THE EFFECT OF MOUTHGUARD DESIGN ON RESPIRATORY FUNCTION IN ATHLETES.

AND

CAN CEPHALOMETRIC AIRWAY ANALYSIS PREDICT VENTILATORY FUNCTION IN ELITE ATHLETES?

This thesis is presented for the degree of Masters of Clinical Research at the University of Western Australia

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Mr Peter Herring prosthetist from ERKODENT who donated the blank mouthguard templates that were used to fabricate the mouthguards used in the trial.
Statement of Originality

This thesis describes original research conducted by the author at the School of Dentistry and School of Sport Science, Exercise and Health at the University of Western Australia from Nov 2007- Dec 2013.

The author, under the guidance and assistance of Professor Raymond Williamson and Associate Professor Karen Wallman is responsible for the research concept and design. Participant recruitment, data collection, and data analysis were carried out by the candidate, as well as the implementation of the experiments.

The candidate drafted the thesis, and the papers which have been accepted and/or are currently being considered for publication, with assistance in writing and submission processes by both Professor Raymond Williamson and Associate Professor Karen Wallman. Feedback on the thesis was provided by Professor Raymond Williamson and Associate Professor Karen Wallman.

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Signature:

Associate Professor Raymond Williamson

Signature:

Associate Professor Karen Wallman (Supervisor)
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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANB</td>
<td>A point-Nasion-B point</td>
</tr>
<tr>
<td>ECG</td>
<td>electrocardiography</td>
</tr>
<tr>
<td>EEG</td>
<td>electroencephalography</td>
</tr>
<tr>
<td>EMG</td>
<td>electromyography</td>
</tr>
<tr>
<td>EOG</td>
<td>electrooculography</td>
</tr>
<tr>
<td>Gn</td>
<td>Gnathion</td>
</tr>
<tr>
<td>Go</td>
<td>Gonion</td>
</tr>
<tr>
<td>GTX</td>
<td>graded exercise test</td>
</tr>
<tr>
<td>MP-H</td>
<td>hyoid to mandibular plane length</td>
</tr>
<tr>
<td>Na</td>
<td>nasion</td>
</tr>
<tr>
<td>NPD</td>
<td>normal palatal design</td>
</tr>
<tr>
<td>NM</td>
<td>no mouthguard</td>
</tr>
<tr>
<td>OSA</td>
<td>obstructive sleep apnoea</td>
</tr>
<tr>
<td>PAS</td>
<td>posterior airway space</td>
</tr>
<tr>
<td>PFD</td>
<td>palatal free design</td>
</tr>
<tr>
<td>PNS-P</td>
<td>soft palate length</td>
</tr>
<tr>
<td>PNS</td>
<td>posterior nasal spine</td>
</tr>
<tr>
<td>(\dot{V}_e)</td>
<td>ventilation</td>
</tr>
<tr>
<td>(\dot{V}_{O_2})</td>
<td>oxygen uptake</td>
</tr>
<tr>
<td>(\dot{V}_{O_2\text{peak}})</td>
<td>maximal effort</td>
</tr>
</tbody>
</table>
CHAPTER ONE

Introduction
The author of this thesis has previously been an Australian Institute of Sport Scholarship holder in the sport of water polo and had played this sport on a regular basis over many years. During this time, many weekends were spent repairing craniofacial trauma injuries sustained by both friends and elite athletes that could have been prevented if the athlete had worn a mouthguard. Surprisingly, some of these athletes had the means to wear a mouthguard but made a deliberate decision not to wear one, citing perceived respiratory difficulties as the reason. Notably, the author had difficulty in comprehending this as he had never encountered such difficulty.

The craniofacial skeleton provides a framework for the upper respiratory tract. New and emerging scientific evidence has demonstrated the beneficial effect of jaw advancement procedures on the patency of the upper airway. If airway features associated with upper airway collapse in obstructive sleep apnoea (OSA) are shown to influence ventilation in elite athletes during exercise states, jaw advancement procedures may benefit the performance of susceptible athletes.

Therefore, the aim of study one was to determine whether a custom made mouthguard of a particular design had an effect on ventilation and/or the work of breathing during exercise when compared to wearing no mouthguard. Furthermore, the aim of study two was to determine if there was a correlation with poor ventilatory performance and an OSA susceptible upper respiratory tract during moderate and maximal exercise states.

Elite athletes are role models to others within their sport, and the use of protective equipment, in particular, the wearing of mouthguards, is very important. Many athletes choose not to wear a mouthguard because they believe that it interferes with their ventilation and hence their exercise performance. Consequently, it is important to determine whether mouthguards actually do
occlude the upper respiratory tract because if it can be established that mouthguards do not impair ventilation, then hopefully this will encourage elite athletes to wear mouthguards. This should also influence this behaviour at an amateur level. As a medical practitioner, the practice of preventative health should always be a consideration where possible. Preventable dento-alveolar and facial trauma is over represented in emergency departments and a reduction in admissions can reduce hospital workload. Conversely, if improvement in an elite athlete’s performance can be achieved by the performance of a surgical procedure that assists the occlusive airway, surgeons can assist that athlete in reaching their full potential and consequently enhance their earning capacity if they are in the professional arena. They will also have additional health benefits of the individual being less susceptible to the effects of OSA later in life if weight gain occurs.
CHAPTER TWO

Study One
The effect of mouth guard design on respiratory function in athletes.

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The Clinical Journal of Sports Medicine

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Presented here in the Journal submission format
Abstract

Objective: To test the hypothesis that two types of custom made mouthguards will have no effect on ventilation ($\dot{V}_E$: L·min\(^{-1}\)), oxygen uptake ($\dot{V}O_2$: mL·kg\(^{-1}\)·min\(^{-1}\)) and heart rate (HR beats per min) at varying exercise intensities (10 km·h\(^{-1}\), 12 km·h\(^{-1}\) and at subjective maximal effort: $\dot{V}O_2$peak) in male field hockey and water polo players.

Design: A randomised, prospective crossover study.

Setting: The Physiology Testing Laboratory, School of Sports Science, Exercise and Health at the University of Western Australia, a tertiary educational institution.

Participants: Twenty-seven male, team-sport athletes.

Interventions: Each athlete participated in three experimental exercise sessions separated by one week intervals. Testing involved a graded exercise test (GXT) performed on a treadmill wearing either a custom laminated mouthguard with normal palatal surface (NPD), a custom laminated mouthguard with palatal coverage up to the gingival margin (PFD), or no mouthguard (NM). The experimental trials were performed in a random, counterbalanced order.

Main Outcome Measurements: $\dot{V}_E$ (L·min\(^{-1}\)) and $\dot{V}O_2$ (mL·kg\(^{-1}\)·min\(^{-1}\)) were measured during the GXT at intensities that equated to 10 km·h\(^{-1}\), 12 km·h\(^{-1}\) and subjective maximal effort ($\dot{V}O_2$peak).

Results: There were no significant differences between trials for $\dot{V}_E$ (L·min\(^{-1}\)) and $\dot{V}O_2$ (mL·kg\(^{-1}\)·min\(^{-1}\)) at any of the intensities assessed (p < 0.05).
Conclusions: The wearing of two different custom made mouthguards during a GXT did not impair $V_e$ or $V_O_2$ during varying levels of exercise intensity in team sport athletes.

Key words: Mouthguard; Ventilation; Oxygen Uptake; Respiration; Athlete.

Introduction

Many contact sports risk either deliberate or accidental contact to the head and neck region.\(^1\) Occasionally, contact to the head of an athlete results in injury ranging from a closed head injury such as concussion, dento-alveolar injury, facial lacerations or fracture of the facial skeleton. Mouth guards provide protection from concussion, dento-alveolar injury, and fractures of the facial skeleton.\(^2\)\(^-\)\(^8\) The protective capability of a mouthguard stems from its ability to distribute and dissipate a point of impact force over a larger area.\(^9\)\(^-\)\(^14\) The severity of peri-oral lacerations may be reduced by the use of a custom fabricated mouthguard.

Currently there are three main types of mouthguard available to provide protection to athletes.\(^4\),\(^9\),\(^10\),\(^15\),\(^16\). These include a stock mouthguard, a boil and bite type, or a professionally fitted custom made mouthguard. The professionally fitted mouthguard is considered the gold standard as it has the greatest area of surface contact between the protective surface and the dentition, hence the best ability to distribute forces.\(^4\),\(^10\),\(^12\),\(^13\)

Many presentations of facial and dento-alveolar trauma resulting from sporting activity could have been prevented or minimised by the use of appropriately fitted mouthguards.\(^2\),\(^17\)-\(^20\). Unfortunately many professional sports administrators do not mandate the use of a protective mouthguard, and many elite athletes refrain from wearing mouth guards during contact sports because they have an
underlying belief that mouthguards reduce ventilation and oxygen uptake and therefore negatively impact upon their exercise performance. A study performed by Sports Medicine Australia\textsuperscript{21} on sport injury in Western Australia during the 1997 and 1998 sporting seasons, reported that only 34\% of Australian rules football players wore mouthguards. These percentages were even lower in hockey (23\%), basketball (~6\%) and netball players (~2\%). This is a major concern when considering both the physical and emotional cost of oro-facial injury.\textsuperscript{21}

Therefore, the aim of this study was to assess the effects of mouthguards on ventilation ($\dot{V}_e$ L·min$^{-1}$) and oxygen uptake ($\dot{V}O_2$ mL·kg$^{-1}$·min$^{-1}$) during an incremental exercise test to exhaustion. Two different types of custom made mouthguards, normal palatal design (NPD) and palate free design (PFD) were compared to a control condition where no mouthguard (NM) was worn.

It was hypothesised that use of a custom made mouth guard (either NPD or PFD design) would have no effect on $\dot{V}_e$ (L·min$^{-1}$) or $\dot{V}O_2$ (mL·kg$^{-1}$·min$^{-1}$) during exercise performed at 10 km·h$^{-1}$, 12 km·h$^{-1}$ or at subjective maximal effort, when compared to a control (no mouth guard) trial.

**Methods**

Prior to recruitment of participants, a power analysis was performed on $\dot{V}O_2$ data obtained from the Australian Institute of Sport. This analysis demonstrated that 30 participants (paired comparison) were required in order to detect an equivalent measurement of +/- 2\% difference in $\dot{V}O_{2\text{max}}$ to $\alpha=0.01$ with a power of 95\%. 

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Thirty-one males who participated in team sports (hockey or water polo) either at first division, state level or national level were recruited into the study. Four participants withdrew during the trials for reasons associated with injury (4) leaving 27 subjects (mean (SD): age - 23.5 yr (3.8), body mass index - 24.6 kg·m⁻² (2.1), ht – 1.82 m (0.08), body-mass – 81.7 kg (8.6)). Participants were informed of the study requirements, benefits and risks before giving written informed consent. The Research Ethics Committee of the University of Western Australia (UWA) granted approval for the study’s procedures. Participants were excluded if they had any respiratory pathology (defined by disclosure by the participant of any lifetime medical history of lung disease), were anaemic (defined by having a haemoglobin level of less than 135 g·L⁻¹), were smokers (defined as having a history of consumption of a tobacco product), wore a removable dental appliance, or had fixed orthodontic appliances.

**Experimental Overview**

Prior to participating in the experimental trials, all participants attended the Oral Health Centre of Western Australia’s (OHCWA) oral surgery clinic where they completed a questionnaire that provided information about their mouthguard attitudes and utilization, as well of any history of facial trauma. During this session, two alginate dental impressions were made of the maxillary teeth (Kromopan 100 – Lascod Firenze Italy). Plaster casts of the impressions were made on the same day using yellow stone (Ainsworth Buffstone Sydney Australia) and were trimmed to standard specifications.
The two mouth guard designs are illustrated below in Figure 1.

Figure 1: Full Palate and Palate Free Mouth Guard Design

Each mouthguard was extended to cover the first maxillary molar, was 4 mm thick and fabricated using a laminated vacuum technique.

The NPD mouthguard was made with the palatal margin extending approximately 4 mm past the gingival margin. The PFD mouthguard only extended to the free gingival margin of the palate.

One plaster cast was used to make the NPD and the other for PFD. The mouthguards were a laminated design using 2 mm thickness layered plastic sheeting to obtain a 4 mm even thickness using a vacuum machine. (Erkoflex - Erkodent Pfalzgrafenweiler Germany). The volume of each mouthguard was then measured by a displacement technique. The volume of the water displaced was measured and recorded (Sartorius GMBH, Model E1200 Goltingen Germany).
Finally, each participant had a 4 mL sample of blood taken and analysed for haemoglobin in a Beckman Coulter LH750 haematology analyser (California USA) in order to screen for anaemia.

Exercise testing was performed at the Exercise Physiology Laboratory in the School of Sport Science, Exercise and Health at UWA. Participants participated in three experimental trials that were undertaken in a randomised, counter-balanced order and performed at the same time of day, approximately one week apart. Use of a counter-balanced design ensured that participants were evenly distributed across the three experimental trials in order to avoid a learning effect associated with one particular trial. The three trials consisted of exercise with no mouthguard (NM), exercise wearing a custom laminated mouthguard with normal palatal surface (NPD), or exercise wearing a custom laminated mouthguard with palatal coverage up to the gingival margin (PFD). Participants were required to maintain their normal diet and training throughout the study, and were required to fast (other than water) during the 2-h period prior to testing. Additionally, participants were asked not to perform vigorous exercise in the 24-h period prior to testing.

During the first session, prior to the exercise test, 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 where the athletes were required to warm-up on the treadmill as if they were preparing for a team game. During this warm-up session, participants wore a heart rate monitor (Polar, Finland) and breathed into a computerised gas analysis system (Meta 2000, UWA, Australia) through a face mask that covered their mouth and nose (Figure 2).
Figure 2: Face Mask Design

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 infra-red 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 (β) standard reference gas, while the ventilometer was calibrated using a one litre syringe, as per manufacturer specifications. After this familiarisation session $V_{E}$ (L·min$^{-1}$), $\dot{V}_{O_2}$ (mL·kg$^{-1}$·min$^{-1}$) and HR (beats per min: bpm) were measured during a GXT
performed on the treadmill. The protocol consisted of the participant running for one minute at 9 km·h⁻¹. This was followed by two plateau stages of 5 min each, with the speed of the treadmill progressively increased following the plateau stages until volitional exhaustion was reached. The first plateau stage occurred at 10 km·h⁻¹, while the second plateau stage occurred at 12 km·h⁻¹. (Figure 3)

![Figure 3: Athlete on Testing Equipment](image)

The two plateau stages were separated by a 1 min increment of 11 km·h⁻¹. The last minute of testing during which volitional exhaustion occurred was considered to represent \( \text{VO}_{2\text{peak}} \).
Upon completion of each exercise test the participants were asked to rate the mouthguard with a score out of ten on a visual analogue scale, with 10 representing the most comfortable score. Participants were also asked to rate their current mouthguard if they wore one prior to the trial. The ratings were compared to detect if there was a preferred mouthguard design.

**Statistical Analysis**

A repeated measure ANOVA was used to analyse HR, $\dot{V}E$, $\dot{V}O_2$ recorded during the two plateau periods of the GXT, as well as $\dot{V}O_{2max}$. Where appropriate, post hoc comparisons were also used. Statistical significance was set at $p<0.05$ for all analyses and data was analysed using Stata Version 9. (StataCorp 2005. Statistical Software Release 9. College Station TX: Stata Corp LP.) Student t tests were used to determine if there were any significant differences between the ratings and volumes of mouthguards NPD and PFD.

**Results**

The physical characteristics and general demographics of the participant population are included in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.82</td>
<td>0.08</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>81.7</td>
<td>8.6</td>
</tr>
<tr>
<td>Haemoglobin (gL$^{-1}$)</td>
<td>150</td>
<td>6.8</td>
</tr>
<tr>
<td>Body Mass Index (kg.m$^{-2}$)</td>
<td>24.6</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Eight water polo players and nineteen hockey players participated in this trial.
Table 2 shows the weight and ratings of the NPD when comparing the PFD mouthguard with the current pre-existing mouthguard (if applicable).

**Table 2. Mouthguard Comparison of Normal Palatal Design Mouthguard (NPD) vs Palate Free Design (PFD), (n= 27)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouthguard Score (Non Experimental)</td>
<td>7.29</td>
<td>6.45 : 8.14</td>
</tr>
<tr>
<td>NPD Score</td>
<td>6.71</td>
<td>6.08 : 7.34</td>
</tr>
<tr>
<td>PFD Score</td>
<td>8.21</td>
<td>7.64 : 8.78</td>
</tr>
<tr>
<td>NPD Weight (g)</td>
<td>11.52</td>
<td>10.97 : 12.06</td>
</tr>
<tr>
<td>PFD Weight (g)</td>
<td>9.47</td>
<td>8.92 : 10.01</td>
</tr>
</tbody>
</table>

**NPD Score vs PFD Score (p<0.001*)

**NPD Weight vs PFD Weight (p<0.0001*)

- Indicates a significant difference (p = 0.05) in score based results analysed with a student t test.

There were significant differences between the rating of NPD and PFD (p<0.001). The PFD type was preferred over the NPD by the athletes. Further, the weight of NPD when compared to mouthguard PFD was significantly less (p<0.0001).

No significant differences were found when comparing NM, PFD and NPD between the trials for $\dot{V}_E$ (L·min⁻¹; p10 km·h⁻¹ – 0.50, p12 km·h⁻¹ – 0.47, p_peak – 0.50), HR (bpm: p10 km·h⁻¹ - 0.76, p12 km·h⁻¹ - 0.55 p_peak - 0.59) or $\dot{V}O_2$ (mL·kg⁻¹·min⁻¹: p10 km·h⁻¹ – 0.14 p12 km·h⁻¹ - 0.44 p_peak - 0.80) at 10 km·h⁻¹, 12 km·h⁻¹ or at subjective maximal intensity (i.e., $\dot{V}O_2$peak). Results are illustrated in Table 3.
Table 3. Minute Ventilation ($\dot{V}_E$), Oxygen Uptake ($\dot{V}_{O_2}$) and Heart Rate (HR) Whilst Exercising at 10 km·h$^{-1}$, 12 km·h$^{-1}$ and Maximal Intensity Levels of Exercise, Wearing No Mouthguard (NM), Regular Palate Design Mouthguard (NPD) and Palate Free Design (PFD). (n = 27)

<table>
<thead>
<tr>
<th>Velocity (km·h$^{-1}$)</th>
<th>NM</th>
<th>NPD</th>
<th>PFD</th>
<th>(p Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>$\dot{V}_E$ (L·min$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 km·h$^{-1}$</td>
<td>63.08</td>
<td>10.24</td>
<td>64.45</td>
<td>9.93</td>
</tr>
<tr>
<td>12 km·h$^{-1}$</td>
<td>83.33</td>
<td>14.37</td>
<td>84.28</td>
<td>14.12</td>
</tr>
<tr>
<td>Max intensity</td>
<td>124.19</td>
<td>15.62</td>
<td>122.51</td>
<td>18.80</td>
</tr>
<tr>
<td>$\dot{V}_{O_2}$ (mL·kg$^{-1}$·min$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 km·h$^{-1}$</td>
<td>36.89</td>
<td>2.88</td>
<td>37.69</td>
<td>2.20</td>
</tr>
<tr>
<td>12 km·h$^{-1}$</td>
<td>45.88</td>
<td>3.77</td>
<td>47.58</td>
<td>6.45</td>
</tr>
<tr>
<td>Max intensity</td>
<td>56.09</td>
<td>4.82</td>
<td>57.22</td>
<td>6.14</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 km·h$^{-1}$</td>
<td>156.70</td>
<td>11.50</td>
<td>156.00</td>
<td>11.80</td>
</tr>
<tr>
<td>12 km·h$^{-1}$</td>
<td>174.11</td>
<td>10.84</td>
<td>174.14</td>
<td>9.65</td>
</tr>
<tr>
<td>Max intensity</td>
<td>191.37</td>
<td>8.04</td>
<td>190.81</td>
<td>9.31</td>
</tr>
</tbody>
</table>

The power calculation performed prior to the trial commencement recommended a minimum of 30 participants. As four participant’s data were not available for data assessment for reasons described above, a post-hoc power calculation was performed to evaluate if the study was powered to acceptable...
standards. These calculations revealed that the group sample size of 27 resulted in a 97% power to detect a difference of +/- 3% in $\dot{V}O_{2peak}$, with the $\alpha$ level being 0.05, which is within an acceptable range for power calculation.

Discussion

This study found no significant differences between respiratory function, oxygen uptake and heart rate results between the NM, NPD and PFD mouthguards trials during exercise of varying intensities. Although not significant, the NM condition resulted in the lowest $\dot{V}O_{2peak}$ values compared to the two other trials (2% and 1.2 % lower than the RPD and the PFD trials, respectively). Anecdotal complaints by athletes that mouthguards “affect breathing” should not be used as a valid excuse to refrain from wearing one.

To date, only eight published papers known to the authors have explored the relationship between respiratory function, oxygen uptake and mouthguard use$^{22-29}$. These studies resulted in equivocal outcomes which most likely relate to the use of varying study designs, methodology and cohort size.

Of previous study designs, only studies by Delaney et al.$^{24}$, Bourdin et al.$^{23}$ and Francis et al.$^{25}$ randomised the testing protocols to minimise the effect of familiarisation bias in the data$^{23-25}$. No previously published study had performed a power analyses in order to determine the number of participants required to obtain statistically significant data.

Further, comparison of previous studies demonstrated a large amount of variability in testing protocols, and only four examined the effect of custom mouthguards, which are considered the gold standard in protective oro-facial care$^{22, 23, 26, 29}$. Also, previous studies have used mouthpieces instead of full face
masks during the GXT, to measure ventilatory and oxygen uptake parameters. A mouthpiece would eliminate the effect of the dentition and lip musculature on airflow dynamics\textsuperscript{22, 24, 28} and significantly affect the results. Finally, the current study is the only study known to the authors that assessed respiratory function and oxygen uptake at various exercise intensities (i.e. 10 km·h\textsuperscript{-1}, 12 km·h\textsuperscript{-1} or at subjective maximal effort; i.e., $\dot{V}O_{2\text{peak}}$).

A limitation to this study was that each mouthguard was fabricated from a different impression and that subtle differences between the two mouthguards may have been normalised by the use of non-identical casts. In addition, testing undertaken in laboratory conditions does not emulate field conditions during competition. However analyses of respiratory, oxygen uptake and heart rate data at varying exercise intensities represents a strength of this study.

Women were excluded from this trial as the primary target group primarily because males are over represented in hospital emergency departments being admitted with injuries sustained when not wearing protective equipment during sporting games\textsuperscript{21}. Possibly this can be speculated to be due to contact sport being generally male dominant, combined with macho tendencies for not wanting to wear protective equipment. Additionally, males are on average, heavier and more capable of transmitting greater force during collisions. However, as respiratory physiology trends in women are similar to males, these conclusions may also be applicable to women. Formal testing would be required to test this conjecture.

Non custom fit mouthguards such as boil and bite type have similar thickness to the laminates used to fabricate custom made mouthguards. The amount of contact between the mouthguards, teeth and gums is less and therefore the total
volume of the mouthguard is greater causing a reduction in airway patency. We speculate that this will cause a reduction of ventilatory function.

Additionally the fit of non-custom mouthguards is usually performed at home by non-professionals. The extension of the periphery of the mouthguard can be incorrectly trimmed, compromising its protective capability. If the periphery of a mouthguard is overextended it can unnecessarily encroach on the airway space.

The participants enrolled in this trial rated the PFD mouthguard significantly higher to the NPD type. This design is more popular and likely to be worn without compromising its protective capability\(^ {30-32} \), and the researchers recommend fabricating this design to encourage utilisation in elite athletes who complain about mouthguards interfering with exercise performance.

Two members of our research team are experienced with dealing in facial and dentoalveolar trauma and reconstruction of lost dentition. This type of preventable facial and dentoalveolar injury is still overrepresented in tertiary hospitals in Western Australia\(^ {21} \). Therefore, the results of this study have the potential to benefit a significant number of sports participants in the professional and amateur arena if governing bodies mandate the use of a mouthguard.

These findings could help professional sports health bodies and dental association’s lobby health insurers to subsidise mouthguards so that cost would not be a factor in preventing access to professionally fitted mouthguards. As respiratory performance is not affected by the wearing of a mouthguard, it could be proposed that injuries sustained as the result of not wearing a mouthguard should not be covered by the insurer or sporting body.

As a result of this study’s outcome, the researchers recommend that sporting bodies mandate the use of mouthguards during professional sporting activities
that are classified as contact sports. This should encourage and motivate the
general population, particularly children, who view elite athletes as role models,
to change their behaviour and to routinely use mouthguards. Consequently, this
would reduce the general incidence of dento-alveolar trauma, facial fracture and
concussion rates that result in visits to emergency departments.

Conclusion

This study demonstrated that use of a regular palate design (NPD) or a palate
free mouthguard (PFD) mouthguard by male team sport athletes had no negative
impact on $\dot{V}_E$, $\dot{V}_O_2$ or HR during exercise of varying intensities compared to a no
mouthguard trial. This has important implications for athletes in encouraging
behaviour that will reduce the incidence of dento-alveolar trauma, concussion
and jaw fracture.
References


CHAPTER THREE

Linking Statements
The recurrent theme of this thesis is one of upper respiratory tract patency. Occlusion due to anatomical or introduced means may have a detrimental effect on an elite athlete’s performance. Study one demonstrated that introduced occlusion due to the wearing of a mouthguard had no effect on ventilation during a graded exercise test compared with not wearing a mouthguard. Furthermore, any improvement in ventilatory capacity in an elite athlete engaged in sport may have a significant affect in the athletes’ sensation of air hunger and fatigability.

Many trials have focused on ventilatory capacity during rest as part of obstructive sleep apnoea research. Airway patency and its effect on ventilatory capacity during exercise states, with a particular slant on orthognathic cephalometrics has not been previously reported in the literature and is being introduced as a new academic concept in this trial. The principals of orthognathic surgical examination and workup include three important parameters, known as FAB - the facial balance, the airway and the bite. Historically, emphasis has been placed on the bite and facial aesthetic parameters. However with the advent of new findings demonstrating the benefit of airway advancement procedures on obstructive sleep apnoea patients, the airway has become an important consideration. In a non-elite athlete population seeking advice for their dento-facial deformity, many patients present in their teens to early twenty’s for treatment, and considerations are made regarding their life long risks of airway patency. Weight gain and associated metabolic syndrome is increasing in prevalence in western society and those with a dento-facial deformity are placed at additional risk of developing obstructive sleep apnoea. This time of life represents a unique preventative health opportunity to improve the airway and consequently avoid years of detrimental health effects of obstructive sleep apnoea, medication and ventilatory support treatments prior to being offered a surgical procedure which is considered by many respiratory physicians to be a last resort option. In many
instances the underlying dento-facial deformity is a main contributing factor. Similar logic can be applied to an elite athlete, many of whom suffer weight gain post completion of their professional careers. If this procedure is applied at the time of the athlete’s development in their teens to early twenty’s, this may have a significant effect on their exercise performance should a correlation be discovered.
CHAPTER FOUR

Study Two
Can Cephalometric Airway Analysis Predict Ventilatory Function in Elite Athletes?

This paper has been published as

“Do craniofacial abnormalities impair elite athletes’ ventilatory performance during submaximal and maximal exercise?”

in the


*Presented here in the journal submission format*
Abstract

-Objective: 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.

-Design: Prospective cohort study

-Setting: The Physiology Testing Laboratory, School of Sports Science, Exercise and Health at the University of Western Australia, a tertiary educational institution.

-Participants: Twenty-seven, male, team-sport athletes.

-Interventions: Each athlete underwent facial cephalometric assessment and was graded into Class 1 (N = 14), Class 2 (N = 10) or Class 3 (N= 3) facial skeletal profile. 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.

-Main Outcome Measures: Minute ventilation (L· Min-1) was measured during the GTX at intensities that equated to 10km.h-1, 12km.hr-1 and subjective maximal effort. A comparison of cephalometric landmarks and ventilation was made.

-Results: No interpretable statistically significant results were found.

Conclusion: There was no relationship between airway cephalometric parameters and ventilatory performance.

Key Words: 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.\textsuperscript{1-6} Four craniofacial variables have been chosen which have been associated with upper airway obstruction, as defined in obstructive sleep apnoea literature.\textsuperscript{2-7} 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.\textsuperscript{5,8-14} 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.

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\textsuperscript{-2} (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. The Research Ethics Committee of the University of Western Australia (UWA) granted approval for the study’s procedures.
Experimental Overview

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.1-5,7 (Method of Ricketts 1972, 1979) The cephalometric landmarks recorded are listed in Table 1.

Table 1 – Cephalometric Landmarks

<table>
<thead>
<tr>
<th>Landmark</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Point (A)</td>
<td>The deepest point on the concavity of the bony surface anterior to the roots of the maxillary incisors. This point represents the anterior limit of maxillary basal bone at the junction of basal alveolar bone.</td>
</tr>
<tr>
<td>B Point (B)</td>
<td>The deepest point on the concavity of the bony surface anterior to the roots of the lower incisors. This point represents the anterior limit of the mandible basal bone and lies at the junction of basal and alveolar bone.</td>
</tr>
<tr>
<td>Nasion (Na)</td>
<td>The intersection of the inter-nasal and fronto-nasal sutures. This usually appears as a notch just above the maximum concavity of the fronto-nasal outline of the bony nasal bridge.</td>
</tr>
<tr>
<td>Gonion (Go)</td>
<td>The lowest and most posterior point on the curvature of the gonial angle of the mandible.</td>
</tr>
<tr>
<td>Posterior Nasal Spine (PNS)</td>
<td>The most posterior projection of the image of the hard palate and defines the posterior landmark of the maxillary plane.</td>
</tr>
<tr>
<td>Gnathion (Gn)</td>
<td>The most inferior point of the mandible in the midline. The midpoint between the most anterior and inferior point on the bony chin, measured at the intersection of the mandibular baseline and the nasion-pogonion line.</td>
</tr>
</tbody>
</table>
The cephalometric measurements are listed in Table 2.

**Table 2 - Cephalometric Measurements**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior Airway Space (PAS)</td>
<td>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.</td>
</tr>
<tr>
<td>Soft Palate Lengths (PNS-P)</td>
<td>Measurement of the length of the soft palate from the posterior nasal spine to the lowest point of the curvature of the soft palate.</td>
</tr>
<tr>
<td>Hyoid to Mandibular Plane Length (MP-H)</td>
<td>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.</td>
</tr>
<tr>
<td>A-Na-B (ANB)</td>
<td>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.</td>
</tr>
</tbody>
</table>

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 +/- 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 relative to the upper jaw (Fig 1).
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$^{-1}$) 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⁻¹. 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⁻¹, while the second plateau stage occurred at 12 km·h⁻¹. The two plateau stages were separated by a 1 min increment of 11 km·h⁻¹.

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 1). 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 infra-red 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 (β) standard reference gas, while the ventilometer was calibrated using a one litre syringe, as per manufacturer specifications.

**Statistical Analysis**

Simple and multiple linear regression analysis were made of the ventilatory parameters (\(\dot{V}_E : \text{L·min}^{-1}\)) 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 3 - Demographic Characteristics of Male Team Sport Players (n=27)

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>MEAN</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.82</td>
<td>0.08</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>81.7</td>
<td>8.6</td>
</tr>
<tr>
<td>Body Mass Index (kg.m$^{-2}$)</td>
<td>24.6</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Table 4 - Mean, Standard Deviation and Range of Cephalometric Values.

*Comparison made with previously published data*\(^5\) *(Previously published data)*

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

Table 5 displays p values where cephalometric variables were compared to ventilatory variables. 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.

Table 5 - 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⁻¹)

(* $P<0.05$ statistically significant)

<table>
<thead>
<tr>
<th></th>
<th>$\dot{V}_e$ Min (p value)</th>
<th>$\dot{V}_e$ Mod (p value)</th>
<th>$\dot{V}_e$ Max (p value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft palate length</td>
<td>0.232</td>
<td>0.674</td>
<td>0.669</td>
</tr>
<tr>
<td>Posterior airway space</td>
<td>0.644</td>
<td>0.557</td>
<td>0.546</td>
</tr>
<tr>
<td>Hyoid perpendicular to mandibular plane</td>
<td>0.619</td>
<td>0.169</td>
<td>0.702</td>
</tr>
</tbody>
</table>

Skeletal classification

| Class 1 (n=14)           | 0.82                       | *0.037                     | 0.604                     |
| Class 2 (n=10)           | 0.754                      | 0.372                      | 0.940                     |
| Class 3 (not done) n = 3 |                           |                           |                           |

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⁻¹).
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. 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:

a) Improving the projection of the facial skeleton on the cranial base.

b) Reducing the length of the soft palate.

c) Reducing the distance from the mandibular plane to hyoid bone.

d) Increasing posterior airway space.

Importantly, surgical advancement of the facial skeleton, namely the maxilla and mandible, has been shown to improve airway patency under resting conditions in OSA patients. 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 dysmorphology 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 $V_{E}^{\text{Mod}}$. 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.\textsuperscript{5,8} 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. Inter examiner reliability assessments were not required as one person performed all of the cephalometric tracings. A potential but unlikely source of bias may have been introduced as no intra examiner reliability studies were performed.

Regarding airway patency, there are a number of alternative ways airway patency can be measured apart from standard cephalometric assessment. 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. Direct nasendoscopy via fibre optic scope can also provide important dynamic information during respiration of airway behaviour. 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. Furthermore, nasendoscopy is an invasive assessment, which is not popular with
those participating and does not provide quantitative data for statistical assessment. 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.

**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.
References


CHAPTER FIVE

Discussion
This thesis investigated the relationship between an elite athlete’s upper airway patency and ventilation and/or work of breathing. Ventilatory comparisons were made in two trials. Study one, a trial examining the effects of occlusion of the upper airway, compared the effects of wearing a mouthguard and not wearing a mouthguard on ventilation during exercise of different intensities in athletes. Study two, a trial interested in anatomic obstruction, compared athletes’ ventilatory performance during exercise of different intensities with known cephalometric parameters of obstructive sleep apnoea.

The results of study one demonstrated that professionally fitted mouthguards do not interfere with the ventilation of elite athletes during various exercise states. Notably, there were no significant differences between trials for $\dot{V}_e$ (L·min$^{-1}$) and $\dot{V}O_2$ (mL·kg$^{-1}$·min$^{-1}$) at any of the exercise intensities assessed ($p > 0.05$).

In study two, athletes who had upper airways that were susceptible to OSA, as measured by cephalometric parameters, were not also susceptible to poor ventilatory performance during exercise of different intensities, as no interpretable statistically significant results were found ($p > 0.05$).

There were limitations of this thesis. These include, in study one, each mouthguard was fabricated from a different dental impression and that subtle differences between the two mouthguards may have been normalised by the use of non-identical casts. In addition, testing was undertaken in laboratory conditions which do not emulate field conditions during competition.

In study two, the value of individual cephalometric evaluation in the assessment of an occlusive airway has been questioned by Miles et al (1996) in recent publications. 3-D airway imaging was not possible in this cohort due to the expense and availability of this technology. Ethics committee approval for
protocols using 3-D CT scanning, due to increases in absorbed radiation dose, is difficult to obtain. Furthermore, the statistical assessment of this trial was underpowered.

The conclusions of study one is that despite the perception that mouthguards occlude the airway, they have no effect on ventilation or work of breathing, independent of the type of mouthguard worn and the level of exercise. Notably, palate free mouthguards are rated higher by athletes and more likely to be worn.

In study two, no statistically significant relationship existed between cephalometric landmarks known to demonstrate airway occlusion at rest and ventilatory performance during exercise of various intensities. Screening and treatment of athletes’ airways to improve performance via cephalometrics is not recommended as it is unlikely that those athletes who demonstrate occlusive airways will benefit from jaw advancement procedures.

The findings of this thesis should support action where sport administrators and sporting bodies mandate the use of mouthguards in those playing contact sport at elite level. Furthermore, health insurers should change policy to heavily subsidise mouthguards and consider not covering athletes who fail to wear them. These recommendations should have taxpayer benefit in Australia by reducing craniofacial trauma rates from contact sport where the current costs are managed by the publically funded health system.

Further research is needed to expand the principles of study two to patients undergoing orthognathic surgery. Longitudinal assessment of ventilatory parameters for pre and post orthognathic advancement procedures can be measured to investigate if ventilatory performance is improved.
CHAPTER 6

Appendices
Dear Professor Williamson,

HUMAN RESEARCH ETHICS OFFICE – FINAL REPORT APPROVED

*The effect of mouthguard use and violent facial profile on respiratory function in elite athletes*

*Student(s):*

Thank you for submitting a final report for the above project. The Human Research Ethics Committee has noted that the report is satisfactory.

Your file for this project has been closed and any further work in this area should be the subject of a new application for ethics approval.

If you have any queries please do not hesitate to contact the Human Research Ethics Office (HREO) on (08) 6488 3703.

Please ensure that you quote the file reference – RA/4/1/1986 – and the associated project title in all future correspondence.

Yours sincerely,

[Signature]

Peter Johnstone
Manager
Human Research Ethics