

**PHYSICAL ACTIVITY, AEROBIC FITNESS,
BODY COMPOSITION AND ASTHMA
SEVERITY IN CHILDREN AND
ADOLESCENTS**

Submitted by
Liam Welsh
Bachelor of Applied Science
(Medical Biophysics and Instrumentation)

A thesis submitted in total fulfillment of the requirements of the
degree of Doctor of Philosophy

School of Exercise Science

Faculty of Health Sciences

Australian Catholic University
Research Services
Locked Bag 4115
Fitzroy, Victoria 3065
Australia

30/09/2006

Statement of Sources Declaration

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma.

No other person's work has been used without due acknowledgement in the main text of the thesis.

This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees (where applicable).

This project was completed in collaboration with staff from the Respiratory Laboratory at the Royal Children's Hospital, Melbourne.

Signature:

Date:

Table of Contents

Statement of Sources Declaration.....	2
Summary	11
Acknowledgements.....	14
List of Publications & Conference Presentations	16
List of Abbreviations	18
List of Figures.....	19
List of Tables	22
Chapter 1 Introduction and Literature Review	27
1.1 Introduction	27
1.2 Body Composition	31
1.2.1 Introduction.....	31
1.2.2 Measures of Body Composition.....	32
1.2.2.1 Multi-Compartment Models	33
1.2.2.2 Hydrodensitometry – Underwater Weighing.....	34
1.2.2.3 Dual Energy X-Ray Absorptiometry – DEXA.....	34
1.2.2.4 Hydrometry – Deuterium Oxide Dilution.....	35
1.2.2.5 Sum of Skinfolds.....	35
1.2.2.6 Body Mass Index – BMI.....	37
1.2.2.7 Bio-Electrical Impedance Analysis – BIA.....	38
1.2.3 Overweight and Obesity	39
1.2.3.1 Introduction and Definition.....	39
1.2.3.2 Natural History of Adiposity	40
1.2.3.3 Prevalence of Overweight and Obesity in Australia.....	41
1.2.3.4 Physical Activity.....	42
1.2.3.5 Health Consequences	43
1.3 Asthma	44
1.3.1 Introduction and Definition.....	44
1.3.2 Pathology	45
1.3.3 Pathogenesis.....	46

1.3.4 Clinical Assessment.....	46
1.3.5 Asthma Severity Assessment.....	47
1.3.6 Spirometry.....	48
1.3.7 Asthma Prevalence in Australia.....	49
1.3.8 Exercise Induced Asthma	50
1.3.8.1 Osmotic Theory	51
1.3.8.2 Thermal Theory	52
1.3.9 Obesity and asthma	53
1.3.9.1 Mechanical Effects.....	53
1.3.9.2 Immune Modification	55
1.3.9.3 Fetal Programming.....	56
1.4 Physical Activity.....	56
1.4.1 Introduction and Definition.....	56
1.4.2 Physical Activity and Health	56
1.4.3 Measures of Physical Activity	57
1.4.3.1 Doubly Labeled Water	58
1.4.3.2 Questionnaires.....	59
1.4.3.3 Accelerometry.....	61
1.4.3.3.1 Basic Physics and Measurement Principles.....	62
1.4.3.3.2 ActiGraph.....	64
1.4.3.4 Heart Rate	67
1.4.4 Age and Gender Differences in Physical Activity.....	69
1.4.5 Physical Activity and Body Composition.....	71
1.4.6 Physical Activity in Asthmatics and Non-Asthmatics.....	73
1.4.6.1 Physical Activity Levels	73
1.4.6.2 Physical Activity Summary	76
1.5 Aerobic Fitness	78
1.5.1 Introduction and Definition.....	78
1.5.2 Aerobic Fitness and Health.....	79
1.5.3 Relationship between Aerobic Fitness and Physical Activity	81
1.5.4 Aerobic Fitness and Body Composition	83

1.5.5 Field Tests of Aerobic Fitness	83
1.5.5.1 Six-Minute Running Test – 6MRT	84
1.5.6 Normative Values of Peak $\dot{V} O_2$ for Children and Adolescents.....	86
1.5.7 Age and Gender Differences in Peak $\dot{V} O_2$	87
1.5.8 Aerobic Fitness in Asthmatics and Non-Asthmatics	88
1.5.8.1 Comparable Aerobic Fitness between Asthmatic and Non-Asthmatic Children	89
1.5.8.2 Differences in Aerobic Fitness between Asthmatic and Non-Asthmatic Children.....	90
1.5.8.3 Aerobic Fitness Summary.....	93
1.5.8.4 Interaction between Aerobic Fitness, Physical Activity and Asthma.....	94
1.5.8.5 Aerobic Fitness, Physical Activity and Asthma Summary.....	96
1.6 Aims of this Thesis	97
Chapter 2 General Methodology	99
2.1 School Tested Participants	99
2.2 School Tested Procedure	100
2.2.1 Height and Weight Measurement	100
2.2.2 Skinfold Measurement and Bioelectrical Impedance Analysis	100
2.2.2.1 Percentage Body Fat Equations	104
2.2.3 Spirometry.....	105
2.2.4 Six-Minute Running Test – 6MRT	108
2.2.4.1 Six-Minute Running Distance (6MRD) to Predicted Peak $\dot{V} O_2$	110
2.2.5 Physical Activity Assessment.....	111
2.2.5.1 Physical Activity Questionnaire for Children.....	111
2.2.5.2 Accelerometry – Activity Monitor.....	111
2.2.5.3 Physical Activity Data Analysis	112
2.2.6 Asthma Severity Questionnaire – ASQ	114
2.2.7 Common Statistical Methods.....	115
2.2.8 Data Management	115
Chapter 3 Relationship between Aerobic Fitness, Physical Activity and Body Composition in Children and Adolescents	117

3.1 Introduction	117
3.2 Methodology	119
3.2.1 Participants.....	119
3.2.2 Procedure.....	119
3.2.3 Data Management.....	121
3.2.4 Statistical Analysis.....	122
3.3 Results	123
3.3.1 Participants.....	123
3.3.2 Testing Data Distribution for Normality.....	124
3.3.3 Body Composition – BMI, %BF.....	127
3.3.4 Aerobic Fitness & Heart Rate Responses.....	128
3.3.5 Physical Activity Measures – PAQ-C, Activity Monitor Counts & Estimated MET.....	131
3.3.6 Relationship between Activity Monitor Counts and PAQ-C.....	137
3.3.7 Relationship between Aerobic Fitness and Body Composition.....	138
3.3.7.1 Aerobic fitness, stratified according to the BMI categories of Cole <i>et al.</i> (2000).....	138
3.3.7.1.1 Estimated energy expenditure (kJ), stratified according to BMI categories of Cole <i>et al.</i> (2000).....	144
3.3.7.2 Aerobic fitness, stratified according to the %BF categories of Taylor <i>et al.</i> (2002).....	146
3.3.8 Relationship between Aerobic Fitness and Physical Activity.....	150
3.3.8.1 Aerobic fitness and PAQ-C.....	150
3.3.8.2 Aerobic fitness and activity monitor counts.....	153
3.3.9 Relationship between Physical Activity and Body Composition.....	157
3.3.9.1 PAQ-C and BMI.....	157
3.3.9.2 PAQ-C categorised by %BF.....	158
3.3.9.3 Activity monitor counts and body composition - BMI and %BF.....	161
3.3.9.4 Estimated MET and body composition – BMI and %BF.....	163
3.3.10 Relationship between Physical Activity, Aerobic Fitness and Body Composition.....	165

3.4 Discussion	167
Chapter 4 Aerobic Fitness, Physical Activity and Body Composition in Asthmatic Children and Adolescents	185
4.1 Introduction	185
4.2 Methodology	188
4.2.1 Participants.....	188
4.2.2 Procedure	188
4.2.3 Data Management	188
4.2.4 Statistics	189
4.3 Results	190
4.3.1 Participants.....	190
4.3.2 Testing Data Distribution for Normality.....	191
4.3.3 Lung Function	191
4.3.3.1 Lung function comparative analysis – non-asthmatic versus asthmatic values	193
4.3.4 Asthma Severity - Asthma Symptoms Questionnaire (ASQ).....	194
4.3.5 Body Composition – BMI and %BF.....	196
4.3.5.1 Body composition comparative analyses – non-asthmatic versus asthmatic values	197
4.3.6 Aerobic Fitness Data – 6MRD, 6MRD/FFM and Predicted Peak $\dot{V}O_2$	197
4.3.6.1 Aerobic fitness comparative analyses – non-asthmatic versus asthmatic values	200
4.3.7 Physical Activity – PAQ-C, Activity Monitor Counts, Estimated MET	201
4.3.7.1 Physical activity comparative analyses – non-asthmatic versus asthmatic values	204
4.3.8 Asthma Severity - ASQ	204
4.3.8.1 Body composition and ASQ	204
4.3.8.2 Aerobic fitness and ASQ	206
4.3.8.3 Physical activity and ASQ	208
4.3.9 Relationship between Activity Monitor Counts and PAQ-C.....	210
4.3.10 Relationship between Aerobic Fitness and Body Composition.....	210

4.3.10.1 Aerobic fitness when stratified according to BMI and %BF	210
4.3.10.2 Energy expenditure (kJ) and BMI.....	217
4.3.11 Relationship between Aerobic Fitness and Physical Activity	218
4.3.11.1 Aerobic fitness, PAQ-C, activity monitor counts and estimated MET.....	218
4.3.12 Relationship between Physical Activity and Body Composition	220
4.3.13 Relationship between Physical Activity, Aerobic Fitness, Body Composition and ASQ.....	222
4.3.14 Odds Ratios and the Relationship between Asthma Status and Body Composition.....	223
4.4 Discussion.....	225
Chapter 5 Peak Oxygen Consumption, Physical Activity and Body Mass Index in Severely Asthmatic Children and Adolescents.....	239
5.1 Introduction.....	239
5.2 Methodology	243
5.2.1 Participants.....	243
5.2.2 Procedure	243
5.2.3 Data Management	250
5.2.4 Statistical Analysis.....	250
5.3 Results	251
5.3.1 Participants.....	251
5.3.2 Forced Expiration Ratio (FER) Comparison	252
5.3.3 Testing Data Distribution for Normality.....	254
5.3.4 Graded Exercise Test (GXT) Data.....	254
5.3.4.1 Comparative analysis – school-tested and laboratory-tested peak $\dot{V}O_2$ and peak heart rate.....	256
5.3.4.2 Comparative analysis - GXT responses between severe asthmatics and non- asthmatic	258
5.3.5 Physical Activity Data	260
5.3.6 Relationship between Activity Monitor Counts and PAQ-C Data	262
5.3.6.1 Comparative analysis - school-tested versus laboratory-tested physical activity	262

5.3.7 Relationship between Peak $\dot{V} O_2$ and BMI	264
5.3.8 Relationship between Peak $\dot{V} O_2$ and Physical Activity	266
5.3.9 Relationship between Physical Activity and BMI	268
5.3.10 Odds Ratios and the Relationship between Asthma Status and Body Composition	270
5.3.11 Multiple Regression Analyses	271
5.4 Discussion	273
Conclusions	Error! Bookmark not defined.
References	289
Appendix A Bioelectrical Impedance and Anthropometric Measurements of Body Composition	
A.1 Introduction	324
A.2 Methodology	327
A.2.1 Participants	327
A.2.2 Procedure	328
A.2.2.1 Body Mass Index	328
A.2.2.2 Bioelectrical Impedance Analysis and Skinfold Measurement	328
A.2.3 Data Management	329
A.2.4 Statistical Analysis	329
A.3 Results	330
A.3.1 Participant Characteristics	330
A.3.2 Body Composition Data	331
A.3.3 Bland-Altman analyses	331
A.4 Discussion	336
Appendix B: Standard Informed Consent	340
Appendix C: Asthma Severity Questionnaire (ASQ)	341
Appendix D: Six-Minute Running Test Equations for Predicted Peak $\dot{V} O_2$	343
Appendix E: Physical Activity Questionnaire for Children (PAQ-C)	349
Appendix F: Instruction sheet for wearing the activity monitor	352
Appendix G: GXT DATA SHEET	353
Appendix H: GXT Data and Graphical Output	355

Appendix I: Human Research Ethics Approval.....	358
Appendix J: Chapter 1 Appendices	359
Appendix K: Chapter 2 Appendices	363
Appendix L: Chapter 3 Appendices.....	366
Appendix M: Chapter 4 Appendices	369
Appendix N: Chapter 5 Appendices	388

Summary

The investigations described in this thesis were conducted in order to increase the understanding of the relationships between physical activity, aerobic fitness, body composition, asthma, and asthma severity in children and adolescents. This was largely achieved by examining the aforementioned factors in a sizeable population of Melbourne school children and adolescents. However, during the course of the school-based testing, it became apparent that the severe asthmatic category was under-represented, typical of the current literature. Thus, effort was also directed at addressing this knowledge gap by examining a severely asthmatic cohort in a laboratory-based setting. The outcomes generated by these investigations can be summarised as follows:

1) In ‘school-tested’ youth aged 10 to 14 years, prevalence rates of overweight and obesity were 19.1% and 4.0%, respectively. Approximately 16% of participants also suffered from asthma. These rates appear to be representative of similarly aged children and adolescents within Australia. The latter observation also adds weight to the view that asthma prevalence has attenuated in recent years. In addition, overweight and obesity were more prevalent in asthmatics than non-asthmatics, supporting the proposed notion of an asthma-obesity association.

2) Asthmatic and non-asthmatic young people had comparable aerobic fitness and daily physical activity levels and the severity of disease did not influence aerobic fitness nor involvement in physical activity. Males possessed greater aerobic fitness and physical

activity levels and had a lower percentage body fat compared to age-matched females, independent of asthma status (i.e. asthmatic or non-asthmatic).

3) There was a significant inverse relationship between aerobic fitness and markers of increased body fat among non-asthmatic children and adolescents, even after corrections to aerobic fitness were made for fat free mass. Differences in daily physical activity could only partially explain this association. In fact, the current findings suggest that decreased levels of daily physical activity are not the cause of the increased overweight/obesity prevalence among this sample, and that physical activity lacks a strong link to paediatric overweight/obesity in this population. These findings were also present in asthmatic youth.

4) Severely asthmatic youth, premedicated with bronchodilator, had aerobic fitness levels comparable to their non-asthmatic and less severe asthmatic peers. This finding indicates that severely asthmatic youngsters should be able to train at work intensities sufficient to bring about improvements in cardio-respiratory fitness without any added functional limitation due to their condition. In addition, a state of well-controlled asthma (as were the severe asthmatics in this study) afforded the participants the ability to engage in similar levels of physical activity as their non-asthmatic or less severe asthmatic peers. In agreement with data from the 'school-tested' asthmatics, a significantly greater proportion of severely asthmatic participants were overweight or obese in comparison to their non-asthmatic peers.

These findings (i) highlight the association between aerobic fitness and overweight/obesity; (ii) suggested that decreased levels of daily physical activity were not associated with the increased overweight/obesity prevalence in a youth sample within Australia; (iii) emphasize that well-controlled asthmatic young people can undertake levels of physical activity and achieve cardio-respiratory fitness similar to that of their non-asthmatic peers, independent of asthma severity, and; (iv) indicated that asthma is either a risk factor for overweight and obesity or that overweight and obesity may precede asthma.