Osteophytes in the Cervical Vertebral Bodies (C3–C7)—Demographical Perspectives

DAVID EZRA,[1,2] ISRAEL HERSHKOVITZ,[1,3*] KHALIL SALAME,[4] DEBORAH ALPEROVITCH-NAJENSON,[1] AND VIVIANE SLON[1]

[1]Department of Anatomy and Anthropology, Sackler Faculty of Medicine, Tel-Aviv University, Tel Aviv, Israel
[2]School of Nursing Sciences, Tel Aviv Yaffo Academic College, Tel Aviv, Israel
[3]The Steinhardt Museum of Natural History and National Research Center, Tel Aviv University, Tel Aviv, Israel
[4]Department of Neurosurgery, Tel Aviv Sourasky Medical Center, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

ABSTRACT

Vertebral osteophytes are an age-dependent manifestation of degenerative changes in the spine. We aimed to determine the prevalence and severity of cervical osteophytosis in a large study population. To do so, we developed a grading system for osteophytosis, enabling the assessment of their presence and severity in the cervical spine, and applied it to the analysis of dried cervical vertebral bodies (C3–C7) from 273 individuals. Statistical analyses were carried out per motion segment, while testing for the effect of age, sex, and ethnicity. The highest prevalence of osteophytes was found in motion segment C5/C6 (48.2%), followed by C4/C5 (44.1%), and last C6/C7 and C3/C4 (40.5%). Severe osteophytes are most commonly seen in motion segment C5/C6. In all motion segments, the inferior discal surface of the upper vertebra manifests more osteophytes than the superior discal surface of the lower one. Osteophytes prevalence is sex-dependent only in the upper cervical vertebrae (C3–C4), and age- and ethnicity-dependent for all vertebrae. Anat Rec, 302:226–231, 2019. © 2018 Wiley Periodicals, Inc.

Key words: osteophytosis; cervical vertebrae; spine; degenerative changes

Vertebral osteophytes (spondylosis) are an age-dependent manifestation of degenerative changes in the spine (Nathan, 1962; Heggeness and Doherty, 1998; O'neill et al., 1999). Osteophytes arise from a proliferation of the annulus tissue, which undergoes metaplasia into hyaline cartilage and then ossifies, similarly to the endochondral ossification of growth plates. Although their etiology is still under debate, experiments conducted using animal models have shown that scalpel-induced disc degeneration results in the growth of osteophytes in adjacent vertebrae (Lipson and Muir, 1980). Similarly, articular degeneration of the knee joint induced by

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*Correspondence to: Israel Hershkovitz, The Steinhardt Museum of Natural History and National Research Center, Tel Aviv University, P.O. Box 39040, Tel Aviv 6997801, Israel. Fax: 972-3-6408287 E-mail: anatom2@tauex.tau.ac.il

Viviane Slon is currently affiliated with Department of Evolutionary Genetics, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany.

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chemical damage leads to the rapid formation of osteophytes (Williams and Thonar, 1989). Notably, several case reports have suggested that osteophytes may develop following spinal trauma (Kissel and Youmans, 1992; McGarrah and Teller, 1997).

Osteophytes are most commonly present at the anterolateral margins of the vertebral bodies, mainly at the lower cervical, lower thoracic, and mid-lumbar vertebrae (Nathan, 1962; O'neill et al., 1999). They are usually divided into "traction" and "claw" spurs (Macnab, 1971), albeit these two types can coexist on the same vertebra (Heggeness and Doherty, 1998) and may simply represent early and late stages of a single process (Nathan, 1962). In middle-aged women, lumbar vertebral osteophytes typically grow by 4% per year (Hassett et al., 2003).

In the cervical spine, osteophytes may cause immobility and stiffness of the neck, osteoarthritis, and headaches (Klaassen et al., 2011). Moreover, osteophytes can be involved in nerve entrapment syndromes (Nathan, 1962) or lead to the compression of the vertebral artery when deriving from the vertebral uncinate processes. Large osteophytes may mechanically cause blockage of the esophagus, causing dysphagia (Strasser et al., 2000; Ozgocmen et al., 2002) and possibly leading to sleep apnea (Hughes et al., 1994), while small osteophytes may cause obstruction by compressing the esophageal segment attached to the cricoid cartilage, most commonly at C5/C6 (Strasser et al., 2000).

Vertebral osteophyte formation has been linked to high compressive load-bearing (O'neill et al., 1999; Echarri and Forriol, 2002) and is suggested to contribute to spinal stability in bending (Al-Rawahi et al., 2011). Increase in body mass and heavy physical activity, mainly in males, may cause intervertebral disc degeneration followed by osteophytes formation (Nathan, 1962; Macnab, 1971; Heggeness and Doherty, 1998; O'neill et al., 1999; Hardcastle et al., 2014). Nonetheless, their mechanical significance remains under debate.

To shed further light on this phenomenon, this study focuses on osteophytes along the articular surfaces of the vertebral bodies, by motion segment in the cervical spine.

MATERIALS AND METHODS

The study population was sampled from the collection of human skeletons housed in the Natural History Museum in Cleveland, OH (The Hamann-Todd Osteological Collection). Information on place of birth, ethnicity, morbidity, age, and sex were collected from the individuals' clinical records (Cobb, 1932).

The study sample (Table 1) included 273 individuals (133 females and 140 males), out of which 143 were African-Americans (69 females and 74 males) and 130 were European-Americans (64 females and 66 males). Eighty-eight individuals were aged between 20 and 39 years, 92 between 40 and 59 years, and 93 were over 60 years of age. The observations were made on the cervical vertebrae C3–C7. A total of 1,365 cervical vertebrae were studied and measured.

TABLE 1. Total study sample (N = 273) by sex, ethnic group, and age group

Sex	Ethnic group	Age group 20–39	40–59	60+	Total
Males	African-Americans	24	24	26	74
	European-Americans	21	23	22	66
Females	African-Americans	23	25	21	69
	European-Americans	20	20	24	64
	Total	88	92	93	273

A grading system for osteophytosis of the cervical spine articular surfaces was developed to assess the presence and severity of the phenomenon in each vertebral body. Four categories of osteophytes were defined, as follows:

Grade 1: Vertebral body with no or minor spurs. The epiphyseal ring and bony surface are intact (Fig. 1A).

Grade 2: Vertebral body with a small degree of osteophytosis. Bony spurs are present on the margin of the vertebral body. The epiphyseal ring is only slightly disturbed, while the bony surface is intact (Fig. 1B).

Grade 3: Vertebral body with a moderate degree of osteophytosis. Bone spurs at the vertebra body margin are >2 mm, the integrity of the epiphyseal ring is affected, the vertebral body is eroded, and the trabecular bone exposed (Fig. 1C).

Grade 4: Vertebral body with severe osteophytosis. The bony spurs are >4 mm, much of the epiphyseal ring is damaged, and there are holes and pores present on the discal surface of vertebral body (Fig. 1D).

Intra- and interobserver reliabilities were assessed using the Kappa test by comparing the grading determined by three observers on a sample of 15 cases with a week-long interval between tests, and were found to be high (Kappa = 0.95, $P < 0.001$).

To investigate the pattern of degenerative processes in the cervical spine by motion segment, we calculated a

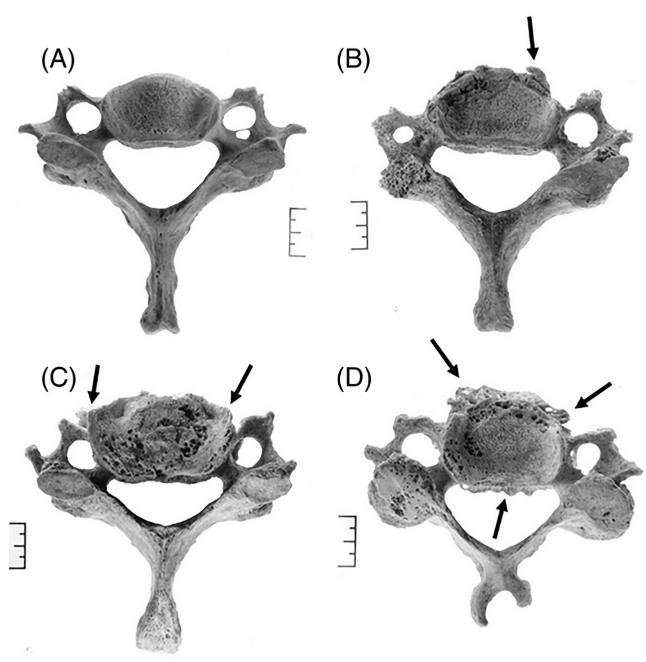

Fig. 1. Grading system of cervical osteophytosis. (**A**) Grade 1: vertebral body with no or minor spurs. (**B**) Grade 2: vertebral body with a small degree of osteophytosis. (**C**) Grade 3: vertebral body with a moderate degree of osteophytosis. (**D**) Grade 4: vertebral body with severe osteophytosis.

TABLE 2. Prevalence of osteophytes (%) by severity on the superior and inferior discal surfaces of the vertebral bodies (N = 1,365 vertebrae)

	Degree of osteophytes severity									
	Grade 1		Grade 2		Grade 3		Grade 4		Overall osteophyte prevalence	
	SDS	IDS	SDS	IDS	SDS	IDS	SDS	IDS	SDS	IDS
C3	74.36	56.04	18.32	24.18	4.03	12.82	3.30	6.96	25.64	43.96
C4	63.00	54.58	17.22	24.18	9.52	10.62	10.26	10.62	37.00	45.42
C5	57.14	48.72	19.05	12.82	10.99	14.29	12.82	24.18	42.86	51.28
C6	54.95	56.41	12.45	15.38	13.55	12.82	19.05	15.38	45.05	43.59
C7	62.64	70.33	17.58	20.51	9.16	6.23	10.62	2.93	37.36	29.67
All	62.42	57.22	16.92	19.41	9.45	11.36	11.21	12.01	37.58	42.78

Abbreviations: SDS = superior discal surface; IDS = inferior discal surface.

motion segment osteophytic prevalence (MSOP) index. This was computed as the average between the prevalence of osteophytes at the inferior discal surface (IDS) of a given upper vertebra and the prevalence at the superior discal surface (SDS) of the adjacent lower vertebra.

To check for any association between the prevalence of osteophytes and sex, age, or ethnicity, the Chi-square test was carried out using SPSS v.20. The level of significance (alpha) was set at 0.05.

RESULTS

Out of 1,365 vertebrae encompassed in our study, we identified 513 vertebrae affected by osteophytes at the margins of the SDS, and 584 affected vertebrae in the IDS, yielding a prevalence of 37.58% and 42.78%, respectively (Table 2). The highest frequency of osteophytes was found on the IDS of C5 (51.28%), while the lowest was in the SDS of C3 (25.64%) (Fig. 2A).

When examined by the MSOP index, the highest prevalence of osteophytes was found in motion segment C5/C6 (48.2%), followed by C4/C5 (44.1%), and C6/C7 and C3/C4 (40.5%) (Table 3). It is noteworthy that the highest rate of Grade 4 (severe) osteophytes was found between the IDS of C5 and the SDS of C6 (Fig. 2B). The IDS of C7 manifests the lowest rate of Grade 4 osteophytes. In all motion segments, the IDS of the upper vertebra manifests more osteophytes than the SDS of the lower one (Table 2). In motion segment C3/C4, the difference in osteophyte frequency between the upper and the lower vertebra is the greatest (7%).

Data on osteophyte prevalence in the two ethnic groups studied appear in Table 4. Overall, the osteophyte prevalence is higher among European-American than among African-American individuals. Only in two vertebrae (C5 and C7), European-Americans show significantly higher rates of osteophytes (by *ca.* 14%) than African-Americans. When only Grades 3 and 4 osteophytes are considered, their prevalence along the cervical spine is similar for both ethnic groups.

The overall prevalence of cervical osteophytes is higher among males than females (Table 5). This is driven by a

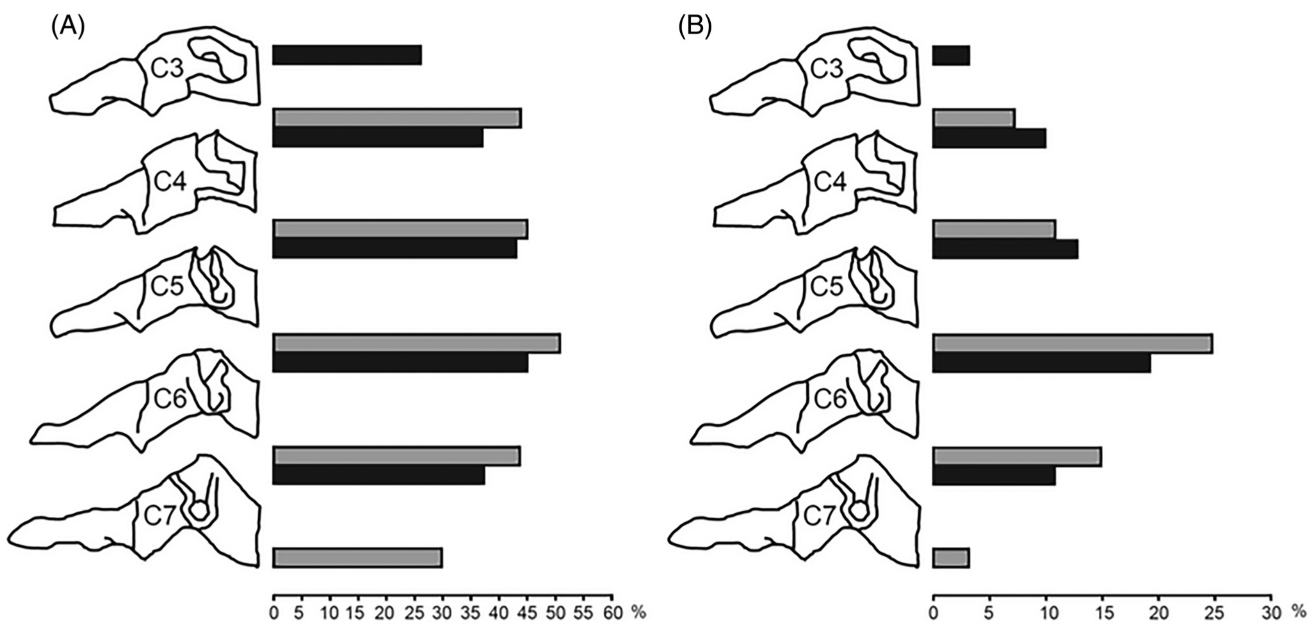

Fig. 2. Prevalence of osteophytes along the cervical spine. (**A**) All osteophyte grades combined. (**B**) Severe (Grade 4) osteophytes only.

TABLE 3. Prevalence of osteophytes (%) by severity, by motion segment in the cervical spine (N = 1,365 vertebrae)

	Grade 1	Grade 2	Grade 3	Grade 4	Overall osteophyte prevalence
C3/C4	59.52	20.70	11.71	8.61	40.48
C4/C5	55.86	21.62	10.81	11.72	44.14
C5/C6	51.84	12.64	13.92	21.62	48.17
C6/C7	59.53	16.48	10.99	13.00	40.48

The motion segment osteophytic prevalence (MSOP) index was computed as the average between the prevalence of osteophytes at the inferior discal surface of a given upper vertebra and the prevalence at the superior discal surface of the adjacent lower vertebra.

significant difference between the two sexes in the upper cervical vertebrae C3 and C4. In the lower cervical vertebrae (C5–C7), the rate of osteophytes is similar in males and females.

In all cervical vertebrae studied (C3–C7), the prevalence of osteophytes increased from the young age group (20–39 years) to the old age group (60+ years) (Table 6). In the young age group, for example, only 3.41% of the individuals studied manifested osteophytes on the SDS of C3 *versus* 50.53% of individuals over the age of 60 years. As expected, the prevalence of severe osteophytes (Grade 4) also increases with age. In C6, for example, only 1.14% of individuals in the 20–39 age cohorts manifested severe osteophytes *versus* 37.63% in the 60+ age cohort.

DISCUSSION

In this study, we show that the highest prevalence of osteophytes, in general and for severe osteophytes (Grade 4), occurs in motion segment C5/C6 (Fig. 2). This coincides with the fact that the cervical lordotic peak is located at C5, exposing the C5/C6 intervertebral disc to the maximum of flexion/extension movements (Harrison et al., 2011). This generates considerable stress on the bones and intervertebral disc, mainly the annulus fibrosus. Previous studies, such as those carried out on skeletal remains from Germany (Weber et al., 2003) and Korea (Kim et al., 2012), had also demonstrated that osteophytes prevail mostly in segments C5/C6 and C6/C7. Notably, a similar observation was found regarding osteophytes in the lumbar lordotic area, namely that the highest prevalence of osteophytes was found one motion segment lower than the lordotic peak (Nathan, 1962). The above findings suggest that loading is not the leading cause for osteophyte development in the cervical spine, because if it was, the highest prevalence would have been found at the C6/C7 segment. In our study, the frequency of osteophytes in the C6/C7 segment is smaller than the C5/C6 segment and identical to the upper cervical segments C3/C4. The fact that the C3/C4 and C6/C7 segments show the least amount of osteophyte formation can be attributed to the relatively small amount of movement occurring in these segments (Panjabi et al., 1991).

Interestingly, we found that within a given motion segment, the upper vertebra (IDS) manifests a higher prevalence of osteophytes than the lower vertebra (SDS). We hypothesize that this is due to the anatomical shape of the spine. The vertebral bodies are trapezoidal in shape: the IDS of the upper vertebra in a given segment of motion is always wider than the SDS of the lower vertebra in frontal view. This phenomenon gives the spine a somewhat "pagodal" shape (Masharawi et al., 2008). This morphological arrangement allows the intervertebral disc to better withstand torsional movements (Ezra, 2006) and at the same time secures spinal stability. Notably, the formation of osteophytes has been linked to an increased resistance to bending of the spine (Al-Rawahi et al., 2011). Although the formation of osteophytes is a pathological process, their presence on the articular surfaces of the vertebral bodies may contribute to the maintenance of spinal stability. We note that a putative adaptive role for osteophytes has been suggested for other parts of the skeleton, such as the observed improvement of hip joint stability following the development of large osteophytes (Perry et al., 1972).

It has been previously reported that individuals of different ethnicities differ in the morphology of the cervical vertebrae (Roche, 1957; Taitz, 1999). We aimed to test whether two populations, African-Americans and European-Americans, would differ in the location and severity of cervical osteophytes as well. In concordance with previous studies (Roche, 1957; Nathan, 1962; Taitz, 1999), we found that for some vertebral levels, the frequencies of osteophytes differed between the two groups, although this was not the case for the prevalence of severe osteophytes.

TABLE 4. Prevalence of osteophytes (%) in 143 African-Americans and 130 European-Americans, in the superior discal surface of the cervical vertebrae

	Degree of osteophyte severity										
	Grade 1		Grade 2		Grade 3		Grade 4		Overall osteophyte prevalence		
	AA	EA	AA	EA	AA	EA	AA	EA	AA	EA	*P* value
C3	73.43	75.38	17.48	19.23	5.59	2.31	3.50	3.08	26.57	24.62	0.782
C4	63.64	62.31	13.29	21.54	9.09	10.00	13.99	6.15	36.36	37.69	0.900
C5	63.64	50.00	12.59	26.15	7.69	14.62	16.08	9.23	36.36	50.00	0.028*
C6	58.04	51.54	11.19	13.85	11.89	15.38	18.88	19.23	41.96	48.46	0.330
C7	69.23	55.38	13.85	22.31	8.39	10.00	9.09	12.31	30.77	44.62	0.024*
All	65.60	58.92	13.57	20.62	8.53	10.46	12.31	10.00	34.40	41.08	0.012*

Abbreviations: AA = African-Americans; EA = European-Americans. The association between the presence of osteophytes and ethnicity was tested using a two-sided Chi-square test
*Statistically significant difference.

TABLE 5. Prevalence of osteophytes (%) in the superior discal surface of cervical vertebrae, in 140 males and 133 females

	Degree of osteophyte severity								Overall osteophyte prevalence		
	Grade 1		Grade 2		Grade 3		Grade 4				
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	*P* value
C3	82.71	66.43	13.53	22.86	1.50	6.43	2.26	4.29	17.29	33.57	0.002*
C4	72.93	53.57	13.53	20.71	6.02	12.86	7.52	12.86	27.07	46.43	0.001*
C5	59.40	55.00	18.80	19.29	10.53	11.43	11.28	14.29	40.60	45.00	0.541
C6	55.64	54.29	11.28	13.57	14.29	12.86	18.80	19.29	44.36	45.71	0.903
C7	63.91	61.43	15.04	20.00	11.28	7.14	9.77	11.43	36.09	38.57	0.708
All	66.92	58.14	14.44	19.29	8.72	10.14	9.92	12.43	33.08	41.86	0.001*

The association between the overall prevalence of osteophytes and sex was tested using a two-sided Chi-square test.
*Statistically significant difference.

TABLE 6. Prevalence of osteophytes (%) on the superior discal surfaces of 1,365 vertebral bodies, by age group

	Degree of osteophyte severity												Overall osteophyte prevalence			
	Grade 1			Grade 2			Grade 3			Grade 4						
	20–39	40–59	60+	20–39	40–59	60+	20–39	40–59	60+	20–39	40–59	60+	20–39	40–59	60+	*P* value
C3	96.59	78.26	49.46	3.41	19.57	31.18	0	1.09	10.75	0	1.09	8.60	3.41	21.75	50.53	<0.001
C4	95.45	59.78	35.48	3.41	23.91	23.66	0	9.78	18.28	1.14	6.52	22.58	4.55	40.21	64.52	<0.001
C5	94.32	54.35	24.73	3.41	21.74	31.18	0	14.13	18.28	2.27	9.78	25.81	5.68	45.65	75.27	<0.001
C6	94.32	53.26	19.35	3.41	14.13	19.35	1.14	15.22	23.66	1.14	17.39	37.63	5.69	46.74	80.64	<0.001
C7	97.73	59.78	32.26	1.14	20.65	30.11	1.14	13.04	12.90	0	6.52	24.73	2.28	40.21	67.74	<0.001
All	95.68	61.09	32.26	2.96	20.00	27.10	0.46	10.65	16.77	0.91	8.26	23.87	4.32	38.91	67.74	<0.001

Differences between the groups were tested using a two-sided Chi-square test.

Higher rates of osteophytes in males' cervical vertebrae compared to females have previously been reported (Nathan, 1962). Based on our study, significant differences between males and females in osteophytes prevalence are evident only for the upper cervical levels (C3 and C4), although at this stage, it is unclear why this difference occurs only in these vertebrae.

Last, the association between cervical osteophytes and age has been reported in other studies (Nathan, 1962; O'neill et al., 1999), a feature which can be used to assist in age-at-death estimations in forensic contexts (Watanabe and Terazawa, 2006). This association is generally attributed to the degeneration of the intervertebral discs with age (Kumaresan et al., 2001). Furthermore, excessive mechanical stress, particularly at a young age, may predispose to the formation of osteophytes later in life (O'neill et al., 1999; Schmitt et al., 2004).

In conclusion, here we show that the prevalence of vertebral osteophytes is dependent on the motion segment within the cervical spine, the C5/C6 segment being the most prone to develop this pathology. Thus, we hypothesize that this phenomenon is mostly due to the anatomical structure of the spine, rather than a result of excessive load bearing. Additionally, we provide a large-scale dataset on cervical osteophytosis by sex, age, and ethnic origin, which could be used as a baseline for future studies investigating this and other pathologies of the cervical spine.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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