



## **Do craniofacial abnormalities impair elite athlete's ventilatory performance during submaximal and maximal exercise?**

**Dr. Dieter Gebauer<sup>1\*</sup>, Professor Raymond Allan Williamson<sup>1</sup>, Associate Professor Karen Elizabeth Wallman<sup>2</sup>, Dr. Brian Dawson<sup>2</sup>**

<sup>1</sup>School of Dentistry / School of Medicine and Pharmacology, the University of Western Australia, 35 Stirling Hwy, Crawley, Western Australia 6009

<sup>2</sup>School of Sport Science, Exercise and Health, The University of Western Australia, 35 Stirling Hwy, Crawley, Western Australia 6009

\*Corresponding authors e-mail: [admin@specialistomfs.com](mailto:admin@specialistomfs.com)

### **Abstract**

**To determine if there is any difference in ventilatory performance in individuals with craniofacial cephalometric landmarks associated with obstructive sleep apnoea during sub-maximal and maximal exertion in elite athletes. Twenty-seven, male, team-sport athletes, underwent facial cephalometric assessment and were graded into Class 1 (N = 14), Class 2 (N = 10) or Class 3 (N = 3) facial skeletal profiles. Posterior airway space (PAS), soft palate length (PNS-P) and hyoid to mandibular plane length (MP-H) were also measured. Each athlete then completed a graded exercise test (GTX) to exhaustion on a treadmill. Minute ventilation (L·Min<sup>-1</sup>) was measured during the GTX at intensities that equated to 10km.h<sup>-1</sup>, 12km.hr<sup>-1</sup> and subjective maximal effort. A comparison of cephalometric landmarks and ventilation was made. No interpretable statistically significant results were found. There was no relationship between airway cephalometric parameters and ventilatory performance.**

**Keywords:** Airway, Cephalometrics, Orthognathic Landmarks, Respiration, Ventilation.

### **INTRODUCTION**

The craniofacial skeleton provides a framework for the oropharyngeal soft tissue to form the upper respiratory tract. Morphological craniofacial variables are recorded by cephalometric (anthropometric) measurements. (DeBerry-Borowiecki et al. 1988; Lyberg et al. 1989a; Tangugsorn et al. 2000). Four craniofacial variables have been chosen which have been associated with upper airway obstruction, as defined in obstructive sleep apnoea literature. (Baik et al. 2002; Hochban and Brandenburg 1994; Strelzow et al. 1988). It is unknown if cephalometric airway features associated with upper airway collapse at rest can influence ventilation during exercise states. Oral and maxillofacial surgeons prescribe jaw advancement procedures to treat upper airway obstruction and to improve ventilation. (Fairburn et al. 2007; Hochban et al. 1997; Pirklbauer et al. 2011). If a correlation did exist, elite athletes who demonstrate these cephalometric parameters may be prescribed treatment such as a surgical procedure used

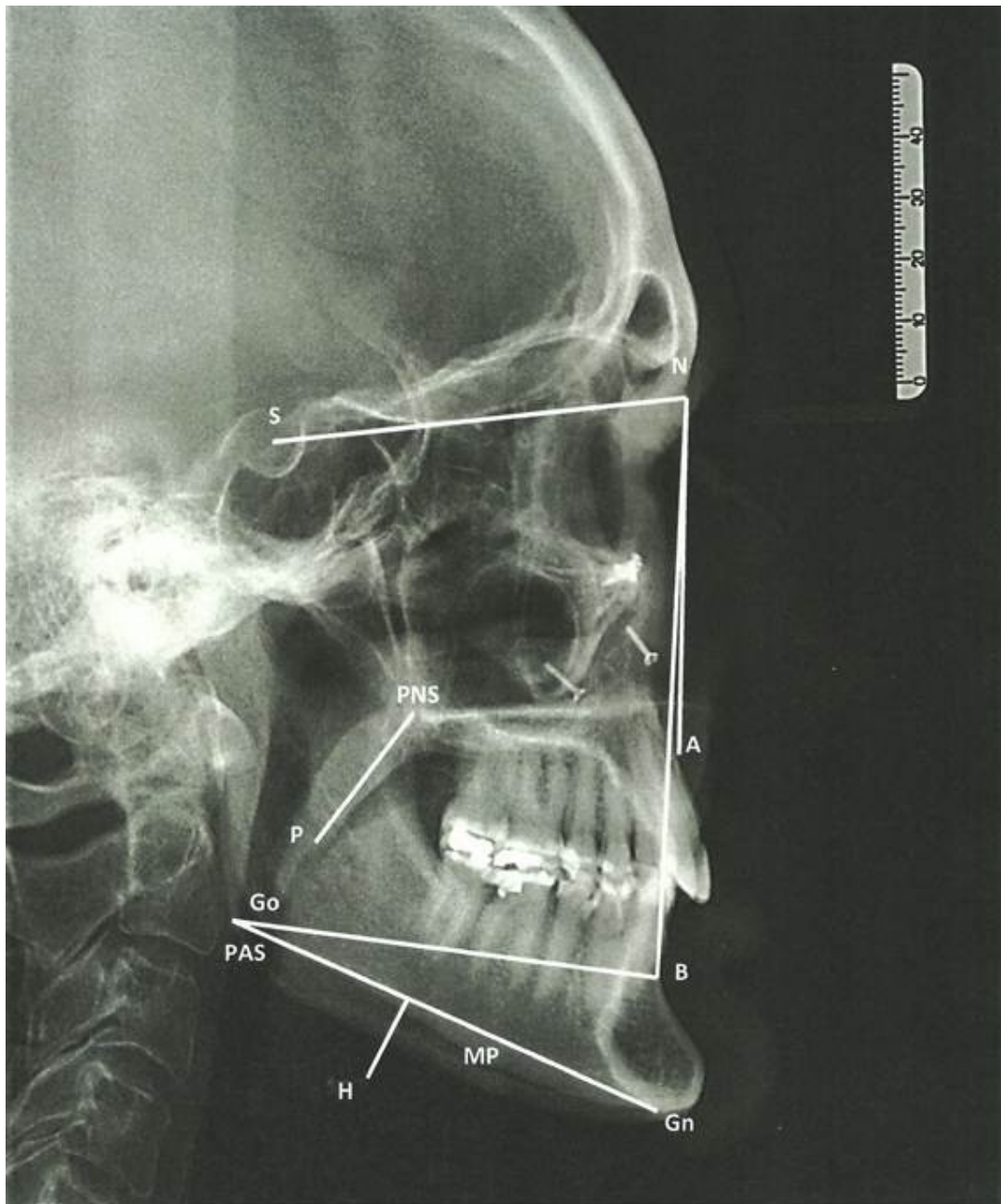
in obstructive sleep apnoea (OSA) to improve ventilation during exercise states.

### **MATERIALS AND METHODS**

Thirty-one elite male athletes who participated in team sports (hockey/ water polo) were recruited into this study. Four participants withdrew during the trials for reasons associated with injury leaving 27 participants (mean (SD): age - 23.5 y (3.8), body mass index - 24.6 kg·m<sup>-2</sup> (2.1), ht - 1.82 m (0.08), body-mass - 81.7 kg (8.6)). Following verbal and written explanation of the trial, all participants provided written informed consent. Individuals were excluded if they had any respiratory pathology (disclosed by a positive medical history of lung disease) or were smokers (defined as having a history of consumption of a tobacco product). No participants met these exclusion clauses.

**Table 1.** Cephalometric Measurements

Posterior Airway Space (PAS)	A line is drawn from B point to Gonion into the pharyngeal space. A measurement is made of the airway space length at this level.
Soft Palate Length (PNS-P)	Measurement of the length of the soft palate from the posterior nasal spine to the lowest point of the curvature of the soft palate.
Hyoid to Mandibular Plane Length (MP-H)	The Mandibular Plane is the line joining the menton and gonion. A measurement is made perpendicular from this plane to the highest point of the hyoid bone.
A-Na-B (ANB)	The difference between the angles S-N-A and S-N-B. It is a measure of the horizontal difference between maxillary and mandibular basal positions often termed the skeletal base relationship.



**Figure1.** Facial Skeletal Cephalometric Measurements

All participants attended the Oral Health Centre of Western Australia and completed a medical history questionnaire. They each had an end expiratory lateral cephalometric radiograph taken and standard airway landmarks were measured. (Cillo et al., 2012; Leighton and Drake 2004 and Lyberg et al., 1989b), (Method of Ricketts 1972, 1979).

The cephalometric measurements are listed in Table 1.

The cephalometric measurements are illustrated in Figure 1.

Facial profiles of the participants are classified into 3 skeletal relationships defining various jaw projections. Class 1 skeletal relationship is where the ANB angle is  $2 \pm 2$  degrees, and denotes a normal jaw projection. Class 2 skeletal relationship is where the ANB  $> 4$  degrees, where the lower jaw projection is reduced relative to the upper jaw. Class 3 skeletal relationship has an ANB angle of  $< 0$ , where the lower jaw is greater relatively to the upper jaw (Fig 1: Facial Skeletal Cephalometric Measurements).

Exercise testing was performed at the Exercise Physiology Laboratory in the School of Sport Science, Exercise and Health at UWA. Participants were instructed to prepare for the tests as if they were preparing for game day. Additionally, participants were asked not to perform vigorous exercise in the 24-h period prior to testing.

Each participant's height was measured using a stadiometer, while body mass was ascertained using Sauter scales (August Sauter GmbH D-7470 Albstadt 1 Ebingen, West Germany). A fifteen minute familiarisation session then took place. Minute Ventilation ( $\dot{V}_E$ : L·min<sup>-1</sup>) was measured during a graded exercise test (GXT) performed on the treadmill. The protocol consisted of the participant running for one minute at 9 km·h<sup>-1</sup>. This was followed by two plateau stages of 5 min each, with the speed of the treadmill progressively increasing following the plateau stages until volitional exhaustion was reached. The first plateau stage occurred at 10 km·h<sup>-1</sup>, while the second plateau stage occurred at 12 km·h<sup>-1</sup>. The two plateau stages were separated by a 1 min increment of 11 km·h<sup>-1</sup>. Participants wore a heart rate monitor (Polar, Finland) and breathed into a computerised gas analysis system (Meta 2000, UWA, Australia) through a face mask which covered their mouth and nose (Fig 2). This system consisted of a ventilometer (Morgan, Kent, United Kingdom) that measured the volume of inspired air and oxygen and carbon dioxide. Analysers (Ametek Applied Electrochemistry S-3A/1 and CD-3A, AEI Technologies, Pittsburgh, USA) measured the percentage of oxygen and carbon dioxide in expired air. The carbon dioxide analyser uses the principle of infrared absorption for measurement, while measurement by the oxygen analyser is based on the principle of high temperature zirconia crystal conductivity. The gas analysers were calibrated before each test using a beta (B) standard reference gas, while the ventilometer was calibrated using a one litre syringe, as per manufacturer specifications.

Simple and multiple linear regression analysis were made of the ventilatory parameters ( $\dot{V}_E$ : L·min<sup>-1</sup>) and the cephalometric measurements (Skeletal classification / PAS / PNS-P and MP - H). Statistical significance was set at  $P < 0.05$  for all analysis, and data were analysed using Stata Version 9 (StataCorp 2005, Statistical Software Release 9; Stata Corp LP, College Station Texas).

## RESULTS

Table 2. Mean, Standard Deviation and Range of Cephalometric Values with Comparison of our cohort of variables to previously published data.

Table 3. Posterior Airway Space (PAS), Soft Palate Length (PNS-P), Hyoid to Mandibular Plane when compared to Ventilation  $\dot{V}_E$  (L·Min<sup>-1</sup>). Significance was set at  $P < 0.05$ .

The cohort of individuals enrolled in the trial had similar demographics to previously published data. Age, height, body mass and BMI were all within the range expected of elite athletes. Posterior airway space (PAS) and MP-H had similar means and standard deviations. Soft palate length PNS-P has a similar mean but a reduced standard deviation with the range skewed towards the higher end of the spectrum.

Individual comparisons of isolated cephalometric parameters to individual ventilatory parameters failed to reveal any statistically significant results apart from significant result ( $P = 0.037$ ) recorded for Class 1 individuals exercising at moderate intensity (12 km·h<sup>-1</sup>).

## DISCUSSION

Craniofacial dysmorphology and abnormal cephalometric parameters have long been associated with abnormal airway patency. In those individuals that display reduced airway patency there is an increased likelihood of suffering from obstructive sleep apnoea. Of relevance, an occlusive airway, as demonstrated by craniofacial cephalometric assessment, may potentially affect an elite athlete's ventilation during exercise as it is known to do so in obstructive sleep apnoea patients during rest states. (Li et al. 2000; Li et al. 2002; Li et al. 1999). In the current study four main cephalometric parameters were chosen for analysis as these represent the most frequently referred to in the OSA literature and the ones used in our surgical department when prescribing surgical procedures to those patients suffering from OSA.

Surgical procedures improve these parameters by:

- Improving the projection of the facial skeleton on the cranial base.
- Reducing the length of the soft palate.
- Reducing the distance from the mandibular plane to hyoid bone.
- Increasing posterior airway space.

Importantly, surgical advancement of the facial skeleton, namely the maxilla and mandible, has been

**Table2.** Mean, Standard Deviation and Range of Cephalometric Values Comparison made with previously published data \* (Previously published data)

VARIABLE	AVERAGE	SD	RANGE
Posterior airway Space (PAS) (mm)	11.5 *(9.2)	3.1 *(2.7)	5-20 *(2-16)
Soft palate length (PNS-P) (mm)	39.2 *(36.3)	4.7 *(5.8)	30-48 *(11-49)
Hyoid perpendicular To mandibular plane (MP-H) (mm)	18.4 *(21.8)	6.3 *(6)	5-27 *(8-41)

**Table3.** Posterior Airway Space (PAS), Soft Palate Length (PNS-P),

Hyoid to Mandibular Plane Length (MP-H) and Skeletal Classification when compared to Ventilation  $\dot{V}_E$  (L·Min<sup>-1</sup>) (\* P<0.05 statistically significant).

	$\dot{V}_E$ Min (p value)	$\dot{V}_E$ Mod (p value)	$\dot{V}_E$ Max (p value)
Soft palate length	0.232	0.674	0.669
Posterior airway space	0.644	0.557	0.546
Hyoid perpendicular to mandibular plane	0.619	0.169	0.702
Skeletal classification			
Class 1 (n=14)	0.820	*0.037	0.604
Class 2 (n=10)	0.754	0.372	0.940

Class 3 (not done) n = 3

**Figure 2.** Face Mask Worn by Participant

shown to improve airway patency under resting conditions in OSA patients. (Costello and Posnick 2003; Fleisher and Krieger 2007; Li 2011). This is

achieved as the facial bony skeleton provides the framework for attachment of the oropharyngeal peri-airway soft tissues. Jaw advancement procedures



place these soft tissues under tension and provide improved airway patency by impairing the ability of the airway to collapse.

Consequently, the purpose of this study was to identify whether elite athletes demonstrating craniofacial dysmorphism consistent with a narrow airway were at risk of poor ventilatory performance during an incremental exercise test to maximal exertion. Importantly, if ventilation was found to be compromised in these individuals, subsequent jaw advancement procedures could potentially benefit this condition.

Results from this study failed to demonstrate statistical correlations between PAS, PNS-P, MP-H and skeletal classification when compared to ventilation assessed at various points during a graded exercise test, apart from one isolated parameter, being a correlation ( $p$  value of 0.037) between Class 1 skeletal classification and  $\dot{V}_E$  Mod. The authors are unable to explain this significant result and believe that it is due to the generation of many  $p$  values for comparison (15). It was expected that significant results would have occurred in the class 2 group with smaller mandibles, which are a known risk for OSA as the mandible provides the foundation for the peri-mandibular connective tissue which supports the airway.

When comparing our data with previously published data, the PNS – P results were not similar. (Cillo et al. 2012; Hochban and Brandenburg 1994). Our data showed an elongated soft palate length with a reduced standard deviation and a skewed distribution at a higher range. In order to avoid inter observer error in this trial, one radiographer performed all radiography, while another investigator recorded measurements from the lateral cephalometric radiographs. Differences between the current study and previously published data may be due to the cohort assessed, as only elite athletes were measured in this trial. These differences may also be due to measurement error, as soft tissue landmarks are more difficult to define on lateral cephalometric radiographs than hard tissue examples.

Furthermore, only three athletes with a Class 3 skeletal profile were recruited into the trial representing a limitation to this study. In order to optimally power a study of this nature due to the population expression of class 3 malocclusion, a multicentre trial would be required.

Airway cephalometric assessment and patency information has been obtained from obstructive sleep apnoea data. In the current study, minute ventilation was chosen as a primary outcome variable as it is most likely to be affected by surgical procedures to improve the patency of the upper respiratory tract and influence airflow due to the changing of upper airway diameter. Assessment of ventilation during exercise states by formal polysomnography as required in OSA literature would be difficult to measure and interpret especially with regards to electroencephalography, electrooculography and electromyography. Lateral radiographic cephalometric analysis was chosen as the preferred airway assessment tool in the current study

as it is a simple and cost effective method of assessment, which is already in common use in the dental office. Furthermore this form of assessment has been referenced in the obstructive sleep apnoea literature.

Regarding airway patency, there are a number of alternative ways airway patency can be measured apart from standard cephalometric assessment. (Baik et al. 2002; Fleisher and Krieger 2007; Tangugsorn et al. 2000). These include 3-D volumetric data of airways via cone beam computerised tomography, magnetic resonance imaging or low dose computer tomography, either supine or erect. (Baik et al. 2002; Fairburn et al. 2007). Direct nasendoscopy via fibre optic scope can also provide important dynamic information during respiration of airway behaviour. (Leighton and Drake 2004; Li 2011; Li et al., 2002). In the West Australian population, it is difficult to obtain MRI scanner access, with testing being extremely costly. Computer tomography scanning does offer 3-dimensional information, however a large radiation dose is absorbed in a young population and the assessment is performed supine which affects airway patency. (Baik et al. 2002; Costello and Posnick 2003). Furthermore, nasendoscopy is an invasive assessment, which is not popular with those participating and does not provide quantitative data for statistical assessment. (Li 2011; Li et al. 2002) Furthermore, at the time of the trial, low dose cone beam CT was not available for research purposes.

Future research should replicate this study in an elite athlete population known to have obstructive sleep apnoea. It would also be of interest to perform the same assessments on individuals who are having jaw advancement procedures prior to and 6 months after this procedure. Jaw advancement procedures do improve airway patency, but it is still unclear if this is accompanied with an improvement in minute ventilation. Additionally, improved minute ventilation may not necessarily result in improved exercise performance. Specifically, at peak exercise capacity, air movement in and out of the thoracic inlet via the upper respiratory tract may not be at a maximal level and therefore not relevant to improved athletic performance. Nonetheless, information on these parameters is of interest to populations where improved ventilation is of importance.

Research Ethics Approval for this study was sought and granted on the 18<sup>th</sup> Feb 2008 by The University of Western Australia Research Ethics Committee, Research Services 35 Stirling Highway Crawley WA 6009 Perth West Australia – Project Number RA/4/1/1986.

## CONCLUSION

No statistically significant relationship exists between cephalometric landmarks and ventilatory performance in elite athletes. There is no reason to screen elite athlete's airways via cephalometric analysis and

recommend treatment on the grounds that it will improve ventilation.

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## REFERENCES

- Baik UB, Suzuki M, Ikeda K, Sugawara J, Mitani H (2002). Relationship between cephalometric characteristics and obstructive sites in the obstructive sleep apnea syndrome. *Angle Orthod.* 72:124-133.
- Cillo JE, Thayer S, Dasheiff RM, Finn R (2012). Relations between obstructive sleep apnea syndrome and specific cephalometric measurements, body mass index, and apnea-hypopnea index. *J Oral Maxil Surg.* 70:e278-e283.
- Costello BJ, Posnick JC (2003). The role of maxillofacial osteotomies in the treatment of obstructive sleep apnea. *Curr Opin Otolaryngol Head Neck Surg.* 11:267-274.
- DeBerry-Borowiecki B, Kukwa A, Blanks RHI (1988). Cephalometric analysis for diagnosis and treatment of obstructive sleep apnea. *Laryngoscope.* 98:226-234.
- Fairburn SC, Waite PD, Vilos G, Harding SM, Bernreuter W, Cure J, Cherala S (2007). Three-dimensional changes in upper airways of patients with obstructive sleep apnea following maxillomandibular advancement. *J Oral Maxil Surg.* 65:6-12.
- Fleisher KE, Krieger AC (2007). Current trends in the treatment of obstructive sleep apnea. *J Oral Maxil Surg.* 65:2056-2068.
- Hochban W, Brandenburg U (1994). Morphology of the viscerocranium in obstructive sleep apnoea syndrome - cephalometric evaluation of 400 patients. *J Cranio Maxill Surg.* 22:205-213.
- Hochban W, Conradt R, Brandenburg U, Heitmann J, Peter PJH (1997). Surgical maxillofacial treatment of obstructive sleep apnea. *Plast Reconstr Surg.* 99:619-626.
- Leighton S, Drake AF (2004). Airway considerations in craniofacial patients. *Oral Maxillofac Surg Clin North Am.* 55:555-566.
- Li KK (2011). Maxillomandibular advancement for obstructive sleep apnea. *J Oral Maxil Surg.* 69:687-694.
- Li KK, Riley RW, Powell NB, Guilleminault C (2000). Maxillomandibular advancement for persistent obstructive sleep apnea after phase I surgery in patients without maxillomandibular deficiency. *Laryngoscope.* 110:1684-1688.
- Li KK, Guilleminault C, Riley RW, Powell NB (2002). Obstructive sleep apnea and maxillomandibular advancement: An assessment of airway changes using radiographic and nasopharyngoscopic examinations. *J Oral Maxil Surg.* 60(5); 526-530.
- Li KK, Riley RW, Powell NB, Troell R, Guilleminault C (1999). Overview of phase II surgery for obstructive sleep apnea syndrome. *Ear, Nose Throat J.* 78:851-857.
- Lyberg T, Krogstad O, Djupesland G (1989a). Cephalometric analysis in patients with obstructive sleep apnoea syndrome: I Skeletal morphology. *J Laryngol Otol.* 103:287-292.
- Lyberg T, Krogstad O, Djupesland G (1989b). Cephalometric analysis in patients with obstructive sleep apnoea syndrome: II Soft tissue morphology. *J Laryngol Otol.* 103:293-297.
- Pirklbauer K, Russmeuller G, Stiebellehner L, Nell C, Sinko K, Millesi G, Klug C (2011). Maxillomandibular advancement for treatment of obstructive sleep apnea syndrome: A systemic review. *J Oral Maxil Surg.* 69:e165-e176.
- Strelzow VV, Blanks RHI, Basile A, Strelzow AE (1988). Cephalometric airway analysis in obstructive sleep apnea syndrome. *Laryngoscope.* 1149-1158.
- Tangugsorn V, Krogstad O, Espeland L, Lyberg T (2000). Obstructive sleep apnoea: multiple comparisons of cephalometric variables of obese and non-obese patients. *J Cranio-Maxill Surg.* 28:204-212.

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