

**OBESITY EFFECTS ON LUNG VOLUME,  
TRANSDIAPHRAGMATIC PRESSURE, UPPER  
AIRWAY DILATOR AND INSPIRATORY PUMP  
MUSCLE ACTIVITY IN OBSTRUCTIVE SLEEP  
APNOEA**

by

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A thesis submitted for the degree of

**DOCTOR OF PHILOSOPHY**

March, 2010

**Discipline of Physiology**

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## ABSTRACT

Obstructive sleep apnoea (OSA) is a common respiratory disorder characterised by repetitive periods of upper airway (UA) collapse during sleep. OSA is more common in males and the obese but the reasons why remain poorly understood. Abdominal obesity, particularly common in males, is likely to indirectly modulate the amount of tension (tracheal traction) exerted on the UA by the trachea and other intrathoracic structures, potentially leading to increased UA collapsibility. Other factors such as lung volume changes with obesity, altered drive to UA muscles and exaggerated arousal responses are also likely to contribute to UA instability. An investigation of these potential contributing factors forms the basis of this thesis.

In the first study, the effect of external abdominal compression on UA collapsibility during sleep was investigated in a group of obese male OSA patients. A large pneumatic cuff wrapped around the abdomen was inflated to increase intra-abdominal pressure, aiming to produce an upward force on the diaphragm, designed to reduce axial tension on the UA. Abdominal compression increased end-expiratory gastric ( $P_{GA}$ ) and end-expiratory transdiaphragmatic ( $P_{DI}$ ) pressure by ~50% and produced a significant rise in UA collapsibility compared to the cuff deflated condition. These data support that increased intra-abdominal pressure has a negative effect on UA function during sleep. This effect may help explain why obesity is the leading risk factor for OSA and why OSA affects men more than women, given that abdominal obesity is particularly common in obese males.

In the second study, differences in minimum expiratory (tonic) diaphragm activity during wakefulness were compared between 8 obese OSA patients and 8 healthy-weight controls. Changes in tonic diaphragm activity and lung volume following sleep onset were also compared between the two groups. There was no evidence of increased tonic diaphragmatic activity during wakefulness in obese OSA patients to support significant diaphragmatic compensation for abdominal compressive effects of obesity. There were small decrements in lung volume following sleep onset in both groups (<70 ml), with significantly greater lung volume and diaphragmatic EMG decrements when sleep onsets were immediately followed by respiratory events. While lung volume decrements at sleep onset were relatively small, this does not discount that UA function is not more sensitive to effects of reduced lung volume in obese OSA patients.

To more closely investigate the potential interactive effects of obesity on physiological variables likely influencing UA function, the third study investigated the temporal relationships between a comprehensive range of relevant physiological variables leading into and following the termination of obstructive apnoeas during sleep in 6 obese OSA patients. Prior to UA obstruction, diaphragm and genioglossus muscle activity decreased, while UA resistance increased. Lung volume and end-expiratory  $P_{GA}$  and end-expiratory  $P_{DI}$  also fell during this period, consistent with diaphragm ascent. There was a substantial increase in ventilation, muscle activity and lung volume immediately following the termination of obstructive events. Respiratory events and arousals occurred in close temporal proximity prior to and following obstructive apnoeas, supporting that cyclical respiratory events and arousals may both help to perpetuate further events. The

results from this study support that there is a 'global' loss in respiratory drive to UA dilator and pump muscles precipitating obstructive respiratory events. The associated decreases in UA dilator muscle activity and lung volume may therefore both contribute to the propensity for the UA to obstruct.

In summary, increased intra-abdominal pressure was shown to negatively impact UA airway collapsibility during sleep. A decrease in lung volume at sleep onset and prior to UA obstruction further support that lung volume decrement, coincident with a decline in overall respiratory drive, potentially contributes to the propensity for airway obstruction. Further studies are needed to elucidate the relative contribution of relatively small changes in lung volume versus changes in respiratory and UA muscle activity *per se* on UA patency in OSA patients.

## PUBLICATIONS

The following are publications that have arisen from work conducted towards this thesis:

### ***Journal article:***

**Stadler DL**, McEvoy RD, Sprecher KE, Thomson KJ, Ryan MK, Thompson CC, Catcheside PG. Abdominal Compression Increases Upper Airway Collapsibility During Sleep in Obese Male Obstructive Sleep Apnea Patients. *Sleep* 2009; **32**(12):1579-1587.

### ***Published abstracts:***

**D Stadler**, RD McEvoy, D Paul, J Bradley, P Catcheside. Lung volume, Gastric and Transdiaphragmatic Pressure Changes Leading Into, During and Following Apnoea in Obese Male Obstructive Sleep Apnoea Patients. *Sleep Biol Rhythms* **7** (Suppl 1), A60, 2009

**DL Stadler**, PG Catcheside, D Paul, J Bradley, RD McEvoy. Changes in Lung Volume and Upper Airway Dilator Muscle Activity at Sleep Onset in Obese Male Obstructive Sleep Apnea Patients. *Am J Resp Crit Care Med* **179** A5405, 2009

**D Stadler**, P Catcheside, D Paul, J Bradley, R McEvoy. Changes in Lung Volume and Upper Airway Dilator Muscle Activity at Sleep Onset in Obese Male Obstructive Sleep Apnoea Patients. *Sleep Biol Rhythms* **6** (Suppl 1) A10, 2008

**Stadler DL**, Catchside PG, George KE, Thomson K, Thompson CC, Ryan M, McEvoy RD. Abdominal compression increases upper airway collapsibility during sleep in obese male obstructive sleep apnea patients. *Proceedings of the American Thoracic Society* A51, 2007

**Stadler DL**, Catchside PG, George K, Thompson C, Ryan M, McEvoy RD. The effect of abdominal compression on upper airway function during sleep in obese male obstructive sleep apnoea patients. *Sleep Biol Rhythms*, 4 (Supp 1) A23, 2006

***Unpublished conference proceedings:***

**D Stadler**, P Catchside, J Bradley, D Paul and R Doug McEvoy. The Effect Of Sleep Onset On Lung Volume In Obese Male Obstructive Sleep Apnoea Patients. *Australian Society for Medical Research Annual Scientific Meeting, South Australian Branch, Adelaide, Australia*. 2008

## **DECLARATION**

This work contains no material which has been accepted for the award of any other degree or diploma in any university or tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Daniel Stadler

Date:           Tuesday, 2 March 2010

## **ACKNOWLEDGEMENTS**

Firstly, I would like to thank Professor R. Doug McEvoy for inviting me to undertake my PhD at the Adelaide Institute for Sleep Health. I feel extremely privileged to have been given the opportunity to be part of an illustrious and well renowned organisation. Doug continued to provide invaluable assistance and mentorship throughout my time as a postgraduate student.

A special thank you goes to my supervisor, Associate Professor Peter Catchside. Peter has been a constant source of inspiration, motivation and encouragement. I am extremely grateful for the generous amount of time Peter has set aside to assist in study designs, technical help, data analysis and proof readings of manuscripts and my thesis. His friendship is very much appreciated.

I kindly acknowledge the research, laboratory, medical and administrative staff of the Adelaide Institute of Sleep Health for their technical assistance, friendship and words of wisdom. I am very grateful to Amanda McKenna for her staging and scoring of sleep studies. I also thank our past and current research assistants; Rachel McDonald, Amanda Adams, Kate Sprecher, Kieron Thomson, Courtney Thompson, Melissa Ryan, Denzil Paul and Jana Bradley who have assisted with subject recruitment, overnight studies and data analysis. I am appreciative for technical assistance provided by David Schembri and the Respiratory Function Unit staff.



I am very grateful for all the participants who took part in my research. This thesis would not have been possible without them.

I also thank fellow PhD students Rajeev Ratnavadivel, Andrew Vakulin, Aeneas Yeo and Danny Eckert for their assistance and general camaraderie.

Finally, a big thank you is reserved for both my dad and my wife Nic who have helped me strive towards my goals. I cherish their love, support, guidance and constant words of encouragement. I would also like to pay tribute to my mum, Sue and my Babcia who sadly passed away in 1996 and 1997 respectively. I am sure I have made both of you proud.

## GLOSSARY OF ABBREVIATIONS

$\Delta AP_{\text{ABDO}}$	Change in abdominal anterior-posterior dimension
$\Delta AP_{\text{CHEST}}$	Change in chest anterior-posterior dimension
<b>AHI</b>	Apnoea hypopnoea index (events·hr <sup>-1</sup> )
<b>BMI</b>	Body mass index (kg·m <sup>-2</sup> )
<b>CPAP</b>	Continuous positive airway pressure
<b>ECG</b>	Electrocardiography
<b>EEG</b>	Electroencephalography
<b>EELV</b>	End-expiratory lung volume
<b>eEMG<sub>DI</sub></b>	Average minimum tonic diaphragm activity
<b>eEMG<sub>GG</sub></b>	Average minimum tonic genioglossus activity
<b>EMG</b>	Electromyography
<b>EMG<sub>DI</sub></b>	Diaphragm muscle activity
<b>EMG<sub>GG</sub></b>	Genioglossus muscle activity
<b>F<sub>B</sub></b>	Breathing frequency (breaths·min <sup>-1</sup> )
<b>FEV<sub>1</sub></b>	Forced expiratory volume in 1 sec (% predicted)
<b>FVC</b>	Forced vital capacity (% predicted)
<b>HC</b>	Hip circumference (cm)
<b>IAP</b>	Intra-abdominal pressure
<b>iEMG<sub>DI</sub></b>	Average inspiratory diaphragm activity
<b>iEMG<sub>GG</sub></b>	Average inspiratory genioglossus activity
<b>NREM sleep</b>	Non rapid eye movement sleep
<b>OSA</b>	Obstructive sleep apnoea
<b>OSAS</b>	Obstructive sleep apnoea syndrome
<b>P<sub>ACO<sub>2</sub></sub></b>	Arterial CO <sub>2</sub>
<b>P<sub>CRIT</sub></b>	Upper airway critical closing pressure

<b>P<sub>CUFF</sub></b>	Cuff pressure (cmH <sub>2</sub> O)
<b>P<sub>DI</sub></b>	Transdiaphragmatic pressure (cmH <sub>2</sub> O)
<b>P<sub>EPI</sub></b>	Epiglottic pressure (cmH <sub>2</sub> O)
<b>P<sub>ETCO<sub>2</sub></sub></b>	End-tidal partial pressure of carbon dioxide (mmHg)
<b>P<sub>GA</sub></b>	Gastric pressure (cmH <sub>2</sub> O)
<b>PIF</b>	Peak inspiratory flow (L·min <sup>-1</sup> )
<b>P<sub>MASK</sub></b>	Mask pressure (cmH <sub>2</sub> O)
<b>P<sub>OES</sub></b>	Oesophageal pressure (cmH <sub>2</sub> O)
<b>REM sleep</b>	Rapid eye movement sleep
<b>R<sub>UA</sub></b>	Upper airway resistance (cmH <sub>2</sub> O·L <sup>-1</sup> ·s)
<b>SDB</b>	Sleep-disordered breathing
<b>SEM</b>	Standard error of the mean
<b>SWS</b>	Slow-wave sleep
<b>T<sub>E</sub></b>	Duration of expiration (secs)
<b>T<sub>I</sub></b>	Duration of inspiration (secs)
<b>T<sub>TOT</sub></b>	Total duration of inspiration and expiration (secs)
<b>UA</b>	Upper airway
<b>UACP</b>	Upper airway closing pressure (cmH <sub>2</sub> O)
<b>V<sub>I</sub></b>	Inspiration minute ventilation (L·min <sup>-1</sup> )
<b>V<sub>T</sub></b>	Inspiration tidal volume (L)
<b>WC</b>	Waist circumference (cm)
<b>WHR</b>	Waist-to-hip ratio