) BM = [2.426*(F18) – 35.1]* 0.9 (Females)

ST – estimated stature (cm), BM – estimated body mass (kg), M1 – maximal femoral length (cm) according to Martin and Saller (1957), F18 – femoral head superoinferior breadth (mm) [M18 according to Martin and Saller (1957) (C.B. Ruff, personal communication)].

popular, and provide comparison with data obtained by other authors. To estimate the stature, measurements of femoral maximum length (M1) were taken from each individual, consistent with standards proposed by Martin and Saller (1957). Body mass was established with use of mechanical method described by Ruff et al. (1991), which uses femoral head measurement (M18). Formulas are presented in Table 2.

Schmorl's nodes were recognized morphologically as depression with sclerotic margins, and varying shape, size, and depth. For each skeleton, these changes in nodes were noted as occurring on each available superior and inferior vertebral plate, if larger than 1 mm trace of herniation on vertebral body was observed. Surfaces of vertebrae damaged by the environment and severely distorted by other pathological changes, were excluded from the study. Observation of SN has been conducted by one researcher.

In order to define the location of Schmorl's nodes, changes were analyzed in four regions of the spine – cervical, upper thoracic (vertebrae from Th1 to Th6), the lower thoracic (vertebrae from Th7 to Th12), and lumbar. Frequencies of SN in each region of the spine were used, separately for upper and lower surface. Due to a very small number of SN traces in the cervical spine, this area was excluded from further analysis.

The relationships between the occurrence of Schmorl's nodes and the stature and body mass were calculated using Spearman correlation. To display age dependency, Tau Kendall method was used. The differences in frequencies of lesions were determined by Wilcoxon test.

Statistical analysis was performed with the Statistica 12.0 software. The degree of statistical significance was established at 0.05.

Results

The average stature and body mass for males and females are presented in Table 3.

Examined pathology was fairly widespread. At least one trace of Schmorl's node was present in 92 of 141 males (65.25%) on the upper surface of the vertebrae, and 110 (78.01%) on the lower surface. In females, SN were found in 35 to 79 individuals (44.30%) on the upper surface, and 46 (58,23%) on the lower surface. In males, 293 of 2320 (12.63%) vertebrae had pathological changes on its upper surface, while on the opposite surface it was 474 of 2454 (19.32%). In females, frequencies were, respective-

Table 3. Mean stature and body mass in males and females

Sample	Stature [cm]		SD		Body mass [kg]		SD	
	Males	Females	Males	Females	Males	Females	Males	Females
Lithuania	168	156	4.69	5.90	69	60	5.87	4.98
Poland	171	159	6.47	6.42	72	63	7.11	5.68
All	170	159	6.17	6.48	71	63	6.88	5.70

SD – Standard deviation.

ly, 76 of 1202 (6.23%) and 162 of 1287 (12.29%) (Table 4).

Connections between age and Schmorl's nodes were statistically insignificant. Detailed results are presented in Table 5. Due to a small number of individuals in age groups, further analysis was performed without division into age categories.

Differences between upper and lower surfaces of vertebrae were observed. Only in females, non-significant disparity was observed in lower thoracic area (Table 6). Disparities between sexes

Table 4. Frequencies (%) of Schmorl's nodes in males and females

Spine segment	Upper surface of vertebrae						Lower surface of vertebrae					
	Males			Females			Males			Females		
	N	n	%	N	n	%	N	N	%	N	n	%
Cervical	743	3	0.4	362	0	0	743	3	0.4	364	1	0.3
Upper thoracic	702	37	5.3	368	2	0.5	711	105	14.8	377	24	6.4
Lower thoracic	495	166	33.5	280	51	18.2	616	310	50.3	351	119	33.9
Lumbar	380	87	22.9	192	23	12.0	384	56	14.6	195	18	9.2
Total	2320	293	12.6	1202	76	6.3	2454	474	19.3	1287	162	12.6

N – total number of examined vertebrae, n – number of vertebrae with Schmorl's nodes.

Table 5. Correlation between age and Schmorl's nodes. Males and females

Correlation	Males			Females		
	N	Tau	p	N	Tau	p
Th1-Th6 Upper surface	130	0.02	0.766	73	0.14	0.078
Th1-Th6 Lower surface	130	0.05	0.442	75	0.10	0.222
Th7-Th12 Upper surface	135	–0.07	0.228	76	0.01	0.943
Th7-Th12 Lower surface	137	0.03	0.550	76	–0.07	0.338
Lumbar Upper surface	139	0.08	0.155	73	–0.07	0.404
Lumbar Lower surface	139	0.08	0.182	74	–0.05	0.563
All Vertebrae Upper surface	141	–0.03	0.629	79	0.00	0.990
All Vertebrae Lower surface	141	0.03	0.596	79	0.01	0.917

N – number of individuals, Tau – correlation coefficient, *p* – probability value.

Table 6. Differences in Schmorl's nodes frequency between superior and inferior surface of vertebrae

Spine segment	Males			Females		
	N	T	p	N	T	p
Upper thoracic	89	1180.50	0.001	38	218.00	0.027
Lower Thoracic	50	271.00	0.000	15	43.00	0.334
Lumbar	41	177.00	0.001	10	0.00	0.005

N – number of individuals, T – t-Student statistic result, *p* – probability value.

Table 7. Differences in Schmorl's nodes frequency between males and females

Segment	U	Z	p	N Males	N Females
Superior surface					
Upper thoracic	4024.50	3.14	0.002	130	73
Lower thoracic	3898.00	3.13	0.002	135	76
Lumbar	4033.00	2.86	0.004	139	73
All	4140.00	3.28	0.001	141	79
Inferior surface					
Upper thoracic	4099.00	2.47	0.014	130	75
Lower thoracic	3904.00	3.11	0.002	137	76
Lumbar	4349.50	2.30	0.021	139	74
All	4297.00	2.84	0.004	141	79

U – U Mann Whitney statistic result, Z – normal distribution variate value, *p* – probability value.

were observed in every segment of the spine, and entire vertebral column (Table 7). Due to these results, upper and lower surfaces of vertebrae were considered separately in males and females.

The most of statistically significant correlations between stature, body mass and Schmorl's nodes were observed among males. Connections were noted for both traits. In females, correlation between body mass and SN was observed in lower thoracic spine (Table 8).

Discussion

The current study found significant correlation of occurrence of Schmorl's nodes with reconstructed stature and body mass in males. Clearly, the aim of the paper is not to diminish the genetic cause of Schmorl's nodes formation (Williams et al. 2007), but to supplement the biomechanical etiology of SN.

Without any doubts, Schmorl's nodes are vertical herniations of intervertebral discs (nucleus pulposus) into the body of neighbouring vertebral endplate (Resnick and Niwayama 1978). Considering the nature of SN, it is justified to concentrate on factors that cause and alter loadings acting on intervertebral discs. Markolf (1972) proved that sudden movements leading to twists of spine may result in pathological changes, caused by heavy load absorbed by discs. Hollinshead (1976) has specified afore-mentioned movements to include bending, stretching, and rotating, move-

Table 8. Correlations between stature, body mass and Schmorl's nodes

Correlation	Males			Females		
	N	R	p	N	R	p
Stature and Schmorl's nodes						
Th1-Th6 Upper surface	130	0.21	0.015	73	–0.24	0.039
Th1-Th6 Lower surface	130	0.14	0.123	75	–0.14	0.247
Th7-Th12 Upper surface	135	0.14	0.106	76	0.09	0.425
Th7-Th12 Lower surface	137	0.28	0.001	76	0.12	0.289
Lumbar Upper surface	139	0.24	0.004	73	–0.08	0.515
Lumbar Lower surface	139	0.30	0.000	74	0.05	0.680
All Vertebrae Upper surface	141	0.20	0.017	79	0.04	0.740
All Vertebrae Lower surface	141	0.31	0.000	79	0.05	0.691
Body Mass and Schmorl's nodes						
Th1-Th6 Upper surface	130	0.28	0.001	73	–0.18	0.127
Th1-Th6 Lower surface	130	0.25	0.004	75	0.05	0.696
Th7-Th12 Upper surface	135	0.16	0.060	76	0.27	0.018
Th7-Th12 Lower surface	137	0.34	0.000	76	0.27	0.020
Lumbar Upper surface	139	0.25	0.003	73	–0.01	0.950
Lumbar Lower surface	139	0.28	0.001	74	–0.02	0.857
All Vertebrae Upper surface	141	0.25	0.002	79	0.12	0.282
All Vertebrae Lower surface	141	0.32	0.000	79	0.21	0.070

N – number of individuals, R – correlation coefficient, *p* – probability value.

ments characteristic of rising up from the ground, lifting and carrying things, and likely to accompany falls. Additionally, factors increasing the loadings on intervertebral discs are related to anatomy of the spine. The rigidity of thoracic area, caused by the presence of the ribs, results in transferring large amounts of force onto intervertebral discs (Markolf 1972). Moreover, moving from less to more flexible regions of the spine is weakening its structure, which leads to absorption of greater forces by cartilage (Markolf 1972).

Above mentioned etiological factors might be modified by traits examined in the present study – stature and body mass. Authors hypothesize that the greater the stature the higher the vertebral bodies and, hence, the lower the ratio of intervertebral discs to vertebral bodies. These two factors increase the risk of Schmorl's nodes formation, according to Plomp et al. (2015) and Dar et al. (2010).

Higher body mass most probably increases forces acting on intervertebral discs, and may modify the morphology of vertebral bodies as a response to increased stress. Relationships between body mass and Schmorl's nodes are observed in areas where the axial loadings are stronger – in thoracic and lumbar areas (Dar et al. 2010), which confirms the hypothesis formulated for this study.

The mobility of particular areas of the spine constitutes an important factor in Schmorl's nodes formation (Hilton et al. 1976; Üstündağ 2009). Cook et al. (Cook et al. 2015) proved that individuals with greater stature and body mass have decreased mobility of lumbar spine. As already mentioned, more rigid regions of the spine are more inclined to develop Schmorl's nodes. Higher stature and greater body mass may be another factors modifying the mobility of vertebrae.

Differences in obtained in the present study correlations between stature and body mass between males and females most probably have biomechanical causes. Males have bigger nucleus pulposus, which is directly connected with SN formation. Moreover, males have decreased mobility of, at least, lumbar spine (Cook et al. 2015). It is also known that males were subject to greater physical loading in past populations (Novak and Šlaus 2011; Novak et al. 2012). Considering these three arguments, difference in frequency of Schmorl's nodes between males and females, and greater influence of stature and body mass on forming of the nodes in males are justified.

Apart from the main aim of the study, the paper touches upon differences in Schmorl's nodes distribution between surfaces of vertebral bodies. Higher frequency of Schmorl's nodes traces in the studied populations was observed on the lower surface of the stems in the case of thoracic vertebrae and on the upper surface in the case of lumbar area. The results presented in the scientific literature are diversified. Some researchers did not observe any such differences (Saluja et al. 1986; Sonne-Holm et al. 2013), while others noticed the SN prevalence on either the upper or the lower surface of the stems (Piekarz and Piontek 1999; Pfirrmann and Resnick 2001; Faccia and Williams 2008; Dar et al. 2010; Burke 2012). Results of the present study confirm observed earlier differences between surfaces. Unfortunately, there is still no explanation indicating any causes of this phenomenon (Dar et al. 2010), except for suggestions that developmental processes of the vertebrae may be of importance (Dar et al. 2010).

Authors hypothesize that differences between superior and inferior surfaces of vertebral bodies might be explained by unequal thickness of vertebral endplates. Some researchers (Hulme et al. 2007; Wang et al. 2011) proved that lower endplate is significantly thinner, less dense, and more porous than the upper one. Fainter barrier of the inferior endplate should be more easily overcome by nucleus pulposus. The reason why the endplate thickness plays an important role in development of differences between upper and lower surface may be the fact that this trait is age and gender independent (Silva et al. 1994; Wang et al. 2011).

Conclusions

High stature and body mass are factors that increase the risk of Schmorl's nodes. Authors hypothesize that those body size traits alter loadings acting on intervertebral discs, and the rigidity of the spine.

Frequencies of Schmorl's nodes are greater on the lower surface of the stems in the case of thoracic vertebrae, and on the upper surface of lumbar area. This may result from unequal thickness of vertebral endplates on both surfaces.

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Authors' contributions

DT designed the research, performed the anthropological analysis and interpretation of obtained results, and wrote the manuscript. AM gave support, and conceptual advice, commented and corrected the initial draft of the manuscript. JP was the project manager and supervisor. All authors read and approved the final version of the manuscript.

Conflict of interest

The authors declare that there is no conflict of interests regarding publication of this paper.

Corresponding author

Dawid Trzciński, Department of Human Evolutionary Biology, Institute of Anthropology, Faculty of Biology, Umultowska 89, 61-614 Poznań
e-mail: dawid.trzcinski@outlook.com

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