

Cervical Angles in Sleep Apnea Patients: A Retrospective Study

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Abstract — The present study was undertaken to evaluate, retrospectively, radiographs from diagnosed Obstructive Sleep Apnea Syndrome (OSAS) patients. Four angles were assessed from the lateral radiographs: (1) atlas/axis, (2) atlas, (3) atlas/occiput, and (4) occiput, which, like the atlas angle, was determined relative to the horizontal plane of the x-ray film. The severity of OSAS was determined by two indices. The first, the standard "Respiratory Disturbance Index" (RDI), indicates the number of apneas and hypopneas per hour of sleep. The second index of OSAS severity, the combined "Sleep Baseline Score" (SBS), was derived from multivariate analysis of a wide variety of sleep parameters. These data were studied through bivariate and multiple regression analyses relative to the level of OSAS severity, sex, and age. Findings suggested that a general kyphotic configuration of the occiput and upper cervical spine existed among the overwhelming majority of OSAS patients. Moreover, data revealed that the greatest extent of flexion was apparent in the most severe OSAS patients, followed by the least severe, and then by the female OSAS patients. Sex differences relevant to the occiput and other upper cervical angles were interpreted cautiously due to the low number of females in the present study, which is characteristic of OSAS patients in general. From the present findings, it is apparent that OSAS patients can be expected to exhibit an upper cervical kyphotic spine. The impact of these findings, and ramifications of OSAS as a somatovisceral model evaluating the effects of chiropractic care are discussed.

Key Words: Sleep apnea, respiratory disturbance index, atlas angle, atlas-axis angle, atlas-occiput angle, sleep baseline score, vertebral subluxation.

Introduction

Obstructive sleep apnea syndrome (OSAS) is typified by recurrent episodes of upper pharyngeal airway obstruction and loud snoring during sleep. It is predominantly a male phenomenon,¹ and is usually associated with obesity.² It has been established that episodes of sleep apnea result from upper airway collapse (peripheral apnea), a lack of diaphragmatic activity (central apnea), or from a combination of the two, i.e., mixed apnea. The majority of the patients fall into the obstructive subgroup with much fewer being classified as mixed.³ This clinical disorder is

generally associated with excessive daytime sleepiness, sleep disruption, loud snoring, excessive oxygen desaturation during sleep and while awake, and can result in major cardiovascular and pulmonary complications.⁴ Although there is some variation from patient-to-patient, the most common area of airway obstruction appears to be within the anatomic region of the pharynx.⁵ There is no known cure. In certain cases sleep apnea can be successfully managed by lifestyle changes including a limit on alcohol (and other CNS depressants) intake and major weight loss,⁶ and/or the use of respiratory assist devices called "continuous positive airway pressure (CPAP)" which pneumatically splints the upper airway open to prevent it from collapsing during sleep.^{7,8} Surgery may be an option in extreme cases, in which a tracheostomy,⁹ uvulopalatopharyngoplasty,^{4,5} or mandibulotomy with or without hyoid advancement¹⁰⁻¹³ have been postulated to alleviate the apneas and hypopneas during sleep. Tongue repositioning devices have also been used to correct for obstruction due to the presence of an enlarged tongue.¹⁰⁻¹³

The understanding of OSAS has been complicated by the paucity of statistically verifiable quantitative data on which to define its severity, and what role spinal pathomechanics may play in association with the severity of OSAS. Accordingly, this paper is linked to the accompanying article by Blanks and Strelzow,¹⁴

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which presents statistical criteria for defining severity of OSAS. These criteria include the respiratory disturbance index (RDI) and a composite "sleep baseline score" (SBS). The RDI has been used as a measure of OSAS severity for a number of years and essentially measures the average number of apneas & hypopneas/hr sleep. The SBS was derived from multivariate (factor and principal component) analyses of data obtained from an eight hour sleep study (polysomnography) of OSAS patients which included RDI and four physiologic measures; (1) oxygen desaturation during sleep, (2) percent of total sleep in stage 1 as a measure of sleep disruption, (3 & 4) average heart and respiratory rate during sleep.¹⁴ Relative to the quantitative measures of the RDI and the SBS, the present study was designed to evaluate, retrospectively, OSAS severity and upper cervical spinal pathomechanics.

The present study evaluated four indicators of the occipital-atlas-axis alignment as depicted on cervical lateral neutral radiographs in a combined population of male and female OSAS patients of varying severity. This preliminary investigation was directed at determining if a predictable, or characteristic, upper cervical alignment pattern could be identified in association with sleep apnea. Such a relationship is of interest to the chiropractor, as the presence of vertebral misalignment, accompanied by neurological insult, suggests the likely presence of vertebral subluxation, which could also contribute to the structural and physiological complications of sleep apnea. Furthermore, unresolved changes to the upper cervical segments would also be expected to promote other areas of spinal pathomechanics.

A second objective of the present study has been to evaluate a possible physiological (somatovisceral) model through which the efficacy of specifically defined chiropractic care, oriented to the correction of vertebral subluxation, can be evaluated. Previous reports have suggested that a variety of adjustment procedures may positively affect both pulmonary function in general,¹⁵⁻¹⁷ as well as aspects of respiratory distress associated with asthma in children and adults.¹⁸⁻²⁴ The association between chiropractic care and enhanced respiratory function, over a spectrum of conditions, has been suggested to be linked to a structural insult at the level of the occipital-atlas-axial vertebral complex, likely involving the brainstem and upper cervical nerves.^{16,25-27} The present study, in conjunction with the accompanying article by Blanks and Strelzow,¹⁴ describes sleep apnea as a mechano-pathophysiological condition involving the respiratory mechanisms which can be quantified as to severity. This level of evaluation of the physiology of the sleep apnea condition could provide a sensitive indicator of change under the influence of chiropractic care which addresses the upper cervical spine directly or indirectly. Thus, the present study has sought to first describe any significant upper cervical structural alignment pattern(s) which might exist in sleep apnea patients and, second, to evaluate these anatomical differences concomitant with varying levels of sleep apnea severity.

Methods

A total of 138 neutral lateral patient radiographs were evaluated from a serial population of patients diagnosed with mild to severe obstructive sleep apnea at the University of California, Irvine, Department of Otolaryngology, Head and Neck Surgery

between May, 1984 and March, 1988 as reported by one of the authors (RHIB) earlier (Strelzow et al., 1988).¹⁴ The clinical diagnosis of OSAS was made on the basis of the presence of OSAS-related symptoms such as excessive daytime sleepiness, loud snoring, patient's sleep history and an all-night polysomnographic (sleep) study (PSG) conducted at the UCI Medical Center Sleep Disorder Center. The PSG included information on sleep stages, respiratory events, oxygen saturation both awake and during sleep, electro-encephalographic activity, and electronystagmic recording as well as auditory and video confirmation of airway activity. Patients were admitted in the late evening and monitored continuously for a minimum of eight hours by a certified polysomnographic technologist in accordance with the guidelines set down by the Association of Sleep Disorders Center.¹⁴ These results were then interpreted by two certified clinical polysomnographers. Although each patient (male or female) was diagnosed using the above criteria, only a male sub-set of the polysomnographic records (59/138) were available for the present analysis.

The lateral radiographs, obtained on each patient before any clinical intervention, were taken by a licensed dental x-ray laboratory utilizing standard techniques. The awake patients were seated in lateral position 90° to the machine and had their head position stabilized by the use of a head-holder to maintain a natural carriage. Exposures were taken with the patient remaining motionless while slowly exhaling a moderately deep breath. Exposure windows included the full face superiorly from the supraorbital ridges down to the mid-thyroid cartilage at the approximate level of the third cervical vertebra. All radiographs were coded to protect the personal identity of the patient during analysis of the film.

Parameters

Respiratory disturbance index (RDI):

Patients were categorized into a standardized OSAS diagnostic severity ranking based upon the RDI (number of apneas and hypopneas per hour of sleep) recorded during the PSG evaluation.²⁸ A range for the RDI index of severity was designated as mild < 20, moderate 20 - 40, moderate to severe 40 - 60, and severe, > 60.²⁹

Sleep Baseline Score (SBS):

A second severity score in the PSG tested group, was the "sleep baseline score" (SBS). This was also found to be helpful in evaluating the severity of OSAS. The SBS was derived from multivariate (factor and principal component) analyses from a separate and larger, unselected sample of 178 patients (164 males; 14 females) evaluated clinically as described elsewhere.¹⁴ As in the present study, the sample was skewed towards males reflecting the naturally occurring paucity of female OSAS patients.¹

Cervical Angles

In the present study, the cervical angles for OSAS patients were assigned following the standard kinematic nomenclature for physiologic accelerations in a right handed coordinate sys-

tem.³⁰ In this convention, the x-axis is anterior-posterior (anterior positive), the y-axis is bitemporal or medial-lateral (left ear positive), and the z-axis is superior-inferior (superior positive). The angles are signed using the appointed reference line (Figure 1,a-c). The atlas and occiput angles were measured against the horizontal of the film; the reference for the atlas-axis angle was the atlas line, and the atlas-occiput angle was referenced against a line drawn relative to the bottom (inferior) of the occiput.

Standard lateral radiographs for the 138 patients in this study were subjected to digitization, according to the procedure of Spinal Logic Diagnostics, Inc. (Seattle, WA). Values were recorded from each patient's radiograph and compared against the reported or derived norm, in degrees. Normal or "typical" values (without range nor standard deviation), relative to the "theoretical ideal" cervical spine have been taken by Spinal -Logic Diagnostics, Inc. as 21.7° (signed as -21.7° relative to the coordinate system used in the present study) for the atlas angle, 0.2° for the atlas-axis (C1/C2) angle, and 5.6° for the atlas-occiput angle (signed as -5.6° relative to the coordinate system used in the present study), derived from the work of Penning,³¹ and Dvorak,³² relative to "typical" ranges of flexion and extension in the cervical spine. However, specific values for the atlas-axis angle, and atlas-occiput angle have not been studied extensively over a wide range of subjects, either clinically or from the general population. Since neither standard deviations nor other measures of variability reflecting a representative pool of the general population are currently available for these angles, an arbitrary range of $\pm 10\%$ was considered within normal limits. This would extend the values, described in the right handed coordinate system to; 0.18 to 0.22° for the atlas/axis angle, and -5.04 to -6.06° for the atlas occiput angle.

Although information is scarce in the literature relative to the normative distribution of the angles evaluated in this study, some investigation has been done relative to cervical curvature, including the axis angle.³³⁻³⁵ Harrison et al., present findings that a randomly selected population of 400 chiropractic patients exhibited a lordotic cervical curve with an average angle of $-34^\circ \pm 9.39$ (range -16.5 to -66.0°), accompanied by an average atlas angle of $24.04^\circ \pm 7.37$ (signed as -24.04° in the coordinate system of the present study).³⁵ Although the angular deviation of the cervical curve could not be calculated in the present study as the radiographic assessments rarely extended beyond the lower margin of C3, the atlas angle derived from standard lateral radiographs (-21.7°), falls within one standard deviation of the previously reported value for this angle by Harrison et al.³⁵

These authors are not aware of normative values for the occiput measured against the horizontal being reported elsewhere, although White and Panjabi³⁶ have described criteria for occiput/C1/C2 instability. Thus, the present data pertains only to the sleep apnea population studied. For comparative purposes, this angle of -15.5° (10% range of -13.95 degrees to -17.05) was calculated as previously described from the standard lateral view provided by Spinal Logic Diagnostics.

Statistical Analysis

Data derived from radiographs of the population were evaluated through bivariate analyses including correlation and inde-

pendent two-tailed t-tests for unequal variances regarding the seven parameters studied (RDI and SBS indicators of OSAS severity, age, and four angular measures). Bivariate correlations and multiple linear regression were used to model the variance of the same seven parameters relative to the appropriate population for the variables applied. The populations included: all males, males with mild/moderate OSAS (RDI < 40) and moderate/severe OSAS (RDI > 40), and all females. Regarding all analyses, when alpha coefficients are not stated, significance was established at $p < 0.05$.

Results

Population Characteristics

The total population of 138 patients ranged in age from 16 to 79 years, with a mean and standard deviation of 47.7 ± 10.8 years. The population was evaluated by different categories depending on which variables were being studied: (1) The total male population ($n = 124$), and (2) the separate female population ($n = 14$) were evaluated with regard to age and upper cervical and occiput angles. RDI and SBS scores were not available for the female subgroup and a subgroup of the male population. Thus, RDI and SBS were evaluated against age, as well as cervical and occiput angles among (3) those males ($n = 59$) for which these data were available. This group was further sub-divided into mild/moderate OSAS (RDI < 40) and moderate/severe OSAS (RDI > 40). These OSAS severity subgroups were evaluated against age, occiput and cervical angles. Additionally, males for which indices of OSAS severity were available ($n = 59$) were compared to males without these scores ($n = 65$) with regard to age, cervical and occiput angles. There were no significant differences regarding cervical angles or age between the population with RDI and SBS scores ($n = 59$) and those that did not have these scores ($n = 65$).

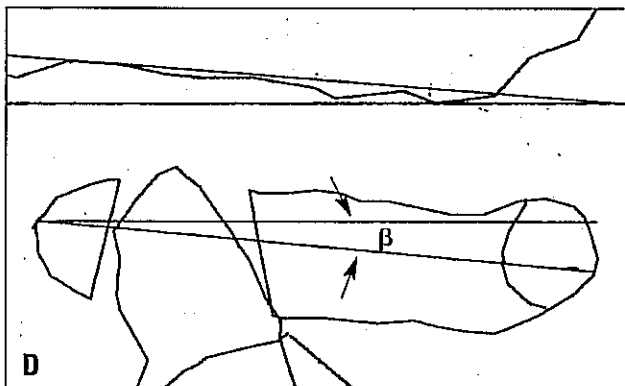
Gender Analysis, Bivariate Correlation

Although there were only 14 females in the population studied, which is characteristic of the sleep apnea population in general,¹ reports in the literature concerning gender differences in cervical angles required that gender effects be examined (see Discussion). As shown in Table 1, the four angles, were compared between all males ($n = 124$) and females ($n = 14$). Comparing males and females with respect to the reference values (see Methods) OSAS patients exhibited gender differences. For example, with regard to the atlas angle, females showed a mean difference of -14.4° versus -7.6° for males; while the atlas/occiput angle varied from the reference value by -5.4° for females versus -0.58° for males. The occiput angle varied from the reference value by -10.2° for females compared to -7.0° for males. The atlas/axis angle was essentially the same for both genders.

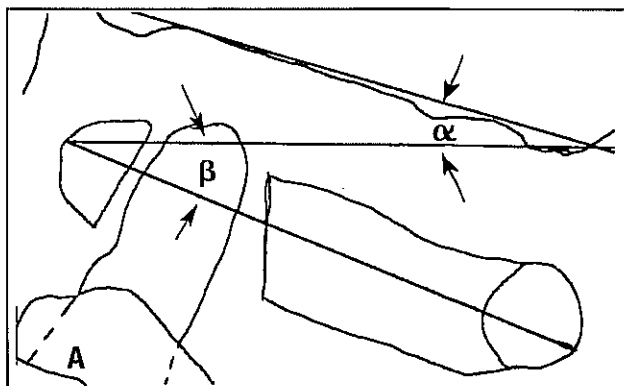
These variations from the reference values, for all but the atlas/axis angle in both genders, corresponded to flexion of the respective angles relative to the reference values used for their evaluation. The differences, evaluated by t-tests revealed a significant increase in flexion of the atlas angle ($p = 0.001$),

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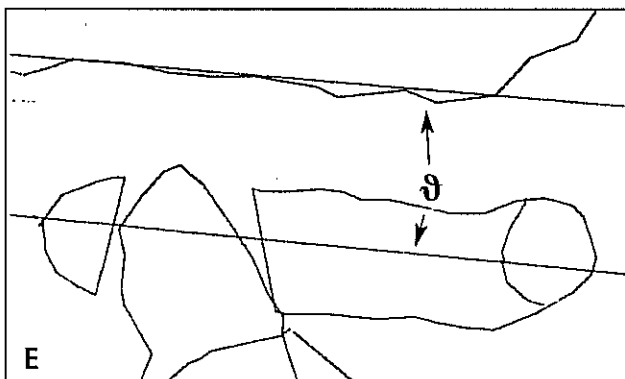
"Normal" Standard Lateral



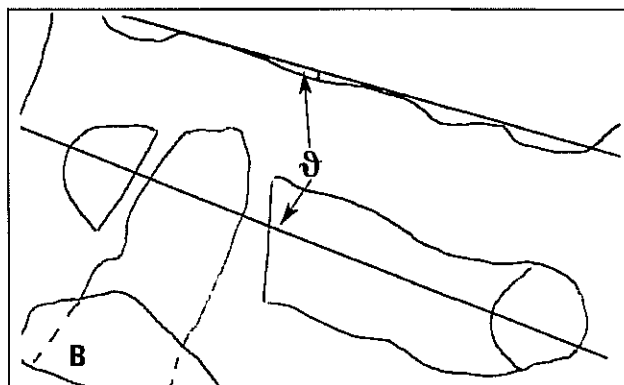
α = Occiput Angle -4.5°
 β = Atlas Angle -5.1° S



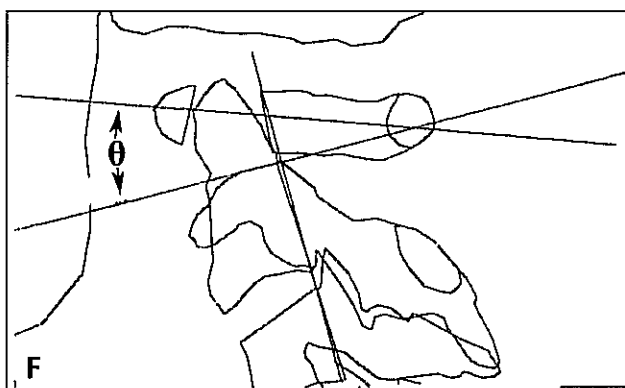
α = Occiput Angle -15.5°
 β = Atlas Angle -21.7° S



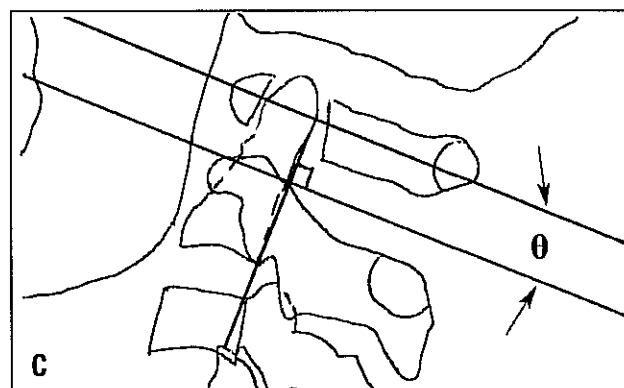
θ = Atlas/Skull Angle -0.7°



θ = Atlas/Skull Angle -5.6°



θ = Atlas/Axis Angle 19.5°



θ = Atlas/Axis Angle 0.2°

Figure 1 a-c. References for the four angles are derived from a "normal" standard lateral cervical radiograph provided by Spinal Logic Diagnostics, Seattle, WA.
d-f. The digitized radiograph represents a typical male OSAS patient with moderate/severe OSAS (see Results). The angles were derived in the same manner as the reference angles in a-c (see Methods.)

Table 1. Comparison of Cervical Angles of OSAS Patients Relative to Standard, Neutral Position, Lateral Radiographs and SBS as a Measure of Severity.

	Angle (degrees)				
	Atlas*	Atlas/axis *	Atlas/occiput*	Occiput*	SBS
Standard ^d Lateral	- 21.7	0.2	- 5.6	-15.5	na
All Males (n = 124)	- 7.6 ± 7.2 ^b	21.5 ± 6.2	- 0.58 ± 7.6 ^b	- 7.0 ± 5.7 ^b	34.0 ± 16.0
RDI Males mild/moderate < 40 (n = 29)	- 8.4 ± 7.0	20.9 ± 5.5	1.6 ± 8.5	- 9.4 ± 5.5 ^c	24.4 ± 7.1 ^c
moderate/severe > 40 (n = 30)	- 5.4 ± 6.8	20.0 ± 6.3	- 1.1 ± 7.8	- 5.3 ± 4.9 ^c	44.7 ± 13.9 ^c
Females (n = 14)	-14.4 ± 6.2 ^b	21.2 ± 5.7	- 5.4 ± 5.5 ^b	-10.2 ± 4.0 ^b	na

+ Less negative values (closer to zero) represent increased flexion. See Methods for a description of angle determination.

* Increasing positive values represent increased flexion.

a Standard deviations do not exist for these reference values.

b Significant (p < 0.05) t-test between all males and females.

c Significant (p < 0.05) t-test between RDI < 40 males, and RDI > 40 males.

na Insufficient data, data not applicable to category.

atlas/occiput (p = 0.007), and occiput angle (p = 0.013) in males compared to females, while the atlas/axis angle in males and females was essentially the same (21.5° ± 6.2, and 21.2° ± 5.7, respectively). Thus, in this population of OSAS patients, females exhibited significantly less flexion than males in three of the four angles studied. There were no other significant gender differences within this OSAS population in regard to age or the atlas/axis angle.

As summarized in Table 2, a bivariate correlation analysis evaluated all males with regard to age, cervical and occiput angles (n = 124), and SBS and RDI (n = 59). As well, the four angles and age were evaluated for correlation in the female population (n = 14). These four angles and SBS were also evaluated in the male population grouped by OSAS severity (n = 29 mild to moderate RDI, n = 30 moderate to severe RDI). In the larger male population (n = 124), the atlas angle and atlas/axis angles were negatively correlated (p = 0.000), and the atlas angle and atlas/occiput angles were positively correlated (p = 0.000). Furthermore, the atlas angle was also positively correlated to SBS (n = 59). The atlas angle was also positively correlated with the atlas/occiput angle in the female population and both RDI groups. The negative correlation between the atlas angle and the atlas/axis angle was also apparent among the females and both RDI groups of males, but were not statistically significant. Thus, the same relationships between the atlas angle, atlas/axis angle, and atlas occiput angle were apparent in all four populations studied, although to a varying extent. However, while the atlas angle was not correlated to SBS in either group of the RDI males, the atlas/occiput angle was positively correlated with SBS

in the mild to moderate RDI group of male patients. The atlas/axis angle was not correlated to any other variables in the female patients nor either group of RDI males.

Thus, relative to the parameters evaluated, females and males varied primarily in the extent of cervical flexion with regard to the occiput, atlas/occiput, and atlas/axis, with females exhibiting considerably less flexion than males. Also, in the female population, only the atlas angle and occiput angles were positively correlated (p = 0.038). Thus, flexion of the cervical spine appeared to be gender related, with females differing from males showing less flexion of three of the angles studied (Table 1).

An example of one of the moderate/severe OSAS male patients evaluated in the present study is shown in Figure 1, d-f. This radiograph of a moderate/severe patient (RDI = 59, SBS = 82) shows the pattern of a kyphotic occiput and upper cervical spine which is visually evident. Further analysis of the radiograph comparing the same angles calculated from the "typical" cervical laterals (Figure 1a-c) indicated a decreased atlas angle from its reference by 16.6°, increased atlas/axis angle of 19.3°, a slightly decreased atlas/occiput angle of 4.9°, and a decreased occiput angle of 11.0°.

The flexion/extension variations for the four angles among the OSAS patients is shown in Figure 2a-d. The patient data for each angle is shown in relation to the reference value derived from the standard lateral radiographs. These data have all been set to the same point on the abscissa to illustrate the interdependence of the four angles. Note that the histograms for all angles are shifted to the right relative to the reference value, indicating a generalized kyphosis of the occiput and upper cervical spine for OSAS patients.

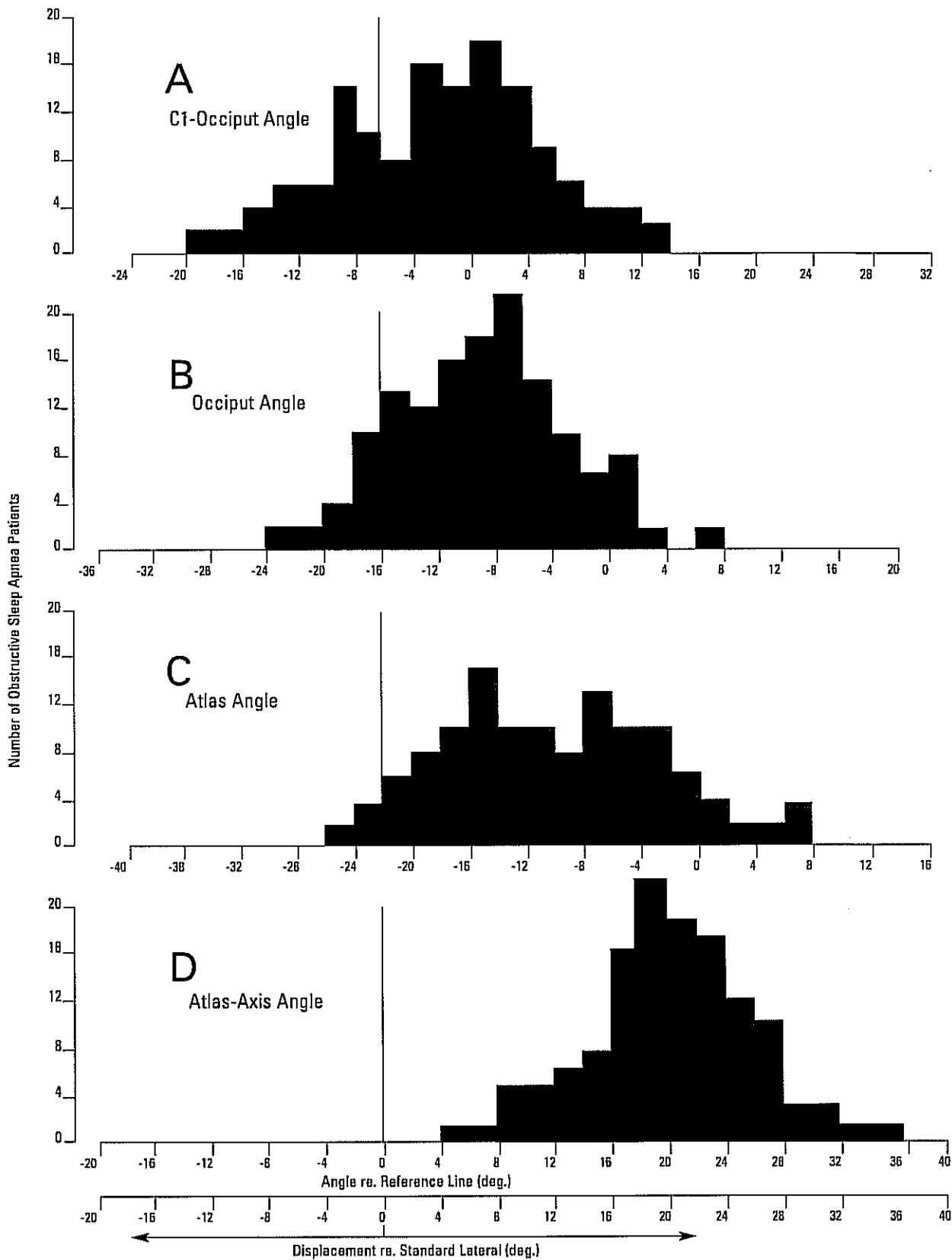


Figure 2 a-d. Flexion-extension variations of the occiput/atlas angle, occiput angle, atlas angle, and atlas/axis angle. Data is relative to the reference values derived from the standard lateral radiographs (see Methods). All angles are set at the same point on the abscissa to illustrate their interdependence. Note that all angles are shifted to the right relative to the reference value, indicating a generalized kyphosis for the occiput and upper cervical angles for OSAS patients.

RDI Subgroups

Males represented 124/138 (90%) of the subject population. As previously described, 59 males had RDI and SBS scores, whereas all males had been evaluated for cervical angles. The mean value for severity, recorded as RDI was 51.8 ± 34.8 (range 2 - 143). This was considered moderate to severe (See Methods), whereas the mean SBS value was 34.0 ± 16.0 (range 17-65) compared against a normal SBS of 8 or less. This was also considered moderate to severe.

Based on the range of scores observed among the patients studied, the males were divided into two subgroups by RDI, which is to date the most frequently used index for OSAS severity. These groups were categorized as mild to moderate, RDI < 40 (n = 29) and moderate to severe with RDI > 40 (n = 30). Across these groups, evaluated by independent t-tests, the two varied significantly with regard to occiput angle ($p = 0.004$), and SBS ($p = 0.000$). In the male OSAS sub-population (Table 1), the occiput angle was significantly lower (less flexed) in the mild/moderate patients (RDI = <40, $-9.35^\circ \pm 5.5$) compared to the moderate/severe patients (RDI >40, $-5.3^\circ \pm 4.9$); i.e., the moderate/severe group exhibited a greater flexion of the occiput than the mild/moderate OSAS patients. As might be expected, the SBS scores for patients with RDI < 40 (mean SBS=24.4) were significantly lower ($p = 0.000$) than those with RDI > 40 (mean SBS = 44.7). Control values, recorded in previous study, had RDI < 5.0.¹⁴

Moreover, as previously described (Table 2) the occiput angle correlated significantly with all cervical angles studied as well as severity of OSAS measured as RDI and SBS in the male population (n = 59, RDI: $r = 0.458$; SBS: $r = 0.405$). Interestingly, as a measure of severity, SBS showed significant positive correlation with two angles (atlas and occiput, n = 124), whereas RDI was only correlated with the occiput angle. In addition, in the moderate/severe RDI patients, SBS also showed significant positive correlation with the occiput angle, while the mild/moderate RDI patients showed significant correlation between SBS and the atlas/occiput angle.

Multiple Linear Regression Analysis

Given the number of differences obtained with the bivariate analyses, multiple linear regression was used to model the influence of each of the cervical angles, age, RDI, and SBS, as independent variables (Table 3).

Multivariate Comparisons

Cervical Angles and the Occiput Angle

The R^2 values (Table 3) indicate that the regression models for each of the OSAS population categories, predicting upper cervical and occiput angles, were strongest for moderate/severe RDI males followed by all RDI males, females, then mild/moderate RDI males. It is of interest that each subgroup; all males, males with RDI < 40, males with RDI > 40, all showed the same ratio of explained variance from the highest to lowest relative to the atlas/occiput angle, followed by the atlas angle, the

occiput angle, and the atlas/axis angle.

When unique predictors were evident in the different regression models, the occiput angle was fundamental, appearing in 7 out of 8 models. That is, in each of the categories (male and female) the atlas/occiput angle was uniquely predicted by the occiput and atlas angles. As well, the atlas angle was also uniquely predicted by the occiput angle in all of the RDI males, but not in the female group. The atlas angle was also uniquely predicted by the atlas/occiput angle in all of the categories, as well as by age in the moderate/severe RDI males. Age was also a unique predictor of the atlas/occiput angle in the moderate/severe RDI males. Among all the males, SBS and RDI were independent predictors of the atlas/occiput angle, while only SBS was an independent predictor of the atlas/occiput angle in the mild/moderate RDI males.

The lowest percentage of explained variance among the different regression models was for the atlas/axis angle as a dependent variable (4 - 9% for males, 33% for females). Moreover, there were no independent predictors of the atlas/axis angle, even though this angle represented the greatest divergence in magnitude from its reference angle, approximately 20° of flexion (Table 1, Figure 1).

RDI and SBS

The occiput angle uniquely explained 14-16% of the variance for RDI and SBS respectively (Table 3). The atlas/occiput angle also uniquely explained 19% of the variance of SBS among mild to moderate RDI males. Although there was no single variable which influenced SBS in moderate/severe RDI males, 9.0% of the variance of SBS as a dependent variable was explained by all independent variables collectively (Table 3).

Discussion

The present study of 138 radiographs (124 males, 14 females) retrospectively evaluated four angles which provided information regarding the alignment of the upper cervical spine. This information has been correlated with age, gender, as well as SBS and RDI measures of OSAS severity. As previously reported,¹⁴ SBS and RDI as measures of OSAS severity are positively correlated, as they were in the present study ($r = 0.92$, $p = 0.000$). Indeed, RDI is one of the five independent variables in the composite SBS value, determined from multiple regression analysis of OSAS patient sleep records.¹⁴ Whereas RDI records the number of apneas and hypopneas per hour of sleep, SBS measures physiologic functions (see Introduction). Therefore, whereas RDI can be thought of as a measure of respiratory distress, the composite SBS is a broader indicator of pathophysiology in OSAS patients during sleep.

The present data confirms the need to view the RDI and SBS as independent predictors of OSAS severity. RDI and SBS predict the atlas/occiput angle in the multivariate model (Table 3). Alternatively, as summarized in Table 2, three angles describing the atlas and occiput separately, and relative to one another, i.e., atlas angle, occiput angle, and atlas/occiput angle, are significantly correlated with OSAS severity defined as the composite severity score (SBS), while only the occiput angle is correlated

Table 2. Bivariate Correlation Matrix of OSAS patients Regarding Cervical and Occiput Angles, RDI, SBS, and Age as Measures of OSAS Severity*

	<i>Variables</i>						
	Atlas angle	Atlas/axis angle	Atlas/occiput angle	Occiput angle	RDI	SBS	Age
<i>Population</i>							
All males (n = 124)							
Atlas angle	-	- 0.31 (0.000)	0.59 (0.000)	0.40 (0.000)	-	0.27 (n = 59) (0.037)	- 0.19 (0.040)
Atlas/axis angle	- 0.31 (0.000)	-	-	-0.25 (0.006)	-	-	-
Atlas/occiput angle	- 0.59 (0.000)	-	-	- 0.35 (0.000)	-	-	-
Occiput angle	0.40 (0.000)	- 0.25 (0.006)	- 0.35 (0.000)	-	0.46 (n = 59) (0.000)	0.41 (n = 59) (0.001)	- 0.18 (0.041)
RDI	-	-	-	0.46 (0.000)	-	0.92 (n = 59) (0.000)	-
SBS	0.27 (0.037)	-	-	0.41 (0.001)	0.92 (n = 59) (0.000)	-	-
Age	- 0.19 (0.040)	-	-	0.18 (0.041)	-	-	-
Males, RDI < 40 (males, n = 29)							
Atlas angle	-	-	0.46 (0.013)	-	-	-	-
Atlas/occiput angle	0.46 (0.013)	-	-	-	-	0.43 (0.009)	-
Males, RDI > 40 (males, n = 30)							
Atlas angle	-	-	0.72 (0.000)	-	-	-	-
Occiput angle	-	-	-	-	-	0.42 (0.023)	-0.44 (0.016)
Age	-	-	0.44 (0.016)	-	-	-	-
Females (n = 14)							
Atlas angle	-	-	-	0.56 (0.038)	-	-	-

* Severity is measured at $p = < 0.05$. (See Methods). Alpha values are provided in parentheses.

with the RDI, which is a particular symptom of sleep apnea. It is, therefore, suggested that both RDI and SBS should be considered non-redundant co-variants in the assessment of severity of OSAS patients. These quantitative indicators of severity render the OSAS an excellent somatovisceral research model upon which to evaluate change based on various interventions. This model appears particularly well suited to the objectives of subluxation-based chiropractic care research.

Compared to the neutral lateral radiograph as a reference, the present study reveals an overall pattern of occiput-upper cervical flexion in OSAS patients in both males and females (Figure 2). Also, the flexion pattern appears exacerbated in males compared to females, and those in the moderate/severe range opposed to the mild/moderate range relative to OSAS severity scores.

The characteristic pattern of flexed occiput and atlas in the sleep apnea patients studied are visually evident when comparing the digitized lateral x-rays and histograms in Figures 1 and 2. The corresponding numeric changes in the four angles (Table 1) confirm this general pattern of occiput and upper cervical spinal flexion. There is significant, positive correlation between the atlas, occiput and atlas/occiput angles in patients. These three angles co-vary in the same direction as indicated by the positive correlation coefficients. All three angles in patients indicate that the atlas and occiput are both flexed relative to standard lateral reference angles, instead of a differential movement of atlas on occiput, which is theoretically more difficult given the strong ligament attachments that characterize the atlanto-occipital joint.³⁶

Similarly, the present data provides indirect evidence for flexion of the axis in sleep apnea patients, measured by changes in mean values of the atlas/axis angle relative to the standard lateral reference (Figure 1, Table 1). Although the atlas/axis angle does not directly provide information regarding axis flexion, in order for this angle to remain essentially constant as the atlas angle is shown to increase in flexion, the axis would also have to increase in flexion. Interestingly, the flexion position of the axis in OSAS patients does not change the atlas/occiput relationship given the absence of bivariate correlation between the atlas/axis angle and the atlas/occiput angle (Table 2) and the fact that atlas/axis angle does not predict any of the other upper cervical angles in multiple regression analysis (Table 3). One might speculate that forces acting upon the atlanto/axial joint, due to chronic flexion of the axis, have only a variable effect upon the stability of the atlanto-occipital joint.

Of the four angles evaluated in the present model, those most important in predicting severity of OSAS describe the atlas/occiput relationship, i.e., the atlas, occiput and atlas/occiput angles. Any one of these three angles predicts the others in multiple regression analysis (Table 3), and in all four patient subgroups (all males, all females, and males by OSAS severity). Furthermore, two of these angles (occiput angle, atlas/occiput angle) also predict severity of OSAS measured as RDI or SBS in the all male population, and SBS in the mild/moderate OSAS group (Table 3).

This is an important finding for at least two reasons: First, to the authors knowledge, this is the first observation linking the atlas/occiput relationship to sleep apnea specifically, although

the upper cervical area has been implicated in other respiratory related disorders,¹⁶ and cervical, head, and shoulder posture anomalies, mostly related to rheumatoid arthritis, have been reported.³⁷⁻³⁹

As well, there are a number of risk factors for OSAS, other than male gender, which were not considered in this study. These include: obesity, older age, familial traits, craniofacial and pharyngeal abnormalities which may include tongue and soft palate enlargement, inferior placement of hyoid bone, retroposition of mandible and/or maxilla, and reduced volume of the oropharyngeal and hypopharyngeal airways.^{3,14,40,41}

The importance of the present report has been to identify another significant co-morbidity for OSAS, the atlas/occiput relationship, and to provide a rough estimate of its contribution in OSAS. Many of these other risk factors were unavailable for analysis in the present study, but an estimate of the contribution of the atlas/occiput relationship to overall OSAS severity can be obtained by examination of the R^2 values in the multiple regression equations (Table 3). These values in the larger all males OSAS group estimate that about 14-16% of the total variance for severity (measured as RDI or SBS) can be explained by the occiput angle; the remaining 84%-86% of total variance being accounted by these other factors. Recognizing that many variables contribute to OSAS severity, a contribution of 14-16% by just the atlas/axis relationship is considered substantial. Additional studies, conducted using a longitudinal format and with a larger patient base (including male and female patients), will be required to confirm the relative contribution of the upper cervical anomalies to OSAS severity, and to evaluate the relative contribution of these other well documented factors (age, male gender, craniofacial anomalies, etc.) on the regression model equation.

Second, the atlas-occiput relationship is linked to the outflow of spinal nerves C1 (between atlas and occiput) and C2 (between atlas and axis) and, a vertebral misalignment at this level, (partially indicative of vertebral subluxation) could negatively impact tone to the upper airway muscles innervated by the cervical plexus (roots C1-C3) thereby leading to muscular collapse of the upper airway during sleep. Specifically, whereas the glossal, laryngeal, and pharyngeal muscles controlling the airway are innervated by cranial nerves IX, X, and XII, the outflow of the cervical plexus (C1-C3) is to the neck strap muscles (geniohyoid, thyrohyoid, sternohyoid, sternothyroid, omohyoid) which are functional during swallowing, phonation and respiration. During respiration, EMG studies in patients with OSAS suggest that the phasic inspiratory activity of the genioglossus, pharyngeal and strap muscles maintain patency of the airway by opposing the negative pressures produced by contraction of the chest wall.^{42,43} These concepts of the behavioral model are developed in detail below.

Given the high correlation between the occiput angle and OSAS severity composite score (i.e., SBS), it is important to validate the method used to estimate the occiput angle reference value. Further, it is necessary to demonstrate if this angle value could be predicted from the present data set in the absence of sleep apnea, i.e., with a SBS = 0. This consideration was based on the fact that the reference occiput angle, like the other angles, was derived from what was assumed to be a "typical" juxtaposi-

Table 3. Multivariate Statistics; Significance* of Cervical Angles, Occiput Angles, and RDI and SBS Measures of OSAS Severity as Independent Variables

	<i>Dependent Variables</i>					
	Atlas Angle	Atlas Axis Angle	Atlas Occiput Angle	Occiput Angle	RDI	SBS
<i>Independent Variables by Population</i>						
All Males (n = 124)	Occiput (0.000) Atlas/occ (0.000)	-	Occiput (0.000) Atlas (0.000) RDI (0.027) SBS (0.029)	Atlas (0.000) Atlas/occ (0.000)	Occiput (0.016) (n = 59)	Occiput (0.029) (n = 59)
Adjusted R ²	58.0	4.0	61.0	50.0	16.0	14.0
Sleep Study Males						
RDI < 40 (n = 29)	Occiput (0.021) Atlas/occ (0.000)	-	Occiput (0.007) Atlas (0.000) SBS (0.025)	Atlas (0.021) Atlas/occ (0.007)	na	Atlas/occ (0.025)
Adjusted R ²	38.0	9.0	52.0	26.0	na	19.0
RDI > 40 (n = 30)	Occiput (0.000) Atlas/occ (0.000) Age (0.015)	-	Occiput (0.000) Atlas (0.000) Age (0.030)	Atlas (0.000) Atlas/occ (0.000)	na	-
Adjusted R ²	81.0	4.0	82.0	59.0	na	9.0
All Females (n = 14)	Atlas/occ (0.038)	-	Occiput (0.017) Atlas (0.038)	Atlas/occ (0.017)	na	na
Adjusted R ²	45.0	33.0	55.0	45.0	na	na

+ F values were < 0.05 for all regression models. Alpha values are in parentheses.

na Data were not available for comparison or categorization did not apply to the population.

- Multivariate test was conducted but value was not significant

R² Percent of the variance of the dependent variable predicted by the regression model. Independent variables presented in the Table significantly and uniquely predict the dependent variables .

tion of the occiput relative to a "typical" lordotic cervical curve. Accordingly, a simple bivariate regression analysis was conducted, comparing SBS vs. occiput angle (the strongest predictor of SBS). This regression equation gave an abscissa intercept (SBS = 0) of -12.5 for the occiput angle which was remarkably similar to that estimated (-15.5°) from the "typical" standard cervical lateral (Table 1, Figure 1). This difference could be due to the difference in x-ray positioning, as the dental x-ray methodology has the patient seated for standard laterals, whereas the reference angles were derived from standing lateral positioning. The significance of this difference is not known in the context of this paper, and certainly will require further investigation. As discussed below, there is also concern about the lack of standardized control values from a wide range of subjects demonstrated to be free of cervical pathomechanics and pathophysiology in the chiropractic literature. As well, the absence of control data for the occiput angle as used for the first time in the present report, is also a concern. In this regard, the present regression analysis data is a very important, albeit independent, validation of the estimate method used for all of the reference angles in the present study. Clearly, additional studies of normal subjects free of demonstrable pathology will be required to confirm the standard lateral values across a larger population of "healthy" volunteers.

Sleep apnea is generally diagnosed in persons between 40-70 years, but it is not uncommon for symptoms to develop in the early teens suggesting that mechanisms that lead to the development of sleep apnea may be operational over many years.¹⁴ In the general population, there is an age-effect in the number of respiratory pauses during sleep.¹⁴ However, age was not related directly to either RDI or SBS as measures of OSAS severity in the present study, or in the accompanying study by Blanks and Strelzow.¹⁴ The lack of correlation between age and severity was further demonstrated in this study by evaluating the age distribution in the two RDI categories; the mean age (50 ± 10 years) for the mild-to-moderate RDI males (RDI < 40), was virtually identical (51 ± 12 years) for the moderate-to-severe RDI males (RDI > 40) (Tables 2-3).

However, other age effects were observed. Age was negatively correlated with atlas angle in moderate-to-severe RDI patients, and positively correlated with atlas/occiput angle in the moderate-to-severe male OSAS patients. Although age predicted these angles, there was no significant difference in age between the two groups, suggesting that an age-effect may be easily masked by (hidden) variables not evaluated in the present study. It has been estimated that about two-thirds of OSAS patients are obese (> 20% ideal body weight) and that obesity (measured as body mass index or simply neck circumference) is the strongest predictor of OSAS.¹⁴ In elderly patients, obesity is estimated to be a four-fold greater influence on severity than age, and two-fold greater influence than gender in predicting OSAS.⁴⁵ Since obesity and other risk factors summarized above were not evaluated in the present study, it seems very likely that these other variables could mask possible age-effects on the two RDI groups.

Across a large number of published studies on OSAS patients,¹ and cross-sectional surveys of "healthy" volunteers ages 7-75,⁴⁵ it is estimated that about 85% diagnosed with the syn-

drome are males. Thus, it is not surprising that present population was overwhelmingly male (90%) and contained only 14 females. And, while gender effects were obtained with bivariate and multivariate analyses, these findings should be viewed cautiously due to the small female sample. Nevertheless, there are other findings that suggest gender differences in regard to cervical curves and angles. Harrison et al., have reported differences representing increased extension (decreased flexion) in the atlas angle in females compared to males.³⁵ However, since the female population in the Harrison et al., study was significantly older than the males, it is not clear whether the differences would be associated with age, gender, or a combination of both. Alternatively, Shaikewitz⁴⁶ found among 188 subjects, that cervical spine curvature was influenced by gender and age independently. That is, the lordotic curve (17 cm radius curve) was more prevalent among males and individuals ranging in age from 45 - 65 years while more kyphotic cervical spines were characteristic of females and ages ranging from 18 - 44 years. Based on this diversity of findings, it is apparent that more data will be required to properly assess the distribution of curve types and cervical angles among the "healthy" population versus those exhibiting pathophysiology, as well as between genders.

Occipital and Upper Cervical Structural Model of the Sleep Apnea Population

The findings of the present study suggest a structural model which could be depicted as a kyphotic or flexed occiput and upper cervical spine in the sleep apnea patient. Regression analysis suggests that the strongest model for the generalized kyphotic pattern was found in the moderate/severe OSAS male group. In this case, the influence of the atlas and occiput angles and age predicted the atlas/occiput angle, explaining 82% of the variance of the atlas/occiput angle (Table 3). Nearly equal in strength, in this same group, was the prediction of the atlas angle by the occiput and atlas/occiput angles and age, in which case 81% of the variance of the dependent variable was explained. While not as strong in terms of explaining variance (52% and 38%, respectively), these angles were predictive of the same dependent variables in the mild/moderate RDI group, but age was not an independent predictor, as discussed above. The strongest models for the influence of flexion on OSAS severity were found in the overall RDI population, and in the mild/moderate RDI male group. In the overall RDI population the occiput angle independently predicted both of these measures, accounting for 14% - 16% of the variance, whereas the atlas/occiput angle uniquely predicted SBS, explaining 19% of the variance in the mild/moderate RDI group only.

Similarly, in the female population, the occiput and atlas angles predicted the atlas/occiput angle, and is considered a strong model as it explained 55% of the variance of the dependent variable. Alternatively, only the atlas/occiput angle independently predicted the atlas angle, with the model explaining 45% of the variance. By comparison, it is of interest that the regression model in the female population explained 33% of the variance of the atlas/angle, although there were no unique predictors, whereas models for the same dependent variable in the male population, also without unique predictors, explained only

4% - 9% of the variance.

Thus, present findings suggest that although the same general (qualitative) flexion pattern exists for all OSAS patients, the influence of the variables; (occiput, atlas, and atlas/occiput angles and age) differ as a function of gender and OSAS severity. The greatest influence of the upper cervical angles was upon each other as found in moderate/severe OSAS males, while the greatest influence of upper cervical angles on predicting severity was found in the general RDI male population, and the mild/moderate RDI group. Apparently, once a certain level of OSAS severity is reached, the occiput and atlas/occiput angles cease to become strong predictors, due perhaps to other contributing (hidden) variables as discussed above.

From these findings of OSAS patients, it appears that other than magnitude of change in flexion, the flexion pattern of the mild/moderate RDI males, moderate/severe RDI males, and females is similar. As indicated by their positive correlation, the occiput and atlas angles change similarly though independently, both increasing in flexion, while the relative constancy of the atlas/axis angle suggests that these two segments move essentially as one, but both also increasing in flexion. The negative correlation between the atlas/occiput and the relatively constant relationship between the atlas and axis, as well as the negative correlation of the atlas/occiput to the occiput angle, but positive correlation between the atlas/occiput and atlas angle, also supports the finding that the atlas moves disproportionately more into flexion as the occiput becomes flexed. While more information will be necessary to confirm these findings, and to further elucidate the biomechanics of the occiput and upper cervical spine in the flexed state, it is apparent in the OSAS patients that an elaborate dynamic is at play as the occiput and upper cervical spine establishes a generalized flexed, or kyphotic, configuration.

Interestingly, studies by Pepin et al.,³⁷ and Drossaers-Bakker et al.,³⁸ have related evidence of patients developing sleep apnea in association with cervical degeneration as a consequence of rheumatoid arthritis, while Takigawa et al.,³⁹ related changes in jaw and head position, and shoulder posture as affecting modes of breathing and sleep apnea in particular. However, considerable variations have been reported in different populations relative to the lordotic cervical curvature.^{33-35,47,48} The ranges reported clearly indicate that wide variation between and among any given populations is considerable. These reports emphasize the importance of the relative uniformity in marked flexion found in the occiput and other cervical angles observed in the present study of OSAS patients (Figure 2).

While the significance of cervical curvature is a controversial issue, it is noteworthy that relative to the present study, although the lower cervical curve could not be analyzed, the upper cervical region was remarkably consistent as a kyphotic, or flexed, configuration. Harrison et al.,³⁵ have proposed a "harmonic classification for cervical configurations." Among these are two variations which include an upper cervical state of flexion, as was apparent in the present study. Harrison et al., also suggest that the kyphotic cervical curvature is not a normal variant.³⁴

These authors^{33,35} cite other studies which suggest that kyphosis has been linked to adverse mechanical cord tension, increased loading on the vertebral bodies and discs, and may be

associated with anterior head translation. This latter observation is consistent with finding in the present study, and appears to be characteristic of the sleep apnea condition within the population studied. Moreover, Harrison et al.,³⁵ point out other studies relating cervical kyphosis after injury to higher incidences of degenerative changes and poor results from treatment regimens. Although not investigated in the present study, kyphosis and autonomic symptoms have also been related.⁴⁹ Additionally, Harrison et al. also present arguments which suggest that a kyphotic configuration has both patho-biomechanical and pathophysiological implications.³⁵

Because of the prevalence of skull flexion in the present study, it could be argued that patient positioning resulted in a state of "slight head nodding." In this respect, Weir⁵⁰ reported that 20% of a "normal" population exhibiting a kyphotic cervical spine, increased to 70% when subjects were asked to depress the chin by one inch. However, Harrison et al.,⁵¹ provide a convincing argument that "slight head nodding" or flexion of the head does not alter the cervical curve from C2-C7. Although the patients in the present study were not subject to faulty head positioning for lateral x-ray, even if the validity of the flexed occiput and atlas were in question, the putative flexed position of the axis argues against a positioning artifact as being responsible for the upper cervical flexion observed in the present study.

The model of the cervical spine in sleep apnea in terms of a possible causal relationship is intriguing. Several possibilities exist which link flexion changes in cervical spine curvature to neuromuscular integrity. Brieg⁵² proposed that cervical spine flexion creates a state of tension on the spinal cord and nerve roots of the hindbrain (Pons cord tract) which, if sustained, could damage nerve roots and cranial nerves V-XII. Alternatively, the present finding that among sleep apnea male patients, the occiput angle was positively correlated, and substantially predictive of SBS and RDI, suggests that this feature of cervical alignment could be related to physiological changes more so than characteristics resulting from anatomical changes in the cervical vertebrae. It may be that as the occiput angle increases in flexion and possibly forward displacement, tension (insult) may be increasing through tractioning of the brainstem and upper cervical nerves. This phenomenon could lead to a state of pathomechanics and pathophysiology with several possible outcomes as described by Breig,⁵² and others.^{53,54}

The link between spinal pathomechanics and the inspiration tone of the upper airway muscles is found in the innervation pattern to these muscles. Whereas many of the upper airway muscles are innervated by cranial nerves (V, VII, IX, X, XI, and XII), the nerve supply to some suprahyoid muscles (C1 branches to geniohyoid and thyrohyoid) and all of the infrahyoid muscles exclusive of the larynx and pharyngeal constrictors are innervated by the cervical plexus C1-C3. Misalignment of the upper cervical vertebrae with accompanying pathomechanics could restrict the flow of inspiration tone via the C1-C3 roots to these critical airway muscles thereby promoting and/or aggravating OSAS.

From a functional perspective, the most salient issues are the observations that virtually all the muscles of the upper airway, including the tongue, suprahyoid, infrahyoid, pharyngeal and laryngeal muscles carry a strong respiration tone during inspira-

tion, even during sleep and surgical anesthesia. This respiratory tone derives from respiratory neurons located in the brainstem. Like the outflow to the diaphragm via the phrenic nerve, the burst of electromyographic activity in these upper airway muscles precedes the flow of air during inspiration by several hundred milliseconds and persists throughout inspiration. The EMG respiratory tone ends with expiration and is frequently silent during the end-expiratory pause, i.e., the interval between expiration and the subsequent inspiration. Remarkably, the respiratory (inspiration) drive in the upper airway muscles, which is well documented, occurs during all levels of respiration in normal subjects in awake (quiet and forced respiration) and sleeping individuals.⁵⁵⁻⁶⁰ However, in OSAS patients, this respiratory tone to the airway muscles is generally lost, suggesting that the mechanism for peripheral OSAS and paradoxical breathing (attempts of diaphragmatic and intercostal breathing against a collapsed pharyngeal airway) is a loss of upper airway dilatory tone in the transition to sleep, which allows the airway to collapse against the negative intraluminal pressures generated by contraction of the diaphragm.⁶¹ The patient must thereby awake to regain tone to the airway muscles, protracting (jutting) the chin, allowing patency of the pharyngeal airway and recovery of normal respiratory airflow.

In an apparent behavioral adaptation, OSAS patients frequently "jut the chin forward" or "anteriorly translate" i.e., extend the head on a flexed neck, while awake and maintain a characteristic underbite (underjet) of the mandible relative to the maxilla to move the tongue forward thereby opening the airway.^{14,39} As well, visual observations of lateral x-rays, as well as the uniform pattern of upper cervical kyphosis demonstrated among the 124 male sleep apnea patients in the present study, suggests the presence of a consistent re-alignment of the occiput, atlas and axis. While awake, this behavioral adaptation of the skull and cervical spine may be useful to expand the upper airway and enhance the flow of air to the patient. However, such a change in upper cervical alignment to the atlantoaxial joint, which features preeminently in the outflow of the C2-C3 roots supplying the indicated neck muscles, could predispose the patient, when asleep, to adverse mechanical pressure on the C1-C3 roots thereby decreasing motor outflow to the associated airway muscles. That is, a general loss of muscle tone in sleep and collapse of the adaptive head-neck posture (i.e. loss of forward head posture) could exacerbate the collapse of the pharyngeal airway during sleep.

It may be that the features of an upper cervical alignment pattern such as that consistently found among the radiographs of the sleep apnea patients presently studied may promote the neurological insult which initiates and/or aggravates OSAS. Alternatively, it may be that some other pre-disposing factors are causative, with the alignment pattern being one of conscious adaptation to the restricted airway, characteristic of OSAS. Sleep apnea is a progressive and long-standing condition, taking several years to develop from mild to severe. However, in the present study, the fact that even patients with "mild" OSAS severity show the abnormalities of skull and upper cervical spine alignment suggest that the skeletal patterns develop early in the progress of sleep apnea. Further, in terms of cause-effect relationships, it has been reported that OSAS patients have other skeletal abnormalities (e.g., rheumatoid arthritis of upper cervi-

cal spine) which could predispose them to the condition.^{37,38}

Based on the demonstrated ability to objectively measure the severity of sleep apnea, as well as to correlate it to upper cervical curvature, it becomes of interest to investigate the clinical outcomes of sleep apnea patients undergoing upper cervical chiropractic care. The findings of this study, coupled to the ability to quantify the severity of OSAS, designates sleep apnea as a feasible model regarding the efficacy of upper cervical care and concomitant changes in spinal configuration relative to changes in pathophysiology. Information gained from such study would be useful in furthering the knowledge base regarding the possible relationship between changes in upper cervical alignment patterns and physiological changes which appear to contribute to the severity of OSAS. Moreover, as the present study also adds to the growing body of information that links certain states of cervical curvature to pathophysiology and pathomechanics, further study is warranted to elucidate the apparent relationships between cervical structure and physiological function, both normal and pathological.

Summary and Conclusions

The findings of the present study regarding OSAS patients suggest a strong relationship between occiput and upper cervical flexion and severity of sleep apnea. It was apparent that:

- (1) RDI and SBS appear to be non-redundant co-variants in the assessment of OSAS severity.
- (2) The majority of OSAS patients exhibited, relative to respective "normative" reference angles, substantial flexion. The flexion configuration was greatest among the most severe OSAS males, followed by those with mild to moderate severity, then females.
- (3) The occiput angle was the most significant predictor of male OSAS severity; i.e., the more flexed the angle, the greater the severity of OSAS. While the R^2 value for the occiput predicted 14-16% of the variance of severity, considering the plethora of variables which could affect OSAS severity, this percentage is considered to be substantial.⁶²
- (4) OSAS females showed less flexion than OSAS males in regard to the occiput and upper cervical spine.
- (5) Caution is required in interpreting sex differences in the present study in regard to the occiput and upper cervical angles due to the low number of females in this study, which is also characteristic of OSAS patients in general. However, these observations warrant further investigation, as other studies report sex differences relative to sleep apnea, cervical angles and/or spinal curvature.
- (6) Due to the disparity of findings in the chiropractic literature, future study requires more information concerning the relationships between occiput and upper cervical angles and spinal curvature in both "healthy" males and females, as well as those demonstrating documented physiological dysfunctions.
- (7) The present study provides a tenable model for evaluating chiropractic care by monitoring changes in a well documented objectively measured somatovisceral model of sleep apnea.

(8) The present study has attempted to describe cervical and occiput angular patterns in OSAS patients. However, it is apparent that considerable work needs to be done to characterize normative reference values, for the angles considered, to validate the present findings.

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