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ORIGINAL ARTICLE

Risk factors for sleep-disordered breathing: the role of craniofacial structure

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Abstract

Objective. To evaluate possible differences in craniofacial structure between overweight patients and normal-weight patients with mild sleep-disordered breathing (SDB). ***Material and methods.*** Subjects were recruited from patients referred to Kuopio University Hospital due to suspicion of SDB. They were divided into two groups based on their body mass index (BMI). The overweight group (BMI > 27 kg/m^2) consisted of 58 males and 19 females and the normal weight group (BMI ≤ 27 kg/m^2) of 33 males and 15 females. The mean age of the subjects was 51.4 years. All subjects underwent an overnight cardiorespiratory recording. The mean apnea–hypopnea index (AHI) was 9.3 events/h for the entire study population. Occlusion and craniofacial morphology were examined by an experienced orthodontist. ***Results.*** Significant differences in craniofacial morphology and occlusion were found between the groups: the craniofacial profile in normal-weight patients was more convex ($P < 0.000$) and the mandible more retrusive ($P = 0.004$) than in overweight subjects. In addition, distal molar occlusion ($P = 0.005$) was more prevalent in normal-weight subjects, and their overjet and overbite were increased as compared to overweight patients ($P = 0.009$ and 0.006, respectively). Similarly, cross bite was detected significantly more often in normal-weight subjects ($P = 0.052$). ***Conclusions.*** These results reveal that deviations in craniofacial morphology and occlusion are more frequent in normal subjects than in overweight subjects with mild SDB; this may well have implications in the pathophysiology of SDB.

Key Words: *Craniofacial morphology, obesity, occlusion, sleep-disordered breathing*

Introduction

Sleep-disordered breathing (SDB), including obstructive sleep apnea (OSA), is a condition caused by recurrent upper airway obstruction during sleep, which manifests as loud snoring, pauses in breathing, and sleep fragmentation [1]. The spectrum of SDB ranges from partial airway collapse and increased upper airway resistance to complete airway obstruction and apneas. Today, SDB represents a major public health burden, and its prevalence is rapidly increasing. Furthermore, SDB has been found to be associated with an increased risk of many other chronic diseases, such as cardiovascular diseases, type 2 diabetes, metabolic syndrome, and an overall deterioration in an individual's quality of life and working capacity [2–7]. The vast majority of patients with SDB remain undiagnosed and it has been estimated that one out of every five adults has at least mild SDB [8]. Untreated SDB has been observed to double the use of health services [9], and since initial mild OSA can progress to moderate or severe OSA [10], early recognition and treatment of the disease are crucial in preventing this progression.

SDB is a complex disorder with a pathogenesis which is not fully understood. It appears to result from a variable combination of anatomical and pathophysiological factors. Although obesity is considered to be the most important risk factor for SDB [11,12], previous studies have also reported

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several craniofacial features that are typical of SDB patients [13–17]. Differences in the pathogenesis of SDB may also depend on gender and age [8]. In addition, abnormalities in neuromuscular properties and ventilation control may be involved in the cause of the SDB.

Previous studies in Asian populations suggested that the etiology of SDB in obese patients may be different from that in non-obese patients [15,18]. Inter-ethnic differences partly explain the degree to which obesity and craniofacial anatomy serve as risk factors for SDB [19,20]. In general, most Asian patients with SDB seem to have a lower body mass index (BMI) than their Caucasian counterparts who display a similar degree of SDB severity [19]. Thus, Asians are believed to be at risk of suffering a more severe degree of illness compared to Caucasians [20]. In particular, the dolicofacial morphology typical of the Japanese [21] and the typical brachyfacial morphology of Caucasians are considered to increase the risk of SDB [20]. In summary, craniofacial anatomy and obesity and their degree of contribution to SDB can vary within the same population [15,17,22] and across different ethnic groups [19,20,23].

In order to improve our understanding of the pathogenesis and evolution of SDB, and to help to select the most applicable treatment modality for every patient, it is important to evaluate the risk factors contributing to SDB in both overweight and in normal-weight patients representing a homogenous population. Although the importance of obesity as a risk factor for SDB is now well established, SDB remains frequently undiagnosed. It is of vital importance that healthcare professionals become aware of the importance of deviant craniofacial morphology and malocclusions if these properties are found to predispose to SDB also in Western populations. Furthermore, it is essential to develop feasible and straightforward clinical methods which can be implemented in primary care settings, i.e. tools for health professionals to assess those deviations. The main objectives of the present study were to evaluate whether there are differences in craniofacial morphology and occlusion between overweight and normal-weight patients with an homogenous degree of SDB, and to estimate the relevance of clinical examination methods for identifying the craniofacial features and malocclusions of SDB patients.

Material and methods

Overview

The present study is a prospective clinical study in consecutive adult patients with a suspicion of SDB. Recruitment was performed during 2004–08 and the overall study population consisted of 125 patients. The weight and height of the patients were registered and their craniofacial morphology as well as occlusion were assessed by an orthodontist. After the clinical evaluation, the patients underwent nocturnal cardiorespiratory recording. The subjects were divided into two study groups based on their BMI: an overweight group (BMI > 27 kg/m^2) and a normal-weight group (BMI ≤ 27 kg/m^2). The present study is part of a larger trial on OSA being conducted as a collaboration between the Kuopio University Hospital, the University of Eastern Finland, the National Institute for Health and Welfare, and the Helsinki Sleep Research Center. All patients were given verbal and written information about the trial and they provided consent to participate. The study protocol was approved by the Research Ethics Committee of the Hospital District of Northern Savo (Kuopio, Finland).

Participants

The study was conducted at a single centre: Kuopio University Hospital. The study is a sub-study of a prospective, randomized trial originally conducted to determine the effects of changes in lifestyle with a weight-reduction program designed to prevent the progression of OSA in overweight patients with mild OSA. A more detailed design of the trial has previously been reported [24]. The study participants were consecutive patients referred to the Department of Oral and Maxillofacial Diseases of Kuopio University Hospital for an orthodontist's evaluation from the outpatient clinics of Otorhinolaryngology or Respiratory Medicine. At the study site, a trained nurse measured height and weight. The overweight group (BMI > 27 kg/m^2) consisted of 58 males and 19 females and the normal-weight group of 33 males and 15 females with mild SDB. The characteristics of the study population are presented in Table I. None of the participants had significant adenotonsillar hypertrophy evaluated by an otorhinolaryngologist.

Procedures and measurements

In nocturnal cardiorespiratory monitoring, apnea was defined as a cessation (>90%) of airflow of >10 s with oxygen desaturation of >4%. Hypopnea was defined as a reduction (>30%) of airflow of >10 s with oxygen desaturation of >4%. The apnea–hypopnea index (AHI) was defined as the number of apneas and

Table I. Demographic data [mean (SD)] for the overweight subjects (n = 77) and normal-weight subjects (n = 48) with SDB.

	Overweight subjects	Normal-weight subjects	P^a
Age (years)	51.9 (8.8)	50.5 (9.9)	0.427
BMI	32.4 (3.0)	25.2 (1.9)	0.000
Total AHI	9.7 (3.2)	8.8 (7.7)	0.364

[a]According to Student's t-test.

hypopneas per hour, and mild SDB was defined as an AHI of 5–15 events/h [25].

Evaluations of the facial profile and occlusion were based on routine orthodontic clinical examinations done by the same orthodontist (R.P.), who has over 10 years' experience in adult orthodontics, jaw orthopedics and treating patients with OSA. Subjects were examined in the supine position. The profile was considered as straight when an imaginary line could connect the bridge of the nose to the base of the upper lip and extend to the chin. A convex profile/line was indicative of a distal molar occlusion, whereas a concave profile/line referred to a Class III mesial molar occlusion [26].

In the vertical direction, the face was divided into approximately equal vertical thirds with the upper third extending from the point trichion (Tr) at the top of the forehead to the soft tissue glabella (G), the most anterior point of the forehead. The second vertical third extended from the soft tissue glabella to the subnasale (Sn), or the point at which the columella of the nose merged with the upper lip in the midsagittal plane. The lower third began with the subnasale and ended with the soft tissue menton (Me), the lowest point on the contour of the soft tissue chin [27]. A 'sunken' appearance of the midface in the middle third may be an indication of maxillary retrognathism, a protrusive midface indicating maxillary protrusion. If the chin was clearly behind the imaginary straight line through the bridge of the nose to the base of the upper lip, the mandible was considered as being retrusive and if the chin was clearly in front of that line, this was indicative of mandibular protrusion. The ratio of the middle third to lower third vertical height of the face should be 5:6 [27], which is indicative of a normal lower facial height. If the lower third is clearly less than this value, then this is interpreted as a decreased lower facial height, and if it is clearly above that value, the lower facial height is increased.

Occlusion in the subjects was recorded in the intercuspal position using the modified method of Björk et al. [28]. Sagittal molar occlusion (Angles' classification) was considered normal (AI) when the mesiobuccal cusp of the maxillary first permanent molar occluded in the line with the mesiobuccal groove of the mandibular first molar. Distal (AII) or mesial (AIII) molar occlusion was recorded when there was bilateral deviation of at least one half cusp. Overjet was measured in millimeters from the most labial point of the maxillary right central incisor to the corresponding point on the antagonistic mandibular incisor, parallel to the occlusal plane. Anterior cross bite was recorded as a reversed incisor bite. Overbite was measured vertically from the incisal edge of the maxillary right central incisor to the incisal edge of the mandibular right central incisor with the teeth in the intercuspal position. Cross bite was recorded if one or more buccal cusps of the maxillary premolars or molars occluded lingual to the tip of the buccal cusp of the antagonist tooth. In addition, the width of the palate was evaluated by performing a routine orthodontic visual inspection and was classified as either normal, decreased, or increased.

Statistical methods

Mean values and standard deviations were used to describe the baseline characteristics of the two study groups. Student's *t*-test was used to compare the group means when the data were normally distributed. Logistic regression with a backward selection setup procedure was used to evaluate the association between the group (0 = overweight group, 1 = normal-weight group) and the following craniofacial parameters (independent factors): overjet (mm), overbite (mm), narrow palatal width (0 = no, 1 = yes), cross bite (0 = no, 1 = yes), and mandibular retrusion (0 = no, 1 = yes). The model was adjusted for age and gender. A variable with a prevalence of $< 5\%$ or which was highly correlated with other independent factors was not included in the model. *P*-values of <0.05 were considered statistically significant. All analyses were performed with the SPSS software 17.0 package (SPSS Inc., Chicago, IL).

Results

Significant differences in craniofacial morphology and occlusion were found between the normal and overweight SDB patients (Table II). Half of the normal-weight SDB patients had a convex profile, while in overweight patients the profile was convex in only one out of every six patients. Since the size and position of the mandible are important determinants of the profile, the same difference between the groups was seen in the sagittal position of mandible, i.e. it was more retrusive in the normal-weight patients compared with the overweight patients (43% and 16%, respectively).

Distal molar occlusion was found in almost half (46%) of the normal-weight patients, while less than one-fifth (18%) of the overweight patients had a Class II molar relationship (Table III). The difference in molar occlusion between the groups was statistically significant ($P = 0.005$). Also, cross bite was more prevalent in the normal-weight patients than in the overweight patients (18% and 7%, respectively), but no difference was found in palatal width between the groups. Interestingly, both overjet and overbite were significantly increased in normal-weight patients compared to their overweight counterparts ($P = 0.009$ and 0.006, respectively; Figure 1). The multiple logistic regression analysis revealed that cross bite, overbite, and mandibular retrusion

Table II. Comparison of craniofacial morphology (%) in overweight subjects (n = 77) and normal-weight subjects (n = 48) with SDB.

	Overweight subjects	Normal-weight subjects	P^a
Profile			<0.000
Convex	15.6	50.0	
Concave	1.3	0	
Straight	83.1	50.0	
Mandible			0.004
Retrusive	15.6	42.9	
Protrusive	1.3	0	
Orthognathic	83.1	57.1	
Maxilla			0.430
Retrusive	2.6	2.4	
Protrusive	3.9	0	
Orthognathic	93.5	97.6	
Lower facial height			0.533
Increased	2.6	2.2	
Decreased	14.3	22.2	
Normal	83.1	75.6	

[a]According to chi-square statistics.

were associated with SDB in normal-weight subjects (Table IV).

Discussion

This study revealed that malocclusal traits such as increased overbite, cross bite, and mandibular retrusion are associated with SDB in normal-weight patients but not in overweight patients. In previous studies, mandibular deficiency especially has been found to be a significant predictor of SDB [22,29]. Increased overjet [22,30], but rarely increased overbite [22], has been found to be related to SDB in normal-weight subjects, mostly in Asian study populations. Increased overjet is usually indicative of distal molar occlusion and mandibular deficiency, whereas increased overbite usually reflects a reduced intraoral intermaxillary space and a decreased lower anterior facial height, e.g. a small oral cavity.

Table III. Comparison of intraoral parameters (%) in overweight subjects (n = 77) and normal-weight subjects (n = 48) with SDB.

	Overweight subjects	Normal weight subjects	P^a
Palatal width			0.551
Normal	87.0	80.0	
Decreased	7.8	10.0	
Increased	5.2	10.0	
Molar occlusion			0.005
Normal	80.8	54.5	
Distal	17.8	45.5	
Mesial	1.4	0	
Cross bite	6.5	17.8	0.052

[a]According to chi-square statistics.

In the present report, the prevalence of occlusal anomalies in the overweight patients was comparable to that of a healthy Finnish population examined previously with the same clinical examination method [31]. In the overweight patients, the mean overjet and overbite were a mere 0.2–0.6 mm greater than in the healthy young adults; however, in normal-weight SDB patients, the mean overjet was 1.8 mm and the mean overbite 1.0 mm greater than those in the healthy population. Distal molar occlusion in the overweight subjects seemed to be as common as in the healthy adults (18% and 15%, respectively), but it was clearly more common in the normal-weight patients (46%). There was also a high prevalence of profile convexity and mandibular retrognathia among normal-weight SDB patients, as a convex profile is indicative of a distal molar relationship. However, the prevalence of cross bite in the normal-weight patients was about the same as that in the healthy adults (18% and 19%, respectively) whereas, in the overweight patients, cross bite seemed to be almost a rarity (6%). These results indicate that although differing from the normal-weight SDB patients, the occlusal features of the overweight SDB patients do not differ from those of the general adult population of Finland. Thus, it is reasonable to assume that the occlusal findings in normal-weight SDB patients in the present study may be the predisposing factor for SDB. Our findings support those of earlier studies that in overweight patients the causative factor for SDB is rarely a craniofacial abnormality, but instead a narrowing of the upper airway structure, alteration in function (such as collapsibility) [32], reduced chest-wall compliance, disturbances in the relationship between respiratory drive and load compensation [33], reductions in functional residual capacity, and hypoxemia [34] due to excessive fat tissue.

Decreased lower facial height [30] and brachycephaly [20,35], especially among Caucasians, are features which occur more frequently in the SDB population compared to controls. On the other hand, non-obese patients with severe OSA tend to have a long (increased) lower facial height typical of a dolicocephalic facial pattern [30,36]. In our study, normal-weight patients with mild SDB seemed to have decreased lower facial height more often than the overweight group, which is in line with previous findings on Caucasian non-obese patients with SDB. Since we did not evaluate patients with severe disease, these conclusions may not be directly generalizable to all SDB patients.

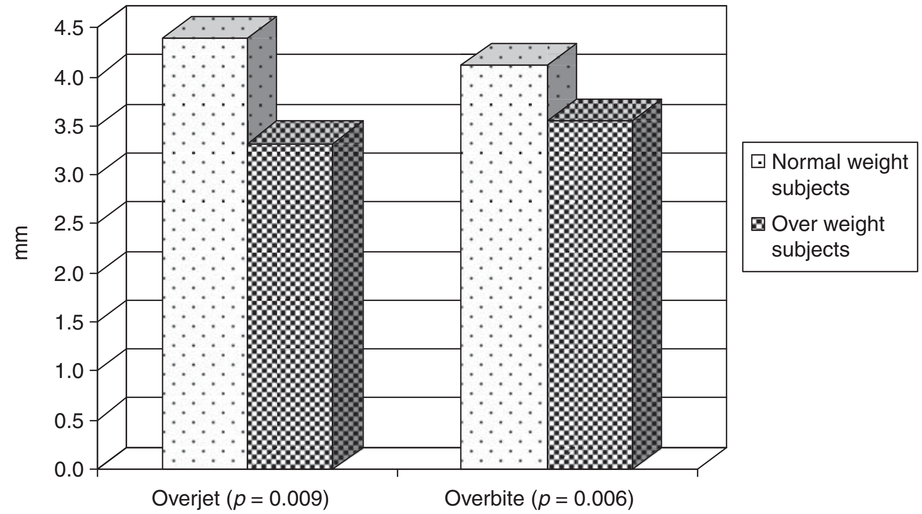

Figure 1. Distributions of mean overjet and overbite in normal-weight and overweight patients with mild SDB. *P*-values according to Student's *t*-test.

Tangugsorn et al. [17] stated in their study on obese and non-obese patients with severe OSA that, irrespective of BMI, the patients display aberrations of cervico-craniofacial and upper airway soft tissue morphology when compared with controls. Our results are parallel to those findings that morphological deviations are related to SDB among non-obese patients but not in obese patients, who instead displayed abnormalities in their upper airway soft tissue morphology, head posture, and position of the hyoid bone. However, this topic is still controversial. Rose et al. [37] concluded in their study on Caucasians that patients with normal body weight display no more SDB-associated morphological anomalies than obese patients. Also, in some other studies, no causal relationship between craniofacial morphology and SDB has been found [38,39]. In contrast to previous studies, we examined a homogeneous study population consisting of middle-aged patients with mild SDB. Therefore the results may not be directly generalizable to all SDB patients. One of the main findings of this study was that even less frequent nocturnal breathing abnormalities in normal-weight patients appear to have an association with occlusion and craniofacial morphology.

Table IV. Independent associations of the studied occlusal factors (overjet, overbite, palatal width, cross bite, and mandibular retrusion) with normal-weight subjects with SDB adjusted for age and gender using a backward stepwise logistic regression model. Only statistically significant variables are listed.

	Odds ratio	95% confidence interval	*P*
Overbite	1.28	1.01–1.63	0.044
Cross bite	4.06	1.04–15.88	0.044
Retrusive mandible	2.85	1.12–7.25	0.028

In a recent study [24], we have demonstrated that lifestyle intervention with early weight reduction is an effective and viable treatment option for OSA, and should be considered as a first-line treatment for all patients when linked with obesity. Mandibular advancement devices (MADs) have also been found to be beneficial in patients with mild-to-moderate OSA [40–42]. It is justifiable to assume that the observations of the present study that normal-weight patients with mild SDB have more frequently abnormal occlusal and craniofacial findings would present a favorable basis for a successful MAD treatment in this group of patients. Our results also suggest that these clinical evaluations may usefully be included in the clinical assessment of patients with a suspicion of OSA, particularly normal-weight patients. Considering the high prevalence of mild SDB, the fact that patients with even mild OSA assess the disease as being detrimental to their health and the natural progression of the OSA, if not treated, means that it is essential to focus on the early detection and treatment of SDB. Since the pathogenesis of the normal-weight SDB patients seems to differ from that of the overweight patients, an orthodontic treatment during growth whenever needed may play an important role in achieving these goals.

In order to understand the pathogenesis of SDB, it is essential to have an awareness of the location of the segments of upper airway narrowing. For public health purposes an early diagnosis is vital, and therefore there has been an interest in how to standardize a feasible craniofacial evaluation for OSA patients. It can be done with cephalometry and MRI, but new, less expensive, techniques are being developed, such as using a low-cost digital photograph with standardized analyses [43,44]. Many different techniques have been used to assess the anatomy of the upper airways; however, most of them are not commonly used or even feasible in routine practise [45]. One of the objectives of this study was to estimate the most convenient clinical methods to diagnose deviant craniofacial features and malocclusions in SDB patients. These methods should be viewed as straightforward and relevant clinical tools to estimate the risk of SDB, i.e. they can be quickly and easily performed, and may be implemented in primary care settings. The cephalometric measurements were not included in the original study protocol. Although cephalometric measurements are routinely used for patients undergoing an evaluation for a MAD, the search for reliable and feasible clinical measurements may be considered essential for screening in primary care settings, particularly since they are low cost, quick and non-invasive to use.

In general, obesity is the most prevalent risk factor for SDB. Nevertheless, one-third of OSA patients are of normal weight, and especially in this group of patients the abnormalities in craniofacial anatomy and occlusion should be kept in mind. If a patient suffers from symptoms that are typical of SDB, such as snoring, breathing pauses, and daytime sleepiness, it is fairly easy to conclude that one should perform the necessary questioning and examinations. However, most patients with even significant SDB remain undiagnosed due to mild symptoms [8]. Therefore, dentists have an important role in recognizing undiagnosed SDB patients and, in the case of malocclusions and/or deviant craniofacial features, patients should be asked about their sleeping habits.

Conclusions

The present study demonstrates that abnormalities in craniofacial morphology and occlusion may be important predisposing factors in normal-weight Caucasian patients with SDB, thus indicating different mechanisms of SDB pathogenesis compared with those in overweight patients.

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