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## Cervical Spine Abnormalities in Professional Singers

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### Key Words

Cephalometry · Cervical spine · Opera singers · Vocal training · Performance level

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### Abstract

A systematic X-ray study of the cervical spine of three populations of subjects (professional singers, beginning singers, and non-singers) who exhibited no vertebral column pathology or postural disorders provided evidence of abnormalities in the shape of the cervical spine in all of the professional singers studied. The disorders observed included hypolordosis, and more frequently, cervical rectitude or hypocyphosis without functional hindrance. The findings can be explained in

terms of deformations undergone by the cervical spine after many years of intensive singing. The resulting functional postures are memorized and become an integral part of the singer's corporal schema. The considerable amount of anterior-posterior movement of the cervical spine in singing explains why lesions which prevent its mobility have an overall impact on the singer's voice, particularly in the upper pitch range.

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### Halswirbelsäulenabnormitäten bei Berufssängern

Die systematische röntgenologische Untersuchung der Halswirbelsäule (HWS) bei drei Untersuchungsgruppen (Berufssänger, Berufssänger am Anfang ihrer Karriere, Nichtsänger), welche weder pathologische Wirbelsäulenbefunde noch grössere Haltungsschäden aufwiesen, konnte bei allen untersuchten Berufssängern Abnormitäten in der Form der HWS nachweisen. Diese treten entweder als Hypolordose oder noch häufiger als Steilstellung der HWS oder Hypokyphose ohne funktionelle Beeinträchtigung auf. Diese Beobachtun-

gen lassen sich aus den Missbildungen der HWS infolge mehrjährigen intensiven Singens erklären. Die Gesangshaltung prägt sich dem Sänger so sehr ein, dass sie zu einem integralen Bestandteil seiner Körperhaltung wird. Die Bedeutung der Vor- und Rückwärtsbewegungen der HWS beim Singen liefert unter anderem eine Erklärung dafür, dass sich jegliche Verletzung, die die Bewegungsfähigkeit der Wirbelsäule unterbindet, auf die Gesangsstimme im allgemeinen und auf das Singen hoher Töne im besonderen auswirkt.

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In memory of Marie-Noëlle Grinneiser (25.9.1946–20.5.1997), osteopathic doctor and kinesiologist, who encouraged me to conduct this study which she felt had significant therapeutic implications.

## Les anomalies du rachis cervical chez les chanteurs professionnels

L'étude radiologique systématique du rachis cervical de trois populations de sujets (chanteurs professionnels, chanteurs débutants et non chanteurs) ne présentant pas de pathologie rachidienne ni de troubles majeurs de la statique a permis d'observer des anomalies dans la forme du rachis cervical chez tous les chanteurs professionnels examinés qui révèlent soit une hypolordose, soit plus fréquemment une rectitude cervicale ou une hypocyphose sans gêne fonctionnelle. Ces constatations peuvent s'expliquer par les déformations que

subit le rachis cervical après plusieurs années de pratique intensive du chant. Les positions de fonction qui en résultent sont mémorisées et font partie intégrante du schéma corporel du chanteur. L'importance des déplacements antéro-postérieurs du rachis cervical dans le chant permet en outre d'expliquer que toute lésion du rachis empêchant sa mobilité ait une incidence sur la voix chantée en général et sur l'émission de l'aigu en particulier.

### Introduction

As part of a research project on the singing voice, undertaken at the request of the French Ministry of Culture between 1983 and 1985, an extensive database was constituted of physiological and acoustic documents for a large number of opera singers. The X-ray study of subjects at rest and during phonation showed that the singers exhibited various degrees of abnormality in the shape and direction of the curvature of their cervical spines. However, because a certain number of factors were not controlled, it was difficult to establish whether the disorders were pathological or functional in origin [1]. In order to determine the exact cause of the abnormalities, we subsequently conducted a systematic X-ray study of the cervical spine of professional and beginning singers, along with a control group of non-singers.

### Material and Methods

#### *Selection of Subjects*

The subjects selected for this study were singers (professionals and beginners) and non-singers without vertebral column pathology or major postural disorders. Their static test results revealed excellent head mobility in all planes of rotation and satisfactory postural evaluations (correct shoulder, wrist, mid-pelvic,

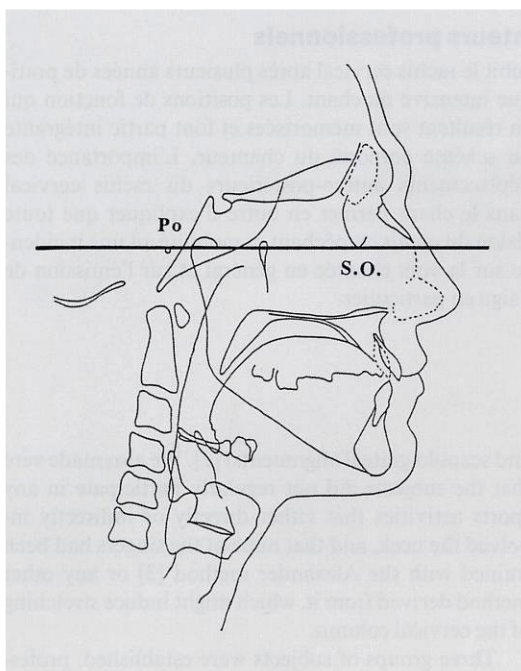
and scapulo-gluteal alignments) [2]. We also made sure that the subjects did not regularly participate in any sports activities that either directly or indirectly involved the neck, and that none of the singers had been trained with the Alexander method [3] or any other method derived from it, which might induce stretching of the cervical column.

Three groups of subjects were established: professionals currently pursuing their careers as opera singers, beginners who practiced daily to an extent analogous to that of the professionals, and non-singers who served as the control group. There were 12 subjects in the professional group (6 men and 6 women, 2 representatives of each vocal category), 12 in the beginner group (6 men and 6 women, 2 from each vocal category), and 12 in the non-singer group (6 men and 6 women). For the professionals, the mean age was 40 and the mean number of years of voice training was 25 for one subgroup and 15 for the other. The beginners averaged 5 years of voice training and were divided into two subgroups having mean ages of 40 and 25, respectively. The mean age of the non-singers was 40 for one subgroup and 25 for the other.

#### *Experimental Procedure*

X-rays were taken of the head and neck in left/plate position (distance: 3 m, exposure time: 0.15 s, voltage: 120 kV, current: 100 mAs), first with the singers at rest and then as they produced the French cardinal vowels in their spoken voice and in their singing voice in the lower, middle, and upper pitch ranges. (In the so-called cardinal vowels [i], [a], [u] the tongue is in its most extreme positions in the buccal cavity: very far forward for [i], very low for [a], and very far back for [u].) The control group was X-rayed at rest and then while yawn-





**Fig. 1.** The Frankfort Plane is determined by the two Porions (Po) and the SubOrbital Point (SO). This plane is considered horizontal when the subject standing upright is looking straight ahead at eye level.

ing so as to obtain a jaw opening similar to that of the singers during upper pitch-range singing.

A cephalostat is generally used to keep the subject's head in the Frankfort plane [4] so that the bilateral bone structures can be superimposed on the resulting X-ray frames (fig. 1). However, while this constraint has little effect on speech, it is a hindrance in singing, where having the head in a fixed position constrains vocal emission and causes the singer to resort to compensation mechanisms. In order to study the lyrical artists' voice under experimental conditions as close as possible to those encountered in real life, we chose to sacrifice the quality of the bone alignment on the X-rays and let the singers take on their natural position for singing. They were simply told to look straight ahead at eye level. In fact, all singers spontaneously placed their head in the Frankfort plane (with variations on the reference frames of  $-1^\circ$  to  $+4^\circ$  relative to the absolute horizontal), most likely because singing requires a strictly upright posture that singers are

accustomed to adopting when they prepare to sing. In order to avoid skewing the results of the analysis, only those singers for whom the head orientation was very close to the Frankfort plane, i.e. deviations of less than  $1^\circ$  in either direction, were retained for the study. The control group subjects were manually positioned in the Frankfort plane by the radiologist before the films were taken.

### *Cephalometric Analysis*

A method for analysing the X-rays was developed based on cephalometric techniques [4] adapted to singing [5]. For this radiographic study of the cervical spine during phonation, the following six cephalometric parameters were used (fig. 2):

**Buccal Opening.** Measure of the jaw angle (A) formed by the palatal plane (as determined by the Anterior and Posterior Nasal Spines) and the mandibular plane (as determined by the Mental Point and the Gonion).

**Head Orientation.** Measure of the cephalic inclination angle (B) formed by the Sella-Nasion line and the absolute horizontal.

**Skull Position Relative to the Cervical Spine.** Measure of the craniocervical angle (C) formed by the Sella-Nasion line and the tangent that goes through the Posterior Odontoid Point and the Inferior Vertebral Point of the fifth cervical vertebra.

**Movements of the Occiput Relative to the Cervical Spine.** Measure of the occiput-axoidean angle (D) formed by the Opisthion-Basion line and the medial line of the axis.

**Anterior-Posterior Displacements of the Cervical Spine.** Measure of the distance between the inferior-anterior point of the sixth cervical vertebra and the perpendicular to the Sella-Nasion line at the sella turcica (E).

**Degree of Cervical Curvature.** Measure of the odontoidocervical angle (F) formed, at the inflection point in the curvature, by the tangent to the superior-posterior point of the odontoid and the tangent to the superior-posterior point of the other vertebrae.

### *Statistical Analysis*

An analysis of variance was used to test for the effects of the following factors: age, sex, vocal category, vocal technique, performance level (beginner vs. professional), and number of years of vocal training. Age was not a significant factor ( $p > 0.01$ ), nor was sex ( $p >$

0.01) or vocal category ( $p > 0.01$ ). In contrast, the number of years of vocal training ( $p < 0.01$ ) and the performance level ( $p < 0.01$ ) had significant effects.

### Physiological Analysis

#### Professionals

**Subjects at Rest.** On the reference X-rays (subjects at rest), abnormalities in the shape of the cervical spine were found for all singers examined. These included hypolordosis (4%), and more frequently, cervical rectitude (54%) or hypocyphosis (42%).

**Subjects during Singing.** The analysis of the X-rays taken during the emission of the French cardinal vowels sung in the lower, middle and upper pitch range indicated the following characteristics for all subjects as they went from the lower to the upper pitch range: (a) a substantial increase in buccal opening, (b) a raising of the head, (c) a backwards shift of the cervical spine, (d) posteriorization and rising of the occiput, and (e) a cervical curvature inversion.

#### Beginners

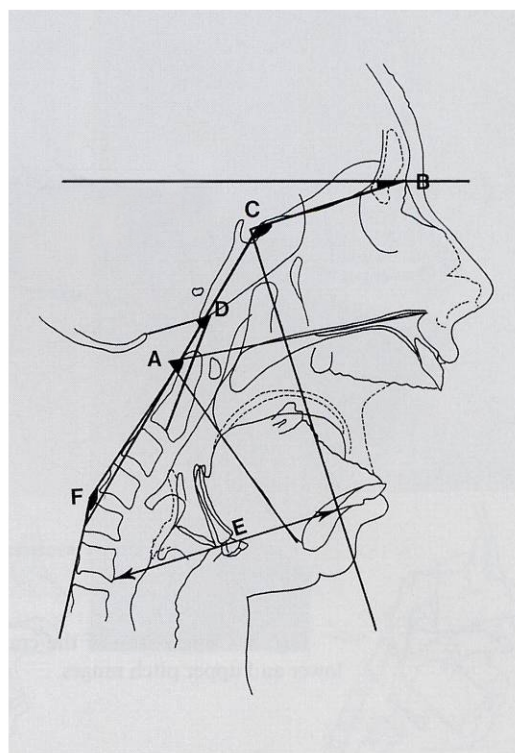
**Subjects at Rest.** The reference X-rays showed that 84% of the singers examined had physiological lordosis, 3% hypolordosis, and 16% cervical rectitude.

**Subjects during Singing.** The X-rays of subjects singing the French cardinal vowels in the three main pitch ranges displayed the following characteristics as the singers progressed from the lower to the upper pitch range: (a) a slight increase in buccal opening, (b) a slight raising of the head, (c) a moderate backwards shift of the cervical spine, and (d) no curvature inversion.

#### Non-Singers

**Subjects at Rest.** No abnormalities were observed in the shape of the cervical spine of these subjects, whose physiological lordosis was normal.

**Subjects Yawning.** The X-rays taken during yawning displayed some slight modifications in the shape of the cervical spine: 54% of the subjects exhibited cervical rectitude, 29% lordosis, and 17% hypocyphosis. Note that the subjects showing hypocyphosis were the ones with the largest buccal opening.

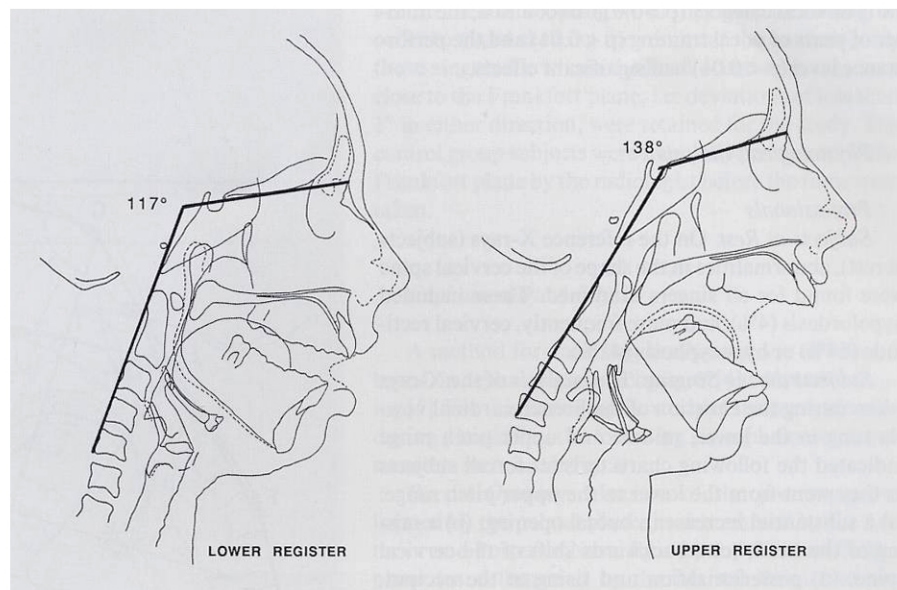


**Fig. 2.** Main cephalometric measures used to study the various physiological parameters. A = Jaw angle (buccal opening); B = cephalic inclination angle (head orientation); C = craniocervical angle (skull position relative to the cervical spine); D = occiput-axoidean angle (movements of the occiput relative to the cervical spine); E = distance between the sixth cervical vertebra and the perpendicular to the Sella-Nasion line at the sella turcica (anterior-posterior displacements of the cervical spine); F = odontoidocervical angle (degree of cervical curvature).

### Results

The data analysis showed that each of the three vocal pitch ranges has its own specific posture. For all subjects, the craniocervical angle increased as pitch increased (fig. 3). This phenomenon is jointly due to the raised head and the backwards shift of the cervical





**Fig. 3.** Comparison of the craniocervical angle in a professional soprano singing in the lower and upper pitch ranges.

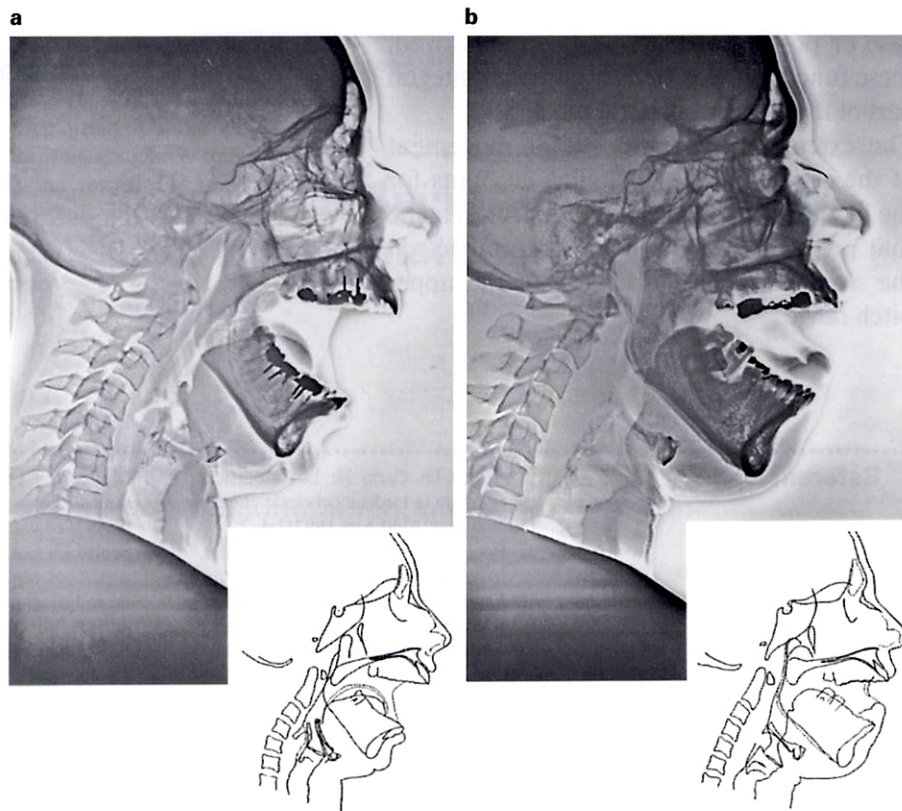
spine, both of which are determined by jaw opening. In the professional singers, the posterior position of the spine during singing in the upper pitch range was accompanied by a relatively large inversion of the cervical curvature (functional cyphosis replacing physiological lordosis; the term functional here means that the cyphosis is not the result of postural disorders but is due to spinal deformations generated by intensive singing). Apparently, this inversion occurs in order to create space for pharyngeal widening and the forward tilt of the thyroid cartilage, a requirement for singing in the upper pitch range [6] (fig. 4).

Jaw opening in the upper pitch range varied as a function of the singer's vocal technique and performance level. For singers with generally wide buccal openings, shifts of the sixth cervical vertebra as large as 4 cm were observed. At rest, these subjects exhibited either hypocyphosis or cervical rectitude. Sing-

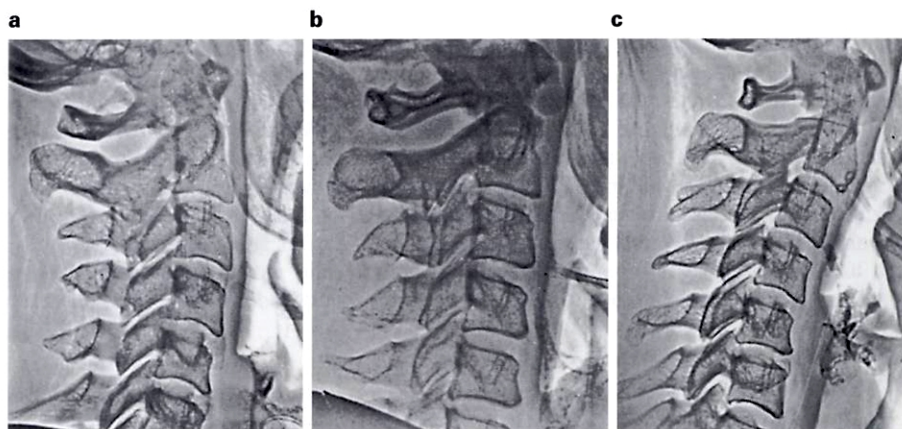
ers with smaller jaw openings, on the other hand, generally exhibited hypolordosis (fig. 5).

### Discussion and Conclusion

The extreme mobility of the cervical spine and the deformations it undergoes during singing are probably the sources of the cervical curvature abnormalities observed here in all singers examined. Insofar as no associated pathological factors appear to exist and that these abnormalities do not cause any functional disturbances, we can conclude that the resting posture of singers in fact corresponds to a *functional position* which results from the cervical deformations generated over extended periods of intensive singing, and not to an *algescic position*, i.e. a comfortable position aimed at relieving pain caused by a spinal dis-



**Fig. 4.** Example of cervical cyphosis observed in the upper pitch range of 2 professional sopranos singing the same note (C6). **a** Professional soprano, group 1: 25 years of vocal training. **b** Professional soprano, group 2: 15 years of vocal training.



**Fig. 5.** X-rays of different types of cervical curvatures of singers at rest. **a** Hypolordosis. **b** Cervical rectitude. **c** Hypocyphosis.

ease or postural disorder. Once memorized, these functional positions become an integral part of the singer's corporal schema. The extensive anterior-posterior movement of the cervical spine in singing accounts for the fact that any damage to the cervical spine that prevents its mobility has an impact on the singing voice, particularly in the upper pitch range.

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