A Cephalometric Comparison of Patients With the Sleep Apnea/Hypopnea Syndrome and Their Siblings

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Study Objectives: To define differences in the skeletal components of facial structure predisposing to the obstructive sleep apnea/hypopnea syndrome (OSAHS) by a comparison of the craniofacial complex between people with OSAHS and their siblings without OSAHS.

Design: Case-control study using sibling pairs.

Setting: Scottish Sleep Centre.

Participants: 104 patients with OSAHS living in Scotland and 107 of their siblings.

Interventions: All subjects had sleep studies, clinical review, and cephalometry performed. All measurements were scored blind to index or control status.

Measurements and Results: 207 cephalograms were available for analysis, of which 145 were for dentate subjects (90 with definite OSAHS; 55 without). In the dentate subjects, regression analysis (correcting for body mass index and age) showed OSAHS was associated with a significantly longer distance from the hyoid bone to the mandibular plane in men ($P = .02$) and in women ($P = .036$). Regression analysis in 22 pairs of dentate brothers, discordant for the diagnosis of OSAHS (controlling for age and body mass index), showed a shorter mandibular corpus ($P = .013$) and lower hyoid in relation to the mandibular plane ($P = .006$) to be significantly associated with a diagnosis of OSAHS.

Conclusions: Men and women with OSAHS have a lower-set hyoid bone than those without OSAHS. This occurs independently of obesity and remains even when intersubject variance is minimized by performing pairwise comparison of the craniofacial complex between siblings with and without OSAHS.

Key Words: Cephalometry; obstructive sleep apnea/hypopnea syndrome; siblings

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INTRODUCTION

The craniofacial complex plays an important role in the development of the obstructive sleep apnea/hypopnea syndrome (OSAHS). Retroposed maxillae and mandibles have been shown to predispose an individual to having OSAHS. Anatomic features occurring more frequently in the OSAHS population include shorter facial height and overbite. There is a strong inherited component to jaw size, although other factors can also be important, for example, nasal occlusion in childhood. Previous studies of cephalometric factors in OSAHS have made comparisons with unrelated controls and thus, encompassed a large variance in normality. This study aimed to better define the differences in facial structure predisposing to OSAHS by reducing intersubject variance by performing pairwise comparison of the craniofacial complex between siblings with and without OSAHS.

METHODS

Recruitment of sibling pairs was undertaken between January 1997 and December 2002 at the Scottish Sleep Centre, Edinburgh, as part of a larger study looking at the genetics of OSAHS. Approval for the study was obtained from the local ethics committee.

Recruitment of Subjects

Five hundred and fifty-seven consecutive patients attending the sleep laboratory with symptoms of OSAHS and an apnea-hypopnea index (AHI) of at least 15 were asked to participate in the study. Recruitment was undertaken directly in the sleep center by approaching patients and by a mail-out based on a register of all patients attending for studies. Only cases living within a 50-mile radius of Edinburgh were approached. Each index patient was sent a letter requesting participation in the study. The letter requested that the index cases contact their siblings. Siblings were then asked to attend the sleep center for polysomnography, cephalometry and to have blood taken.

Response rates were as follows: of 557 index subjects contacted, 312 were willing to participate in the study. Of these, 155 had siblings who were available for the study. However, 44 siblings defaulted on attendance, and 8 sibling pairs had inadequate data collected. One hundred three index cases and 108 siblings successfully completed the study. All were Caucasian.

Data Collection

All subjects had height, weight, neck circumference, and blood pressure measured and were asked to fill out a standard sleep questionnaire used in the Scottish Sleep Centre (which includes an Epworth Sleepiness Scale [ESS]). All siblings had overnight polysomnography (PSG) using our standard techniques. Index patients had either overnight PSG or a home study (16/209 cases). The latter were performed using the limited sleep study system Edentrace (EdenTec Model 3711 Digital Recorder, Nellcor, Eden Prairie, Minn). All subjects were asked to have cephalometry per-
formed the morning after the sleep study (see below).

All sleep studies were scored manually using standard criteria for sleep staging\(^4\) and standard criteria for scoring obstructive apneas and hypopneas.\(^6,9\) For home-based sleep studies, apnea was defined as the cessation of airflow for at least 10 seconds and hypopnea as a reduction of at least 50% in chest wall movement for at least 10 seconds. An AHI thus obtained was considered significant for sleep-disordered breathing if it measured more than 30 events per hour.\(^10\) All studies were scored blind to index and control status, and intra-rater and inter-rater variability was measured with high correlation (\(q = 0.8-0.97; P < .0001\)).

OSAHS was defined on the basis of the apnea + hypopnea frequency together with symptoms as assessed using the ESS score. Each subject’s AHI was first scored as definitely abnormal, indeterminate, or definitely normal on the basis of sex and age using normative data for Caucasian subjects (see Table 1).\(^11-13\) The ESS score (maximum of 24) was scored as either sleepy (ESS \(> 11\)) or not abnormally sleepy (ESS \(< 11\)). OSAHS was then classified as definitely present, indeterminate, or definitely absent. The subjects without OSAHS were classified into snorers or non-snorers. Snoring was self-reported. All subjects gave written informed consent for the study.

**Cephalometry**

Cephalometric radiographs were carried out in the department of radiology at the Royal Infirmary Edinburgh using the Orthoceph\(^\text{®} 10\) (Type No.: D 3198; Siemens AG, UB Med; Germany). Subjects were seated and facing at 90° to the x-ray beam, 152.4 cm (60 inches) from the target of the x-ray tube with their left side toward the film. The distance of the median plane beam, 152.4 cm (60 inches) from the target of the x-ray tube with their left side toward the film. The distance of the median plane beam, 152.4 cm (60 inches) from the target of the x-ray tube with their left side toward the film. The distance of the median plane beam, 152.4 cm (60 inches) from the target of the x-ray tube with their left side toward the film. The distance of the median plane beam.

Radiographs familiar with the procedure took films using a 24 × 30 fast-speed cassette with Agfa\(^\text{®} \) Ortho H film and Curix\(^\text{®} \) Standard screens (Agfa Ltd; Belgium).

The reference work for all points and planes was Rakosi\(^14\). All radiographs were read on a light box, and superimposed acetate tracing paper was used for marking points, lines, and angles using a fine-tip permanent pen (0.5 mm). All measurements were recorded manually and corrected for the magnification factor (1:1.1). The sella-nasion-point A angle (SNA), sella-nasion-point B angle (SNB), and nasion-sella-basion angle (cranial base angle) (NSBA) were recorded in degrees. Cephalometric landmarks measured are represented in Figure 1 and planes in Figure 2.

Cephalograms were scored blind to index or control status, and sleep study results were scored by 2 two authors (MV, RR) who had 3 calibration sessions together. The correlation coefficient (using Spearman rank correlation) for both inter-rater and intrarater scores was high for all measurements (\(q = 0.8-0.95; P < .01\)).

**Statistical Analysis**

SPSS (release 10.0 for Windows, SPSS, Inc., Chicago, Ill) was used for statistical analysis. The \(\chi^2\) test, Student \(t\) test, and Wilcoxon rank test were utilized to examine for differences between groups. Tests of correlation were carried out using Spearman rank test. Logistic regression analysis was used to assess the association of variables. \(P\)-values derived from standard parametric and nonparametric tests were corrected for multiple comparisons by the method of Holm.\(^13\) Significance was defined at an experiment-wise error of \(\alpha \leq .05\), 2-sided. The Holm adjustment procedure for each set of comparisons involved first ordering the \(P\) value from smallest to largest and then assigning a rank number (\(i\)) of 1 through to \(n\). Starting with the smallest \(P\) value, each \(P\) value was compared with its critical value \(a/(n-i +1)\). If the \(P\) value was less than or equal to its critical value, the paired comparison was considered statistically significant at an experiment-wise \(a\) of .05.

Random method error in the series of radiographs was assessed using the Dahlberg method and ranged from 0.46 to 1.6 mm and 0.035 to 0.64 degrees.\(^16\) The Houston coefficient of reliability\(^16\) was calculated for all repeated measurements and ranged from 86% to 95%. No systematic errors were detected. Results were considered significant at the \(P = .05\) level.

**RESULTS**

Two hundred and seven cephalograms were available for analysis (4 subjects failed to have a cephalogram). Thirty-five subjects were indeterminate for a diagnosis of OSAHS and were excluded from the study. Twenty-seven subjects were edentulous.

Regression analysis comparing the dentate (145) and edentulous (27) populations and controlling for body mass index (BMI), age, and sex showed that the edentulous had a significantly more backset maxilla (more acute SNA) (\(P = .009\)) and shorter anterior maxillary height (\(P < .0001\)). Since location of the occlusal plane is difficult to determine with any degree of accuracy in those without teeth and affects other measurements that are dependent on it—such as posterior maxillary height, internal maxillary length, and anterior mandibular height—no further analysis was undertaken in the edentulous. There was no significant increase in the prevalence of OSAHS in the edentulous group compared to the dentate group (\(P = .6\)).

Thus, the main analysis focused solely on the 145 dentate subjects, of whom 90 had OSAHS and 55 did not (see Table 2). Forty-eight of the latter reported that they snored at least occasionally, and 7 did not snore at all. In the dentate group of men, overall, regression analysis (correcting for BMI and age) for each variable showed that longer distance of the hyoid bone to the mandibular plane was significantly associated with a diagnosis of OSAHS (\(P = .02\), explaining 12% of the variance. There was a trend for

### Table 1—Classification of Apnea-Hypopnea Index According to Sex and Age

<table>
<thead>
<tr>
<th>Category</th>
<th>Age, yrs</th>
<th>Apnea-hypopnea index, no./h Men</th>
<th>Apnea-hypopnea index, no./h Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>20-40</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>40-60</td>
<td>&lt;15</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>&gt;60</td>
<td>&lt;20</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>20-40</td>
<td>10-15</td>
<td>10-15</td>
</tr>
<tr>
<td></td>
<td>40-60</td>
<td>15-20</td>
<td>10-15</td>
</tr>
<tr>
<td></td>
<td>&gt;60</td>
<td>20-30</td>
<td>15-20</td>
</tr>
<tr>
<td>Abnormal</td>
<td>20-40</td>
<td>&gt;15</td>
<td>&gt;15</td>
</tr>
<tr>
<td></td>
<td>40-60</td>
<td>&gt;20</td>
<td>&gt;15</td>
</tr>
<tr>
<td></td>
<td>&gt;60</td>
<td>&gt;30</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>
mandibular length to be shorter in the OSAHS group ($P = .08$).

In the group of women, the same analyses revealed that OSAHS was associated with a greater distance of the hyoid bone from the mandibular plane ($P = .036$), a greater gnathion-occlusal plane distance ($P = .01$) and a more backset mandible ($P = .028$ for SNA and $P = .05$ for SNB).

A comparison was made between craniofacial dimensions of men and women, controlling for age, BMI, and a diagnosis of OSAHS. All measurements were significantly shorter in the women. The women had more backset mandibles, as judged by SNB, compared to men ($P < .0001$).

Men with OSAHS and a BMI $\geq 30$ kg/m$^2$ had significantly greater posterior maxillary height ($P = .003$), mandibular rami height ($P < .0001$), and hard-palate length ($P < .0001$) compared to the nonobese. Women with OSAHS and a BMI $\geq 30$ kg/m$^2$ had a significantly more obtuse cranial base angle ($P = .027$), compared to the nonobese subjects with OSAHS.

In order to reduce intersubject variance, data from 22 pairs of dentate brothers, discordant for the diagnosis of OSAHS, were analyzed. These sibling pairs were not significantly different in terms of BMI or age (Table 3). Results showed trends for the brothers with OSAHS to have a smaller mandible and a longer distance of the hyoid bone from the mandibular plane (Table 3). Regression analysis in the sibling pairs (controlling for age and BMI) showed a shorter mandibular corpus and lower hyoid in relation to the mandibular plane to be significantly associated with a diagnosis of OSAHS ($P = .013$ and $P = .006$, respectively). There were only 2 pairs of sisters discordant for the diagnosis of OSAHS and no statistically significant differences between those with and without the diagnosis on any cephalometric parameters measured (data not shown).

The effect of aging on the craniofacial complex was examined by dividing the dentate men and women respectively into 2 groups using 51 years as a cutoff (evident morphologic changes in the craniofacial complex occur around the age of 50 years.$^{17-19}$ In the men, the mandibular rami height was significantly greater in those older than 51 years ($P = .01$). There were no significant differences in any bony measurements or angles in the women.

Facial profile, based on the difference between the angles SNA and SNB (the derived value ANB), showed that women were significantly more likely to have skeletal class II profiles owing to their backset mandibles compared to men ($P = .004$) (see Table 4).

**DISCUSSION**

This study is the first to examine the differences between brothers discordant for a diagnosis of OSAHS and to compare bony landmarks and angles in dentate men and women with and without OSAHS, separately. Using a conservative statistical approach, our results show that there are few differences in cephalometric measures between OSAHS patients and their unaffected siblings. Only a longer distance from the hyoid to mandibular plane and a shorter mandibular corpus were associated with OSAHS (regression analysis).

**Subjects With and Without OSAHS**

There were few differences between men with and without OSAHS. The trend toward a shorter mandibular length in the OSAHS group reflects similar observations in previous models for predicting sleep-disordered breathing.$^{20}$ Most significantly, however, the hyoid bone was lower in relation to the mandibular plane in those with OSAHS ($P = .02$).

This finding is compatible with that of Battagel et al,$^{21}$ who studied 115 Caucasian dentate men in the United Kingdom—45 of whom had OSAHS, 46 of whom were snorers, and 24 of whom were controls—and found that the most significant difference after correcting for multiple comparisons among the groups lay in the hyoid-mandibular plane distance. Previous cephalometric studies have also supported this observation.$^{22-25}$ Using data from the Bolton-Brush longitudinal study in the United States on

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**Figure 1**—Cephalometric Points of Reference

1 = nasion; 2 = anterior nasal spine; 3 = point A; 4 = point B; 5 = gnathion; 6 = retrognathion; 7 = hyoid; 8 = cervical vertebra 3; 9 = posterior pharyngeal wall; 10 = basion; 11 = articulare; 12 = posterior nasal spine; 13 = sella; 14 = tip of tongue; P = porion.

**Figure 2**—Cephalometric Planes and Angles

1 = gonion-gnathion; 2 = hyoid to retrognathion; 3 = hyoid to mandibular plane; 4 = cervical vertebra 3 to hyoid; 5 = gonion to articulare; 6 = posterior nasal spine to basion; 7 = internal maxillary length; 8 = gonion; 9 = anterior nasal spine to posterior nasal spine; 10 = sella-nasion-basion angle; 11 = sella-nasion-point A angle; 12 = sella-nasion-point B angle; P = porion.
orthodontic and craniofacial parameters, Nelson et al.\textsuperscript{27} showed that men who snored, compared to those who did not, had a more inferiorly positioned hyoid bone throughout life. This implies that the tongue mass is more concentrated in the hypopharyngeal region with a low-set hyoid, and this feature may be present from childhood. A lower-swung hyoid has been found significantly more often in children who snore and have sleep apnea than those who do not.\textsuperscript{27, 28} Our results extend these observations by documenting the finding among adult sibling pairs who are discordant for the diagnosis of OSAHS, with the differences in the hyoid-mandibular plane occurring independently of BMI.

Women with OSAHS had a lower-set hyoid bone in relation to the mandibular plane than did women without OSAHS ($P = .036$). Furthermore, women with OSAHS had a significantly longer lower facial height (mirrored in the greater anterior mandibular length) and more backset mandible. This was not present in the men. Possible reasons for this difference could be small sample size (false positive association), environmental or behavioral influences on the development of the face (eg, lifelong mouth breathing or nasal obstruction), and possible dental influences such as missing molar teeth, (although all subjects in this analysis were dentate). Studies specifically addressing the differences and similarities between women with and without OSAHS who snore are not available in the literature.

### Obesity

Our study confirms\textsuperscript{29,30} that obese men with OSAHS (BMI $\geq 30$ kg/m\textsuperscript{2}) had significantly longer mandibular rami, hard-palate lengths, and posterior maxillary heights compared to the nonobese men, with trends toward a longer mandibular corpus. In the women, the only significant difference between the obese and nonobese subjects with OSAHS was in a more-obtuse cranial base angle. However, the number of women with OSAHS was small ($n = 15$).

### Age

In the men, mandibular corpus height was significantly greater in those over the age of 51 years. No differences were observed between the younger and older women. Behrents,\textsuperscript{18} using subjects from the Bolton-Brush study, was the first to systematically show that the craniofacial complex continues to grow in adult life. Several studies have demonstrated that the hyoid bone descends with age,\textsuperscript{23,26,31} and this is thought to be the result of the tongue’s enlargement in relation to the intermaxillary space—a trend that is pronounced in men.\textsuperscript{31}

### Sex

Differences in the craniofacial complex with sex are well-recognized.\textsuperscript{18,32} Women are smaller at all ages, grow less, and have significantly shorter mandibles than do men. In men, the mandibular plane rotates in a forward direction, and in women, posteriorly.

### Table 2—Bony Measurements and Angles for Dentate Men and Women With and Without Obstructive Sleep Apnea-Hypopnea Syndrome*

<table>
<thead>
<tr>
<th>Variable</th>
<th>OSAHS</th>
<th>Men ($n = 104$)</th>
<th>Women ($n = 41$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoGn</td>
<td>Present</td>
<td>$75 \pm 5$ (65 - 87)</td>
<td>$70 \pm 4$ (64 - 77)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$77 \pm 5$ (66 - 86)</td>
<td>$71 \pm 5$ (63 - 84)</td>
</tr>
<tr>
<td>GoAr</td>
<td>Present</td>
<td>$56 \pm 7$ (44 - 73)</td>
<td>$46 \pm 6$ (35 - 58)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$57 \pm 5$ (47 - 65)</td>
<td>$46 \pm 5$ (34 - 60)</td>
</tr>
<tr>
<td>HMP\textdagger</td>
<td>Present</td>
<td>$23 \pm 6$ (6.4 - 36)</td>
<td>$20 \pm 6$ (5.5 - 35)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$19 \pm 6$ (11 - 30)</td>
<td>$17 \pm 4$ (11 - 24)</td>
</tr>
<tr>
<td>ANSFOp</td>
<td>Present</td>
<td>$30 \pm 4$ (19 - 41)</td>
<td>$29 \pm 3$ (21 - 34)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$29 \pm 3$ (23 - 34)</td>
<td>$28 \pm 3$ (22 - 33)</td>
</tr>
<tr>
<td>GNFOp\textdagger</td>
<td>Present</td>
<td>$44 \pm 4$ (26 - 54)</td>
<td>$41 \pm 3$ (38 - 48)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$44 \pm 3$ (37 - 52)</td>
<td>$38 \pm 3$ (33 - 43)</td>
</tr>
<tr>
<td>IntMax</td>
<td>Present</td>
<td>$77 \pm 6$ (64 - 89)</td>
<td>$69 \pm 6$ (60 - 83)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$77 \pm 6$ (69 - 84)</td>
<td>$71 \pm 5$ (57 - 79)</td>
</tr>
<tr>
<td>PMAXHT</td>
<td>Present</td>
<td>$41 \pm 7$ (26 - 58)</td>
<td>$35 \pm 6$ (18 - 45)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$40 \pm 6$ (26 - 52)</td>
<td>$34 \pm 7$ (23 - 53)</td>
</tr>
<tr>
<td>SNA</td>
<td>Present</td>
<td>$82 \pm 4$ (72 - 95)</td>
<td>$79 \pm 3$ (72 - 84)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$82 \pm 5$ (72 - 88)</td>
<td>$82 \pm 5$ (74 - 91)</td>
</tr>
<tr>
<td>SNB</td>
<td>Present</td>
<td>$79 \pm 4$ (70 - 87)</td>
<td>$75 \pm 2$ (72 - 80)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$80 \pm 4$ (71 - 87)</td>
<td>$77 \pm 6$ (66 - 86)</td>
</tr>
<tr>
<td>NSBA</td>
<td>Present</td>
<td>$129 \pm 6$ (116 - 144)</td>
<td>$131 \pm 5$ (121 - 138)</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>$128 \pm 6$ (120 - 142)</td>
<td>$129 \pm 4$ (122 - 136)</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD (range). The number of men with obstructive sleep apnea-hypopnea syndrome (OSAHS) = 74 and without OSAHS, $n = 30$; women with OSAHS, $n = 16$, and without OSAHS, $n = 25$.

Except for the angles sella-nasion-point A angle (maxillary angle, SNA), sella-nasion-point B angle (mandibular angle, SNB), and nasion-sella-basion angle (cranial base angle, NSBA), which are measured in degrees, all other measurements are in mm.

\textdagger In men, the P value = .008 for difference in hyoid to mandibular plane distance (HMP) between those with and without OSAHS; insignificant after correction for 10 comparisons.

\textdagger In women, the P value = .01 for the difference in gnathion to occlusal plane distance (GNFOp) between those with and without OSAHS; insignificant after correction for 10 comparisons. GoGn refers to goion to gnathion distance; GoAr, gonion to articulare distance; ANSFOp, anterior nasal spine to occlusal plane distance; IntMax, internal maxillary length; PMAXHT, posterior maxillary height.
Women have, on average, significantly more buckset mandibles than do men, as was confirmed in the current study population.

Sibling Pairs

In 22 pairs of brothers discordant for OSAHS, those with the diagnosis had a trend toward a shorter mandibular corpus and mandibular ramus and a lower-swung hyoid in relation to the mandibular plane. Those without OSAHS, however, were largely snorers, thus perhaps limiting the likelihood of finding cephalometric differences. We excluded the 2 discordant sister pairs from the analysis as there are sex differences in cephalometric variables. However, posthoc analysis in all 24 pairs did not alter the significance of the results.

Edentulism

Our edentulous population had a significantly more buckset maxilla and a shorter maxillary height compared to the dentate. Whether this may independently contribute to a diagnosis of OSAHS has never been examined. We did not find a significant increase in the prevalence of OSAHS in the edentulous subjects. One report documents the worsening of OSAHS with complete edentulism. Studies examining the effect of denture wearing over time have documented changes in hyoid position due to changes in the mandibular and cervical inclination and cranio-cervical angulation and significant reduction in anterior mandibular height.

A major limitation of this study lies in the examination of a 3-dimensional structure using a 2-dimensional technique. However, the method is sufficiently powerful to allow for the recognition of trends and changes in the craniofacial skeleton in a way that makes it comparable to other studies in similar populations. Furthermore, its relative simplicity, ease of access, low radiation exposure, and low cost, as well as its routine use in the practice of prosthodontics and orthodontics, makes it a more practical tool in the investigation of the craniofacial complex than more-sophisticated techniques.

Another possible limitation is the use of siblings that, of necessity, will minimize the differences between groups. However, this was entirely deliberate in an attempt to clarify the importance of differences in facial structure while other differences between the groups were minimized.

Soft-tissue measurements were not performed because these measurements change when the person is using continuous positive airway pressure therapy, which most members of the OSAHS group were doing.

Table 4—Distribution of Skeletal Classes Between Dentate Men and Women

<table>
<thead>
<tr>
<th>CLASS</th>
<th>CLASS II</th>
<th>CLASS III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women (n = 61)</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Men (n = 129)</td>
<td>60</td>
<td>51</td>
</tr>
</tbody>
</table>

P = .004; χ²-test; 2 x 3 contingency table

ACKNOWLEDGMENTS

Dr. N. Mc Ardle, the staff of the Scottish National Sleep Laboratory, and the radiographers at the Department of Radiology, Royal Infirmary Edinburgh, provided helpful assistance with this study.

REFERENCES


