Polysomnographic signal processing for advanced diagnostics of paediatric sleep disordered breathing

by

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Thesis submitted for the degree of

Doctor of Philosophy

in

Electrical and Electronic Engineering,
Faculty of Engineering, Computer and Mathematical Sciences
The University of Adelaide, Australia

December 2014

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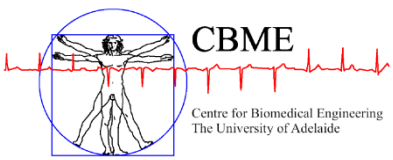

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Abstract

Sleep disordered breathing (SDB) is a highly prevalent but an under-diagnosed disease especially in children. Childhood SDB is characterised by an increased work of breathing, restless night sleep and excessive daytime sleepiness and has been associated with neurocognitive impairment, behavioural disturbances and early cardiovascular changes that may predispose them to an increased risk of developing cardiovascular diseases. Thus there is an increasing need for the investigation and management of childhood SDB, so as to instigate early and appropriate treatment. Polysomnography (PSG) is the reference test for diagnosis of SDB and to measure the effectiveness of treatment. During PSG, a number of physiological signals including electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG) and respiration are recorded during an overnight sleep and then manually scored for sleep/wake stages, cardio-respiratory events, arousals, periodic limb movement etc. Indices commonly used to assess SDB severity are the obstructive apnea/hypopnea index (OAHI) and the respiratory disturbance index (RDI) and these reflect the average number of obstructive events and/or arousals per hour of sleep.

Signal processing approaches have been developed to perform automated detection and quantification of cardio-respiratory events based on analysis of EEG, respiratory, ECG, oximetry and airflow signals acquired during overnight PSG. These methods automate the application of standard scoring criterion on corresponding signals and thus aim to overcome the limitations of manual PSG scoring. However, the diagnostic criterion in current clinical guidelines may under-estimate the severity of SDB when children exhibit partial obstructive hypoventilation-a pattern of SDB commonly seen in children, where even in the absence of frank apnea or arousal, there might be underlying manifestations indicating SDB pathology. Thus it is important to investigate sleep periods free of frank events, i.e. scored event free (SEF) periods in children suspected for SDB and compare them to healthy controls. This would shed light on altered physiological measures, if any, in children with SDB that are subtle yet persistent and prolonged. With this as a focus of this Thesis, signal processing methods

were developed and applied on respiratory, EEG and ECG signals to investigate SEF periods of sleep in children. In the studies conducted thoracoabdominal asynchrony (TAA), respiratory timing and their variability, respiratory waveform regularity, respiratory cycle related EEG changes (RCREC) and heartbeat related evoked potentials (HEP) were the measures quantified and investigated within specific sleep stages in both study groups. To analyse the impact of SDB on breathing mechanics, respiratory timing and their variability were quantified. Inspiratory and expiratory timing were found to be significantly elevated in children with SDB. Secondly, to quantify the impact of SDB on the breathing movements, TAA was estimated using a novel Hilbert transform based approach and respiratory waveform regularity was measured using a wavelet based low-frequency estimation approach. Breathing waveform regularity and TAA were influenced by sleep stages. The level of asynchrony was found to be significantly elevated in children with SDB and also breaths immediately before apnea/hypopneas were associated with a high degree of variability in both TAA and respiratory timing. Further, to investigate the impact of SDB on breathing phase dependent EEG responses that might be indicative of subtle cortical arousals, RCREC were quantified using normalised EEG power changes and symbolic dynamics based EEG fluctuations. In children with SDB, the earlier approach revealed higher overall and frequency band specific RCREC during REM and the later showed altered respiratory phase-related reduction in EEG variability during the expiratory phase. Finally, to elucidate the impact of SDB on visceral cortical processing of intrinsic stimuli, HEP were quantified and analysed. Importantly, this study provides the first evidence for the existence of HEP during sleep in children. Sleep stage specific HEP were observed and the potentials were found to be attenuated in children with SDB compared to healthy controls. Importantly, associations between HEP and daytime behavioural scores were observed. Thus, this Thesis provides a summary of studies based on signal processing of pediatric sleep data that led to significant findings emphasising the impact of childhood SDB on cortical and respiratory measures and the effect of surgical intervention on normalising the parameters.

Thesis Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other 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. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree. I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time. The author(s) acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works.

Sarah Immanuel……..... Date……

Acknowledgements

I express my gratitude and heartfelt thanks to my supervisor Assoc Prof Mathias Baumert for his guidance, encouragement and continued support throughout my candidature. His insight and ideas were a great resource that helped me move forward throughout my candidature. Working with him has broadened my knowledge in biomedical signal processing, built my confidence as a researcher and has made my PhD journey a pleasant and interesting one. I thank my co-supervisor Assoc Prof David Saint for his support and guidance in every stage of my candidature. The encouraging attitude of my supervisors and the confidence they had in me was a huge inspiration all along. I thank my co-investigators Dr Yvonne Pamula, Dr Declan Kennedy, Dr James Martin (Women's and Children's Hospital, Adelaide) and Dr Mark Kohler (University of South Australia, Adelaide) for providing me with the data, helping me with interpretation of results and strengthening the findings with their vast knowledge in paediatric sleep research. Working with them and co-authoring articles provided an unique learning experience. I would like to thank A/Prof Eugene Nalivaiko (School of Biomedical Sciences and Pharmacy, University of Newcastle) for his valuable inputs and suggestions. I thank the Head of School Assoc Prof Cheng Chew Lim, Dr Said Al-Sarawi and Dr Brian Ng for their support. A special thanks to all my friends and colleagues from the School of Electrical & Electronic Engineering: Dr Muammar Muhammad Kabir (currently at Oregon Health and Science University, Portland) Dr Muhammad Asraful Hasan, Dr Ali Karami, Mrs Zhara Shaterian, Mrs Fatima ElHamad, Mr Sam Darvishi, Dr Syed Mostafa Rahimi Azghadi and Mr Mostafa Numan for their collegiality and encouragement throughout my candidature. I am grateful to Ms Rose-Marie Descalzi, Ms Ivana Rebellato, Ms Jodie Schluter, Ms Deborach Koch, Mr Greg Pullman and Mr Stephen Guest at School of Electrical & Electronic Engineering for their assistance in administrative work during my candidature. I would also like to thank Mr David Bowler and other IT support and technical officers for their timely technical support. I gratefully acknowledge the School of Electrical & Electronic Engineering at the University of Adelaide and the Walter and Dorothy Duncan Trust Fund for their financial support and travel grants. I would also like to thank Australian

Research Council for its support in the research studies presented in this Thesis (grant # DP 110102049). I would like to take the opportunity to extend my deepest gratitude to all my family members, friends and colleagues who were always there with a helping hand in time of need. I am greatly indebted to my husband and my loving children for their understanding, support, patience and co-operation without which my dream to do a PhD would not have come true. My special thanks to my parents for their prayers, encouragement and motivation. Above all, I thank the ALMIGHTY for his abundant grace and blessings that fills me with an inner strength and takes me forward in every step of my life.

Thesis convention

The following conventions have been adopted in this Thesis:

1. **Spelling.** Australian English spelling conventions have been used, as defined in the Macquarie English Dictionary, A. Delbridge (Ed.), Macquarie Library, North Ryde, NSW, Australia, 2001.

2.Typesetting. This document was compiled using Microsoft Word 2010.

3.Mathematics. MATLAB code was written using MATLAB Version R2010b; URL: http://www.mathworks.com.

4. Referencing. The Harvard style has been adopted for referencing.

Publications arising from this Thesis

Journal Articles

IMMANUEL, S. A., PAMULA, Y., KOHLER, M., MARTIN, J., KENNEDY, D., KABIR, M. M., SAINT, D. A. & BAUMERT, M. 2012. Respiratory timing and variability during sleep in children with sleep-disordered breathing. *Journal of Applied Physiology,* 113**,** 1635-1642.

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