# A retrospective study: Does upper airway morphology differ between non-positional and positional obstructive sleep apnea?

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**Objective:** To explore the differences in upper airway morphology between positional (POSA) and non-positional (NPOSA) obstructive sleep apnea. **Methods:** This retrospective study enrolled 75 patients (45 NPOSA and 30 POSA) who underwent polysomnography (PSG) and computed tomography (CT). The differences in, and relationships of, the PSG values and CT data between POSA and NPOSA were analyzed. **Results:** Significant ($p<0.05$) differences between the two groups were found in the apnea/hypopnea index (AHI), lateral-AHI (L-AHI), soft palate length (SPL), cross-sectional palatopharyngeal area, and the coronal diameter (CD) of the palatopharyngeal area at the narrowest part of the glossopharynx, which were all higher in POSA, except for SPL, AHI, and L-AHI. L-AHI was correlated with the cross-sectional area (r=−0.306, $p=0.008$) and CD (r=−0.398, $p<0.001$) of the palatopharyngeal area, the cross-sectional area (r=−0.241, $p=0.038$) and CD (r=−0.297, $p=0.010$) of the narrowest level of the glossopharynx, the CD of the glossopharynx (r=−0.284, $p=0.013$), body mass index (BMI, r=0.273, $p=0.018$), SPL (r=0.284, $p=0.014$), and vallecula-tip of tongue (r=0.250, $p=0.030$). The SPL and CD at the narrowest part of the glossopharynx were included in the simplified screening model. **Conclusions:** In NPOSA, the CD of the upper airway was smaller, and the soft palate was longer, than in POSA. These differences may play significant roles in explaining the main differences between NPOSA and POSA.

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3  **The manuscript type:** Original contribution

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23    **Abstract**

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28    relationships of, the PSG values and CT data between POSA and NPOSA were analyzed.

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30    apnea/hypopnea index (AHI), lateral-AHI (L-AHI), soft palate length (SPL), cross-sectional

31    palatopharyngeal area, and the coronal diameter (CD) of the palatopharyngeal area at the

32    narrowest part of the glossopharynx, which were all higher in POSA, except for SPL, AHI, and

33    L-AHI. L-AHI was correlated with the cross-sectional area ($r=-0.306$, $p=0.008$) and CD ($r=-$

34    $0.398$, $p<0.001$) of the palatopharyngeal area, the cross-sectional area ($r=-0.241$, $p=0.038$) and

35    CD ($r=-0.297$, $p=0.010$) of the narrowest level of the glossopharynx, the CD of the

36    glossopharynx ($r=-0.284$, $p=0.013$), body mass index (BMI, $r=0.273$, $p=0.018$), SPL ($r=0.284$,

37    $p=0.014$), and vallecula-tip of tongue ($r=0.250$, $p=0.030$). The SPL and CD at the narrowest part

38    of the glossopharynx were included in the simplified screening model.

39  **Conclusions:** In NPOSA, the CD of the upper airway was smaller, and the soft palate was longer,

40  than in POSA. These differences may play significant roles in explaining the main differences

41  between NPOSA and POSA.

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43

44  **Introduction**

45  Obstructive sleep apnea-hypopnea syndrome (OSAHS) is harmful to health. Its major clinical

46  features include snoring, apnea, and daytime hypersomnolence; it is also correlated with diabetes,

47  ischemic heart disease, chronic cor pulmonale, and cerebrovascular disease. Based on differences

48  in the apnea/hypopnea index (AHI) in different positions, OSAHS is divided into positional

49  obstructive sleep apnea (POSA) and non-positional obstructive apnea (NPOSA). POSA is

50  defined as having an AHI in the supine sleeping position that is at least twice the value in other

51  positions (Oksenberg, et al. 2012); otherwise, the condition is considered to be NPOSA. NPOSA

52  patients are prone to having more severe OSAHS than POSA patients (Oksenberg et al. 1997;

53  Oksenberg et al. 2012). Additionally, a variety of treatment methods are available for OSAHS,

54  but the effects of the these treatments on NPOSA and POSA vary (de Vries et al. 2015; Lee et al.

55  2012; Levendowski et al. 2014)). However, the exact mechanisms underlying NPOSA and

56  POSA are unclear; anthropometric characteristics, upper airway morphology, and anatomical

57  structures may all play roles. Many studies have focused on the differences between NPOSA and

58    POSA, such as age and body mass index (BMI) (Oksenberg, et al. 1997; Oksenberg A, et al.

59    2012). There are differences in the contributions made by age and BMI to POSA (Oksenberg et

60    al. 1997; Teerapraipruk et al. 2012). Only a few studies have compared the palatopharyngeal

61    morphology (Soga et al. 2009), craniofacial structures and soft tissues of the lateral pharyngeal

62    wall (Saigusa et al. 2009) between POSA and NPOSA in Caucasians. Differences in the upper

63    airway morphology at other levels, and differences in the soft tissues of the upper airway (such

64    as the length and thickness of the soft palate) between NPOSA and POSA are not known.

65    Currently, the impact of these factors on the substantial differences evident between NPOSA and

66    POSA is uncertain; there are especially few studies on Chinese populations. Therefore, to

67    enhance our understanding of the pathogenesis of NPOSA and POSA, this study explored

68    differences in the upper airway morphology and anatomical structures between two groups of

69    Chinese patients using computed tomography (CT) and polysomnography (PSG).

70

71    **Materials & Methods**

72    This project was approved by the Ethics Committee of our hospital and complied with all

73    relevant tenets of the Declaration of Helsinki (2016-31-(1)). All participants provided written

74    informed consent before inclusion in the study.

75    1. Subjects

76    The study initially recruited 105 consecutive adult patients with OSAHS who underwent surgery

77    because they refused CPAP in our hospital from January 2005 to December 2014 (BMI < 35

78    kg/m$^2$). Patients with chronic airway diseases, obstructive pulmonary disease, and systemic

79   diseases were excluded. Eleven subjects were excluded because they refused to undergo CT

80   testing or because the orbitale-porion plane (*i.e.*, the Frankfort horizontal plane) was not parallel

81   to the ground plane on CT of the head (Yu XJ, Fujimoto K & Urushibata K. 2003). All patients

82   were asked to complete the Epworth Sleepiness Scale and a sleep questionnaire, and to undergo

83   overnight PSG. The study excluded 17 patients who slept for less than 30 min in the lateral or

84   supine position (Oksenberg et al., 1997), and 2 patients whose central or mixed sleep-disordered

85   breathing events accounted for more than 25% of all sleep-breathing episodes (Strollo et al.,

86   2014). Ultimately, the study included 75 patients (Fig. 1).

87   2. Methods

88   The head and neck multislice CT, overnight PSG test, and physical parameters were

89   retrospectively reviewed in all subjects.

90   *2.1 Body parameters*

91   BMI was calculated by dividing the patient's weight in kilograms by height squared in meters

92   squared. The tongue position and tonsil size were assessed using the Friedman staging system

93   before overnight PSG.

94   *2.2 PSG test*

95   All subjects underwent overnight PSG (Alice 4; Respironics, Pittsburgh, PA, USA), which not

96   only identified sleep-disordered breathing events but also included a position sensor that could

97   differentiate the sleep position as supine (S), left side (L), right side, and prone. The AHI is

98   classified into three types depending on the sleep position: the overall AHI, AHI in the supine

99   position (S-AHI), and AHI in the lateral position (L-AHI). The monitoring time was >7 h. The

100    records were analyzed by professionals the next morning. Patients with OSHA who had AHI

101    values in the supine sleeping position at least two-fold greater than the values in other positions

102    were defined as having POSA; the other OSHA patients were defined as having NPOSA

103    (Oksenbergl. 2012). No subjects consumed strong tea, coffee, or drugs that would have had

104    calming effects or caused sleep before the PSG test.

105    *2.3 CT analysis*

106    CT (peak voltage, 120 kV; tube current, 130 mA; pitch, 0.75; section thickness, 2 mm; and tube

107    current-time product, 100 mA) was performed on all patients in the supine position, from the

108    skull base to the hyoid bone, with the head positioned correctly (the orbitale-porion plane

109    parallel to the ground plane), the upper and lower teeth naturally together, the tongue tip against

110    the premaxillary teeth, and with all patients breathing quietly without swallowing or chewing.

111    Philips DICOM viewer software was used to measure CT parameters including the angles, cross-

112    sectional areas, and soft tissue parameters of the upper airway: the sella (S), nasion (N),

113    subspinale (A), supremental (B), basion (Ba), vallecula (V), tip of tongue (T), anterior nasal

114    spine (ANS), posterior nasal spine (PNS), angles relative to each other (*e.g.*, SNA, SNB, BaSN,

115    and ANB), and the posterior airway space    (Fig. 2). Then, the sagittal (SD) and coronal (CD)

116    diameters and cross-sectional area were measured at the palatopharynx, glossopharynx ,

117    hypopharynx, and the narrowest part of the glossopharynx (Sakatet al. 2016) (Fig. 3). In addition,

118    the soft tissues of the upper airway were measured, including the vallecula-tip of tongue (VT, the

119    tongue length), soft palate length, and soft palate thickness (SPT).

120    3. Statistical analysis

121 The statistical program SPSS 20.0 (IBM, Armonk, NY, USA) was used to compare the data

122 associated with anthropometric characteristics, upper airway morphology, and PSG between the

123 POSA and NPOSA groups. Normally distributed data were compared using the independent

124 samples *t*-test and are presented as the mean ± standard deviation. Non-normally distributed data

125 were analyzed using the Mann-Whitney test and are presented as the median (interquartile range).

126 Correlations between variables were examined using Spearman's correlation or the Pearson test.

127 Forward logistic regression analysis was performed to select the main correlative parameters of

128 POSA. The accuracy of the diagnostic model was examined using the receiver operating

129 characteristics (ROC) curve. A value of $p<0.05$ was used to indicate statistical significance.

130

131 **Results**

132 The 75 subjects were divided into NPOSA (n=40) and POSA (n=35) groups. The mean age of

133 the subjects was 39.2 ± 9.4 years, while the mean age of the NPOSA and POSA groups was 40.8

134 ± 5.3 and 38.6 ± 11.2 years($p$=0.043). The mean BMI was 27.4 ± 3.2 kg/m$^2$. There was a

135 significant ($p$ <0.01) difference in the AHI between NPOSA and POSA (60.1 ± 19.4 *vs*. 42.5 ±

136 18.5 event/h), and the L-AHI of POSA was significantly ($p$<0.001) lower than that of NPOSA.

137 However, no significant difference between the two groups was found for BMI, tongue position,

138 tonsil size, Friedman staging, or S-AHI ($p$>0.05) (Table 1).

139 The SPL was significantly ($p$=0.005) longer in NPOSA (36.1 ± 5.0 mm) than in POSA (33.0 ±

140 3.9 mm). The cross-sectional area of the palatopharynx was significantly ($p$=0.027) smaller in

141 the NPOSA group [67.4 (31.1) *vs*. 80.3 (43.0) mm$^2$]. In addition, the CD of the palatopharynx

142    and the narrowest part of the glossopharynx were significantly ($p<0.05$) smaller in NPOSA than

143    in POSA. However, there were no statistical differences in SNA, SNB, ANB, BaSN, ANS, PNS,

144    SPT, VT, or the SD to CD ratios of the glossopharynx and hypopharynx (all $p>0.05$) between the

145    two groups. Although, no significant difference group was found in CD or the cross-sectional

146    area of the glossopharynx or hypopharynx, the values were smaller in NPOSA than POSA

147    (Table 2).

148    After adjusting for age as a confounding factor, the AHI, SPL, and SD to CD ratios of the

149    glossopharynx and L-AHI were significantly ($p<0.05$) larger in NPOSA than POSA, and the CD

150    of the glossopharynx was significantly smaller. However, no significant difference was found in

151    CD or the cross-sectional area of the palatopharynx between the two groups.

152    As assessed using Pearson and Spearman correlation analyses, L-AHI was correlated with the

153    cross-sectional area (r=–0.306, $p=0.008$) and CD (r=–0.398, $p<0.001$) of the palatopharynx, the

154    cross-sectional area (r=–0.241, $p=0.038$) and CD (r=–0.297, $p=0.010$) of the narrowest part of

155    the glossopharynx, the CD of the glossopharynx (r=–0.284, $p=0.013$), BMI (r=0.273, $p=0.018$),

156    SPL (r=0.284, $p=0.014$), and VT (r=0.250, $p=0.030$) in all subjects.

157    Forward logistic regression analysis of the relative influence of these independent variables on

158    NPOSA, the soft palate length, the CD of the narrowest part of the glossopharynx, and age were

159    included in the regression model (Supplementary Table 1). The cut-off point for soft palate

160    length was 35.4 mm.

161

162    **Discussion**

163    The AHI is significantly higher in NPOSA than POSA (Oksenberg et al. 1997), consistent with

164    our results. Aging is known to be a major contributor to the risk of OSAHS; its prevalence and

165    severity increase with age and may be associated with factors such as a reduction in muscle tone,

166    a reduced airway lumen, and changes in lung volume and ventilatory control stability ((Edwards

167    et al. 2010; Kim et al. 2015). In the present study, the NPOSA patients were older than the POSA

168    patients. Although there was no correlation between age and AHI or L-AHI, the difference in

169    upper airway parameters between the two groups changed after adjusting for age. Age was

170    included in the regression model as one of the independent risk factors for NPOSA. This may be

171    because the activity of the pharyngeal dilator muscles in response to negative pharyngeal

172    pressure is impaired upon aging, increasing the compliance of the pharyngeal wall in both the

173    supine and lateral positions. Furthermore, age may affect upper airway collapse in different

174    planes and play a role in the susceptibility to NPOSA.

175    Cephalometry is used to screen for anatomical abnormalities in OSAHS patients. Various studies

176    have shown that the pharyngeal dimensions are correlated with both craniofacial skeletal

177    morphology (Bacon et al. 1988; Wang et al. 2014; Yu XJ,;Fujimoto K, Urushibata K 2003) and

178    airway obstruction in OSAHS patients (Ardehali et al. 2016), including those with ANB (Ceylan

179    & Oktay, 1995), SNB (Ardehali et al. 2016), and ANS-PNS (Yu XJ, Fujimoto K & Urushibata K.

180    2003). It is well-known that significant differences are apparent between NPOSA and POSA in

181    terms of clinical symptoms, and, theoretically, the characteristics of the craniofacial skeleton

182    may play a role in this context. However, we found no significant difference in craniofacial

183    morphology (apart from soft palate length) between NPOSA and POSA, suggesting that skeletal

184    morphology did not play a significant role in NPOSA.

185    We found that the L-AHI was associated with soft palate length; specifically, the more the length

186    of the soft palate exceeded > 35.4 mm the greater the risk of NPOSA. This may be explained in

187    several ways. Historically, the soft palate was larger in OSAHS than non-OSAHS patients (Lowe

188    et al. 1996), and has been shown to play a key role in OSAHS (Bacon et al. 1990). In addition,

189    fatty infiltration (regardless of obesity status) (Zohar et al. 1998) impairs soft palate sensation,

190    which correlates with the severity of snoring (Jeong et al. 2016); the soft palate becomes altered

191    and exhibits a fiber-type appearance caused by the additional load on the velopharyngeal

192    muscles (Lindman & Stål 2002) in OSAHS patients. These factors may affect compliance of the

193    soft palate and can cause narrowing of the upper airway. Also, inflammatory processes increase

194    the thickness of the soft palate (Berger et al. 2002), which also tends to be thicker in the supine

195    position in OSAHS patients because gravitational force reduces the SD of the upper airway

196    (Lowe et al. 1996). In comparison, in the lateral position, the gravitational force acting on the

197    longer soft palate of NPOSA patients should decrease the CD of the upper airway. Furthermore,

198    our simplified PRE screening model included soft palate length as an independent predictor of

199    NPOSA. Our results suggest that soft palate length plays a significant role in the direction of

200    upper airway collapse during sleep, although the reason for the increased susceptibility to

201    NPOSA in those with longer soft palates remains unclear. Our work suggests that NPOSA not

202    only involves anteroposterior collapse, but also transverse collapse in the plane of the

203    palatopharynx, whereas POSA involves only the former.

204    In OSAHS patients, single or multiple planes of upper airway collapse, such as the

205    palatopharyngeal, glossopharyngeal, and hypopharyngeal planes (Tang et al. 2012; Torre et al.

206    2016; Vroegop et al. 2014), and the complete concentric collapse of the glossopharynx, are

207    correlated significantly with the severity of OSAHS (Ravesloot & de Vries 2011; Schwartz et al.

208    2015; Vroegop et al. 2014). In our study, the negative correlations between L-AHI and the CD of

209    the palatopharynx and glossopharynx demonstrated that the lateral diameter of the upper airway

210    was highly predictive of the value of AHI (Tsai et al. 2003). Second, after adjusting for age,

211    patients with NPOSA tended to have more severe OSAHS, with a smaller CD at the narrowest

212    level of the glossopharynx and a higher L-AHI. Third, the CD of the narrowest level of the

213    glossopharynx, age, and SPL were included in the regression model. These results indicate that

214    the smaller lateral distance in NPOSA patients (Pevernagie et al. 1995; Soga et al. 2009),

215    particularly at the level of the glossopharynx, plays an essential role in the differences between

216    NPOSA and POSA. There was no significant difference in the SD of the upper airway or S-AHI

217    between the two groups, suggesting that the pathogenesis of NPOSA in the supine position might

218    be similar to that of POSA. Additionally, in NPOSA, a round airway was seen in the

219    palatopharynx and an elliptical airway, with the SD as the long axis, was seen at the narrowest

220    level of the glossopharynx. In the supine position in POSA, an elliptical airway with the CD as

221    the long axis was seen in the palatopharynx ((Ciscar et al. 2001; Walsh et al. 2008). Perhaps the

222    different airway shapes between NPOSA and POSA, caused by the fat distribution in the lateral

223    pharyngeal wall and the reduction in muscle tone (Saigusa et al. 2009), led to differences in the

224    direction of upper airway collapse and impaired breathing in sleep (Foster et al. 2009). Hence,

225    the upper airway morphology characteristics of the two groups may play a significant role in the

226    substantial differences between NPOSA and POSA.

227    Our small sample size and the lack of a control group are limitations of our study. Also, the

228    patients were very young and the results might thus not be generalizable. Moreover, we did not

229    collect nocturnal rostral fluid shift or electroencephalographic data, and may also have ignored

230    other factors that could affect our results. Such limitations are disadvantages common to many

231    retrospective studies. Another limiting factor is that CT was performed with all patients awake

232    and the data may thus not accurately reflect the dynamics of upper airway collapsibility during

233    sleep. Thus, future studies with larger sample numbers are warranted to further examine and

234    prospectively elucidate the mechanisms underlying NPOSA and POSA.

235    This study identified characteristic differences in the upper airway between NPOSA and POSA,

236    which may partly explain the differences in clinical characteristics and treatment success rates

237    between the two groups. The prognosis of OSAHS may be improved by choosing the appropriate

238    treatment according to the upper airway morphology characteristics. POSA patients may gain

239    more benefit from positional therapy (de Vries et al. 2015; Levendowski et al. 2014)),

240    mandibular advancement devices, (Lee et al. 2012) and uvulopalatopharyngoplasty (Li et al.

241    2013), whereas NPOSA patients will probably almost always require continuous positive airway

242    pressure therapy and/or more complex treatment.

243

244    **Conclusion**

245    In terms of upper airway morphology, the NPOSA group had a smaller pharyngeal CD and a

246     longer soft palate than the POSA group. In addition to the AHI, the main differences between

247     NPOSA and POSA patients were in the soft palate length and the CD at the narrowest part of the

248     glossopharynx.

249

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360    **Figure Legends**

361    **Figure 1**. Flow diagram of the recruitment of study participants

362    PSG test = polysomnography test, CT= computed tomography

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364    **Figure 2.** Diagram showing the anatomical points, lines, and angles used to evaluate craniofacial

365    morphology

366    S = sella, n = nasion, A = subspinale, B = supremental, b = basion, V = vallecula, T = tip of tongue,

367    ANS= anterior nasal spine, PNS= posterior nasal spine.

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369    **Figure 3**. Cross-sectional views of the upper airway in the four planes in NPOSA (a,b,c,d) and

370    POSA (e,f,g,h)

371    NPOSA= non-positional obstructive sleep apnea; POSA= positional obstructive sleep apnea; a, e = cross-

372    sectional views of the palatopharynx; b, f = cross-sectional views of the glossopharynx; c, g = cross-

373    sectional views of the hypopharynx; d, h = cross-sectional views of the narrowest part of the

374    glossopharynx

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376     **Table 1**. Comparison of the data associated with anthropometric and cephalometric

377     characteristics and polysomnography (PSG) in positional (POSA) and non-positional (NPOSA)

378     obstructive sleep apnea.

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380     **Table 2**. Comparison of the data associated with the cephalometric characteristics in POSA and

381     NPOSA.

382     The English in this document has been checked by at least two professional editors, both native

383     speakers of English. For a certificate, please see:

384     http://www.textcheck.com/certificate/ZVHTfO

Flow diagram of the recruitment of study participants

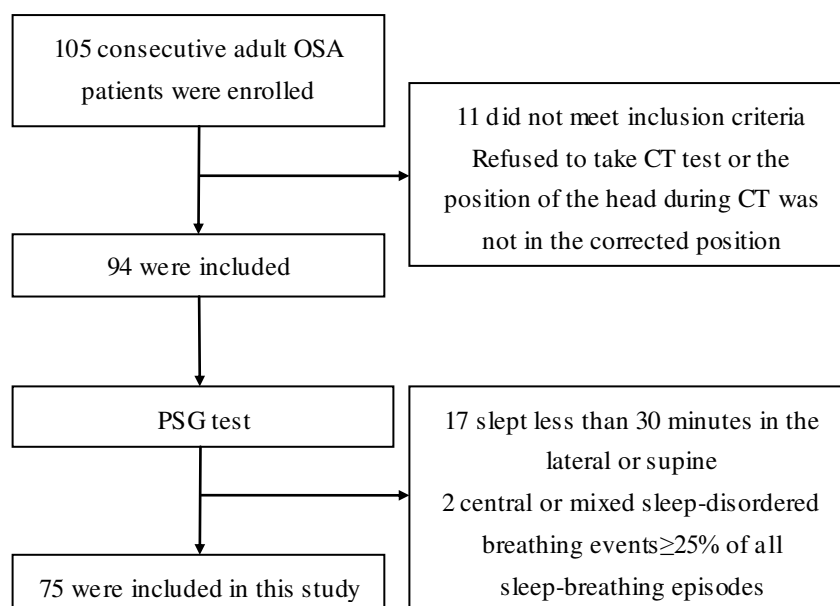
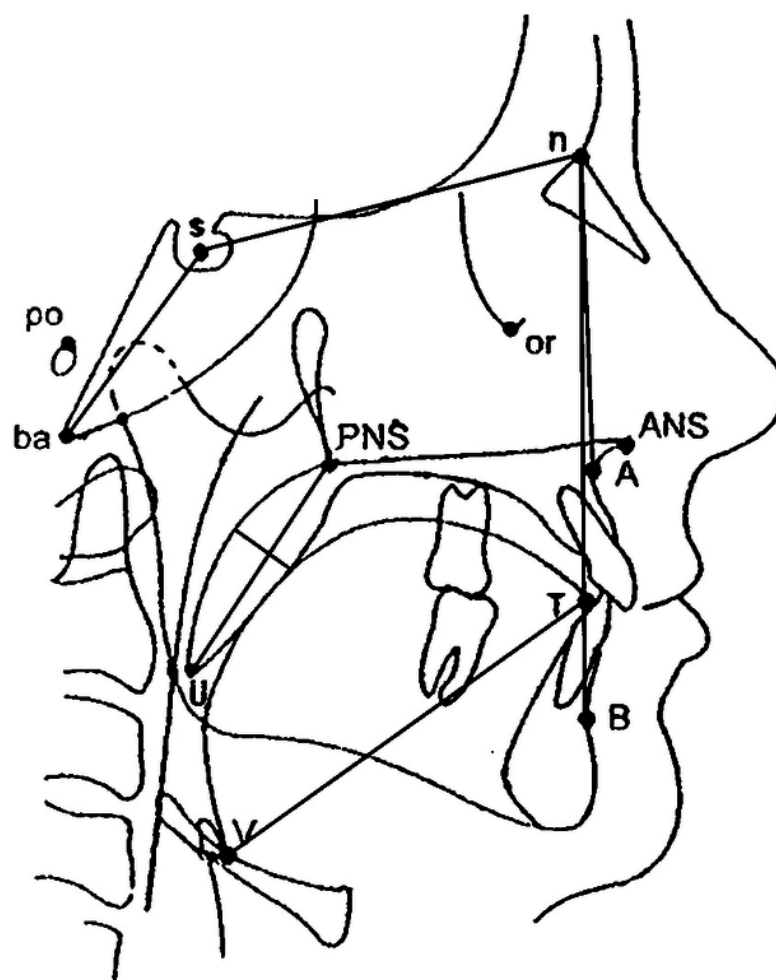
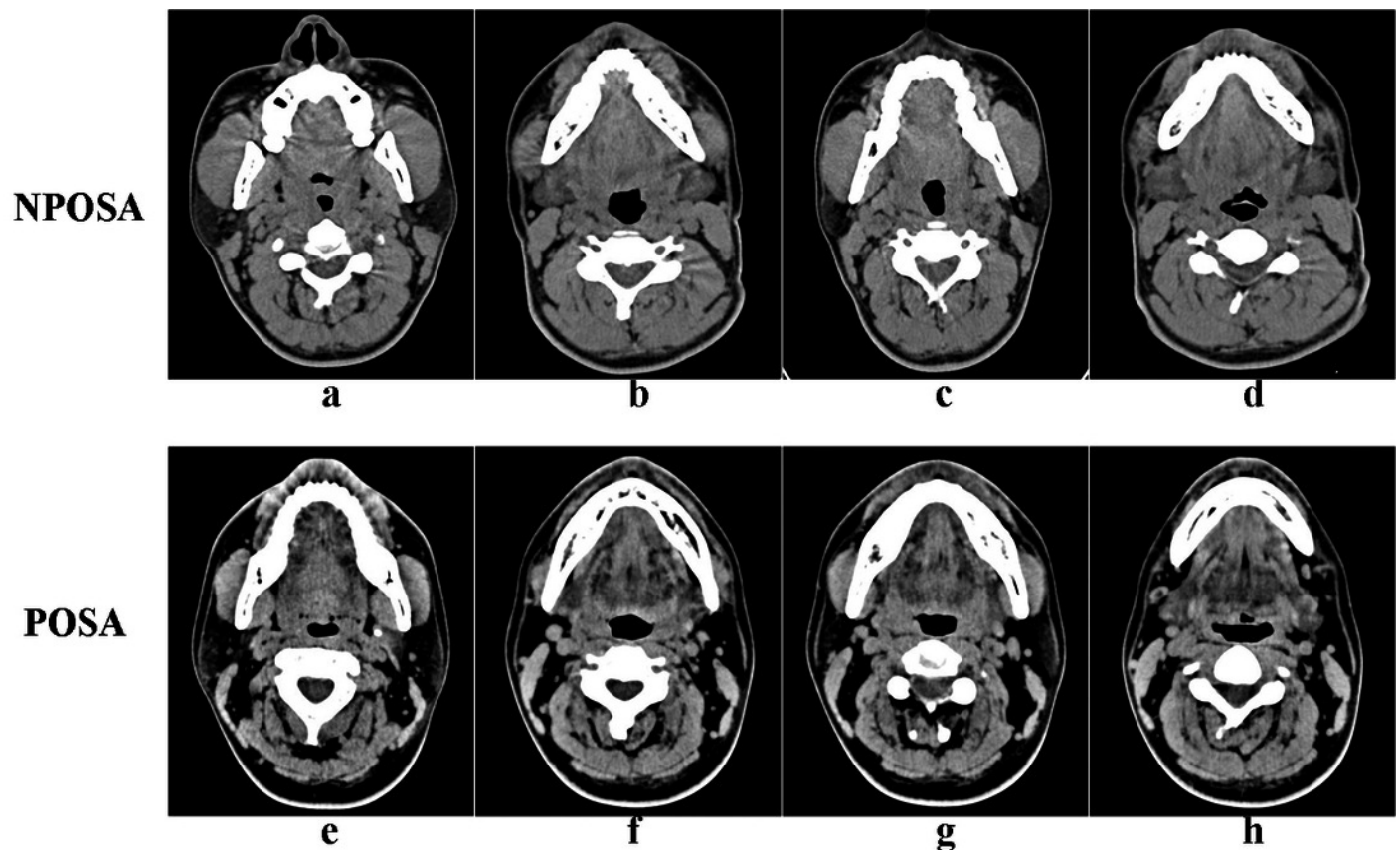
PSG test = polysomnography test, CT= computed tomography

# Figure 2

Diagram showing the anatomical points, lines, and angles used to evaluate craniofacial morphology

s= sella, n= nasion, A= subspinale, B= supremental, ba= basion, V= vallecula, T= tip of tongue, ANS= anterior nasal spine, PNS= posterior nasal spine.

# Figure 3

Cross-sectional views of the upper airway in the four planes in NPOSA (a,b,c,d) and POSA (e,f,g,h)

NPOSA= non-positional obstructive sleep apnea; POSA= positional obstructive sleep apnea; a, e = cross-sectional views of the palatopharynx; b, f = cross-sectional views of the glossopharynx; c, g = cross-sectional views of the hypopharynx; d, h= the cross-sectional views of the narrowest part of the glossopharynx

Comparison of the data associated with anthropometric and cephalometric characteristics and polysomnography (PSG) in positional (POSA) and non-positional (NPOSA) obstructive sleep apnea.

*: Mann-Whitney test or t test for equal change between groups. †: Test for equal change between groups, adjusted for age ⬚ Normally distributed data are presented as mean ± standard deviation; non-normally distributed data are presented as median (interquartile range). NPOSA= non-positional obstructive sleep apnea; POSA= positional obstructive sleep apnea; BMI= body mass index; SPL= soft palate length; SPT= soft palate thickness; VT = the tongue length; AHI= apnea hypopnea index; S-AHI= supine-AHI; L-AHI= lateral-AHI.

1   **Table 1.** Comparison of the data associated with anthropometric and cephalometric
2   characteristics and polysomnography (PSG) in positional (POSA) and non-positional (NPOSA)
3   obstructive sleep apnea.

| Indicators | #NPOSA (45) | #POSA (30) | p* | p† |
|---|---|---|---|---|
| Age (year) | 40.1±9.0 | 36.6±9.6 | 0.043 | - |
| BMI (kg/m²) | 27.9±3.1 | 26.6±3.1 | 0.106 | 0.069 |
| SNA (°) | 83.4±4.2 | 82.3±3.8 | 0.254 | 0.148 |
| SNB(°) | 79.1±4.5 | 78.5±4.6 | 0.539 | 0.289 |
| ANB(°) | 4.4(2.5) | 3.9±2.7 | 0.479 | 0.666 |
| BaSN(°) | 139.1±5.3 | 140.6±5.3 | 0.222 | 0.134 |
| PAS (mm) | 11.3(3.9) | 10.8±3.2 | 0. 449 | 0.288 |
| ANSPNS (mm) | 45.2±3.8 | 44.8±2.9 | 0.617 | 0.576 |
| SPL (mm) | 36.1±4.9 | 33.0±3.9 | 0.005 | 0.005 |
| SPT (mm) | 10.2±2.0 | 9.6±1.5 | 0.159 | 0.219 |
| VT (mm) | 71.2±5.8 | 69.1±4.9 | 0.106 | 0.094 |
| Total AHI (events/h) | 60.1±19.4 | 42.5±18.5 | <0.001 | <0.001 |
| S-AHI | 62.0±20.3 | 64.0(20.1) | 0.405 | 0.347 |
| L-AHI | 60.1±23.5 | 9.5(11.6) | <0.001 | <0.001 |

4   *: Mann-Whitney test or t test for equal change between groups.

5   †: Test for equal change between groups, adjusted for age

6   # Normally distributed data are presented as mean ± standard deviation; non-normally distributed data

7   are presented as median (interquartile range). NPOSA= non-positional obstructive sleep apnea; POSA=

8   positional obstructive sleep apnea; BMI= body mass index; SPL= soft palate length; SPT= soft palate

9   thickness; VT = the tongue length; AHI= apnea hypopnea index; S-AHI= supine-AHI; L-AHI= lateral-

10   AHI.

Comparison of the data associated with the cephalometric characteristics in POSA and NPOSA.

*: Mann-Whitney test or t test for equal change between groups. †: Test for equal change between groups, adjusted for age. □Normally distributed data are presented as mean ± standard deviation; non-normally distributed data are presented as median (interquartile range). NPOSA= non-positional obstructive sleep apnea; POSA= positional obstructive sleep apnea; SD= sagittal diameter ; CD= coronal diameter ; SD/CD= sagittal diameter to coronal diameter ratios.

1 **Table 2.** Comparison of the data associated with the cephalometric characteristics in POSA and
2 NPOSA.

| | Variables | #NPOSA(45) | #POSA(30) | p* | p† |
|---|---|---|---|---|---|
| palatopharyngeal | cross-sectional area | 67.4(31.1) | 80.3(43.0) | 0.027 | 0.107 |
| | SD | 8.1(3.5) | 8.5±2.0 | 0.563 | 0.940 |
| | CD | 8.8 (3.8) | 9.7(5.2) | 0.040 | 0.124 |
| | SD/CD | 0.9 (0.6) | 0.9±0.3 | 0.320 | 0.666 |
| glossopharynx | cross-sectional area | 287.4±86.6 | 311.5±94.0 | 0.257 | 0.363 |
| | SD | 16.3±3.8 | 15.9(6.6) | 0.888 | 0.955 |
| | CD | 21.8±6.4 | 24.4±5.5 | 0.076 | 0.103 |
| | SD/CD | 0.7(0.4) | 0.6(0.2) | 0.261 | 0.242 |
| hypopharynx | cross-sectional area | 123.8(55.6) | 153.2±61.5 | 0.098 | 0.441 |
| | SD | 10.7(2.5) | 10.9±2.7 | 0.516 | 0.793 |
| | CD | 15.7±5.9 | 17.2±5.3 | 0.276 | 0.218 |
| | SD/CD | 0.7(0.5) | 0.7±0.3 | 0.706 | 0.155 |
| The narrowest level of glossopharynx | cross-sectional area | 189.0±82.3 | 211.5±69.1 | 0.222 | 0.177 |
| | SD | 16.1±5.1 | 14.9(6.9) | 0.393 | 0.347 |
| | CD | 11.5(9.3) | 14.5±6.0 | 0.055 | 0.029 |
| | SD/CD | 1.2(1.6) | 1.1(0.9) | 0.119 | 0.042 |

3  *: Mann-Whitney test or t test for equal change between groups.

4  †: Test for equal change between groups, adjusted for age.

5  #Normally distributed data are presented as mean ± standard deviation; non-normally distributed data are

6  presented as median (interquartile range).

7  NPOSA= non-positional obstructive sleep apnea; POSA= positional obstructive sleep apnea; SD= sagittal

8  diameter ; CD= coronal diameter ; SD/CD= sagittal diameter to coronal diameter ratios.