

Assessing the impact of maternal  
Omega-3 LCPUFA DHA on the body  
composition of children at 7 years of  
age using Air Displacement  
Plethysmography (ADP)

Katie Wood

MND BNutFoodSc



School of Agriculture, Food and Wine  
The University of Adelaide  
South Australia

A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

July 2016

## TABLE OF CONTENTS

LIST OF FIGURES .....	vi
ABSTRACT.....	viii
DECLARATION .....	x
ACKNOWLEDGEMENTS .....	xi
LIST OF ABBREVIATIONS.....	xiii
CHAPTER 1 .....	2
INTRODUCTION AND LITERATURE REVIEW .....	2
PART 1 .....	5
CONTRIBUTORS TO CHILDHOOD OBESITY AND THE ROLE OF N-3 LCPUFA	5
1.1 The Early Origins of Obesity .....	5
1.2 N-3 LCPUFA in Perinatal Nutrition.....	6
1.3 Perinatal N-3 LCPUFA and Body Composition – Animal Models and <i>in vitro</i> studies .....	9
1.4 Maternal n-3 LCPUFA supplementation and infant body composition: Evidence from human studies .....	11
1.5 Other Contributors to Childhood Obesity .....	16
1.5.1 Dietary intake .....	16
1.5.2 Methods of measuring dietary intake in children.....	19
1.5.3 Physical Activity and Screen Time .....	21
PART 2 .....	25
ASSESSMENT OF BODY COMPOSITION IN CHILDREN.....	25
1.6 Defining overweight and obesity in children: the use of Body Mass Index (BMI) .....	25
1.6.1 Limitations of BMI for defining overweight and obesity .....	27
1.7 Current approaches for measuring body Composition in children.....	29
1.7.1 Challenges in measuring body composition .....	29
1.7.2 Body composition compartment methods.....	30
1.7.3 Skinfold Thickness (SFT) .....	33
1.7.4 Dual energy X-ray Absorptiometry (DXA) .....	34

1.7.5	Bioelectrical Impedance Analysis (BIA) and Bioelectrical Impedance Spectroscopy (BIS) .....	35
1.7.6	Air Displacement Plethysmography using the BOD POD .....	38
1.8	Validation of the BOD POD.....	42
1.9	Comparison of BIA and ADP measurements in children .....	44
1.10	Other/additional limitations to the use of the BOD POD in paediatric populations .....	45
1.11	Other Considerations: The importance of fat distribution.....	46
1.12	Conclusion.....	47
1.13	Rationale and outline of this thesis.....	48
CHAPTER 2 .....		53
METHODS AND MATERIALS.....		53
2.1	Study Population .....	53
2.2	Follow-up and Clinic Appointments .....	54
2.3	Anthropometric outcomes .....	56
2.4	Body composition outcomes .....	57
2.4.1	Bioelectrical Impedance Spectroscopy (BIS) measurements .....	57
2.4.2	Air Displacement Plethysmography (ADP) .....	58
2.4.3	BOD POD reproducibility.....	59
2.5	Dietary Intake .....	60
2.5.1	Quantification of diet quality .....	61
2.6	Physical Activity and Screen Time .....	65
2.7	Other Measures.....	65
CHAPTER 3 .....		67
RESULTS .....		67
EFFECT OF MATERNAL DHA SUPPLEMENTATION ON BODY COMPOSITION OF THE CHILD .....		67
3.1	Introduction .....	67
3.2	Methods .....	69
3.2.1	Flow of participants.....	69
3.2.2	BOD POD and BIS testing.....	70
3.2.3	Sociodemographic characteristics.....	70

3.2.4	Statistical Analysis .....	70
3.3	Baseline characteristics of participants .....	73
3.4	Sociodemographic Characteristics at the time of the 7 year follow-up.....	73
3.5	Body composition measurements (fat mass and fat free mass) using BIS and the BOD POD.....	78
3.5.1	Body composition outcomes by treatment group.....	78
3.5.2	Male vs Female children .....	78
3.6	Anthropometric measurements.....	81
3.6.1	Anthropometric outcomes by treatment group .....	81
3.6.2	Male vs Female children .....	81
3.7	Summary of the results .....	84
3.8	Discussion.....	84
3.9	Limitations.....	91
4.0	Overall conclusions and implications.....	93
CHAPTER 4 .....		95
RESULTS .....		95
DIETARY INTAKE, PHYSICAL ACTIVITY AND SCREEN TIME.....		95
4.1	Introduction .....	95
4.2	Methods .....	97
Assessment of Dietary intake, Physical Activity and Screen Time.....		97
4.2.1	Study population .....	97
4.2.2	Diet and family food environment .....	97
4.2.3	Determination of DGI-CA SCORE .....	98
4.2.4	Physical Activity and Screen Time .....	98
4.2.5	Statistical analysis .....	98
4.3	RESULTS.....	99
4.3.1	Dietary intake .....	99
4.3.2	Dietary intake by treatment group.....	100
4.3.3	Male vs Female children .....	102
4.3.4	Family food environment.....	102

4.3.5	Relationship between DGI-CA, fat mass % and BMI z-score.....	103
4.4	Physical Activity and Screen Time .....	106
4.4.1	Physical Activity by treatment group.....	107
4.4.2	Male vs Female children .....	107
4.4.3	Screen Time (television and computer games) by treatment group....	107
4.4.4	Screen Time (television and computer games) in Male vs Female children .....	108
4.4.5	Relationship between Physical Activity and Screen Time and BMI z- score and fat mass % .....	108
4.5	Summary of the results .....	113
4.6	Discussion .....	114
4.7	Limitations.....	120
4.8	Conclusion.....	122
	CHAPTER 5 .....	124
	RESULTS .....	124
	COMPARISON OF BIOELECTRICAL IMPEDANCE SPECTROSCOPY (BIS) AND BOD POD MEASUREMENTS OF FAT/FAT FREE MASS .....	124
5.1	Introduction .....	124
5.2	METHODS.....	126
5.2.1	Study population .....	126
5.2.2	BOD POD and BIS testing.....	126
5.2.3	Statistical analysis .....	126
	RESULTS .....	128
5.3	BOD POD vs BIS fat mass percentage .....	128
5.4	Relationship between fat mass measures using BOD POD or BIS and BMI z- score.....	128
5.5	BOD POD vs BIS compliance .....	129
5.6	Summary of the results .....	137
5.7	Discussion.....	137
5.8	Limitations.....	142
5.9	Overall conclusions and implications.....	143

CHAPTER 6 .....	145
General discussion .....	145
Concluding remarks and future direction .....	153
APPENDIX 1.....	155
DIET AND PHYSICAL ACTIVITY QUESTIONNAIRE .....	155
REFERENCES .....	170

## LIST OF FIGURES

Figure 1.1 Diagram representation of major system components BOD POD machine .	38
Figure 2.1 Clinic room Norwich building, North Adelaide where all appointments ..... were conducted .....	55
Table 2.2 Components of the Dietary Guideline Index-Children and Adolescents (DGI- CA) reflecting the 2013 Australian Dietary Guidelines .....	64
Figure 3.1 Flow of study participants .....	72
Table 3.1 Demographic characteristics of primary and secondary carers of the DOMInO study at 7 years of age.....	75
Table 3.2 Body composition outcomes by treatment group .....	79
Table 3.3 Body composition outcomes by sex .....	80
Table 3.4 Anthropometric outcomes by treatment group .....	82
Table 3.5 Anthropometric outcomes by sex .....	83
Table 3.6 BMI for age cut off levels for overweight and obesity in 7 year old children	89
Table 3.7 Differences between number of children classified as overweight and obese using WHO BMI-for-age (using average age) vs WHO BMI z-score (using actual age) .....	90
Table 4.1 DGI-CA total and component scores and percentage of children in the control and DHA groups achieving maximum component score .....	101
Table 4.2 DGI-CA total and component scores and percentage of male and female children achieving maximum component score .....	104
Figure 4.1 Relationship between BOD POD Fat Mass % and Total DGI-CA score ...	105
Table 4.3 Treatment Group Comparison of family food environment, physical activity and screen time at 7 years of age .....	109

Table 4.4 Male vs Female Comparison of family food environment, physical activity and screen time at 7 years of age .....	111
Table 5.1 Body composition outcomes.....	130
Figure 5.1 Relationship between BOD POD FM% and BIS FM % at 7 years of age in male and female children. ....	131
Figure 5.2 Bland-Altman of mean differences between percentage body fat (BF%) in male and female 7 year olds measured with the BOD POD and BIS.....	132
Figure 5.3 Bland-Altman of mean differences between percentage body fat (BF%) in female 7 year olds measured with the BOD POD and BIS. ....	133
Figure 5.4 Bland-Altman of mean differences between percentage body fat (BF%) in male 7 year olds measured with the BOD POD and BIS. ....	134
Figure 5.5 Relationship between BIS FM% and BMI at 7 years of age in male and female children. ....	135
Figure 5.6 Relationship between BOD POD FM% and BMI at 7 years of age in male and female children.....	135
Figure 5.7 Relationship between BIS FM% and BMI z-score at 7 years of age in male and female children.....	136
Figure 5.8 Relationship between BOD POD FM% and BMI z-score at 7 years of age in male and female children. ....	136

## ABSTRACT

The first 1000 days of a child's life, from conception to their second birthday, is a critical window of development during which environmental exposures have a particularly important role in determining the future health outcomes of a child. Omega-3 long chain polyunsaturated fatty acids (LCPUFAs) are essential fatty acids that play an important role in the health of the mother and growth and development of the fetus. On the basis of the role of n-3 LCPUFAs in decreasing fat deposition in adult rodents and *in vitro* studies, it has been hypothesised that an increased supply of n-3 LCPUFA, in particular docosahexaenoic acid (DHA) before birth, could reduce body fat mass later in childhood. However, there is a lack of robust evidence from human studies to support this.

The first aim of this thesis was to assess the impact of maternal n-3 fatty acid supplementation, chiefly as DHA, during pregnancy on the body fat mass of children at 7 years of age using Air Displacement Plethysmography (ADP). This study was a follow-up of the largest RCT to date to examine the effect of maternal n-3 LCPUFA supplementation on maternal/infant outcomes, the DOMInO (DHA to Optimise Mother Infant Outcome) trial in which the women were supplemented with 800mg DHA/day from 20 weeks gestation to delivery. The second aim was to undertake a comparison of the body composition results obtained using the BOD POD with Bioelectrical Impedance Spectroscopy (BIS).

A total of 252 children participated in this study. During clinic appointments, body composition testing was conducted using both ADP and BIS. Anthropometric measurements including weight, height, waist and hip circumference were obtained. The child's dietary information was obtained using a Diet and Physical Activity Questionnaire

which included 116 food frequency questions. Nutritional intake was assessed using the Healthy Diet Index for children (HDI-CA).

I found no effect of maternal DHA supplementation on body fat mass, assessed by either BIS or BOD POD, BMI z-score or any other anthropometric measures in the children at 7 years of age. While the results for body fat mass obtained using the BIS and BOD POD were significantly correlated, BIS consistently over estimated body fat mass in comparison with the BOD POD, especially in girls. Most children showed a poor compliance to the Australian Dietary Guidelines, and this was not affected by maternal DHA supplementation.

The findings from this thesis provide new and important insights into our understanding of the relative importance of the nutritional environment before birth, in early infancy and later in childhood on body composition and the risk of obesity. The results from the comparison of body composition methods in this thesis highlights the variation that can occur between methods and therefore the importance of using the same method in studies where the aim is to directly compare results. In conclusion, high dose maternal DHA supplementation had no significant positive or negative effect on childhood growth/body composition, at least until 7 years of age, and is therefore not likely to be an effective strategy for addressing the current obesity epidemic.

## 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.

.....

Katie Wood

## ACKNOWLEDGEMENTS

It seems in life your direction can change at any given moment and for this reason I am grateful. In the beginning of this PhD chapter in my life I was lucky enough to have two mentors, who not only encouraged this direction in my research career but passed on their passion for what research is all about, that we can make a difference. For this, my heartfelt thanks firstly goes to Bev Muhlhausler and Evangeline Mantzioris for your never ending support throughout this process. I also wish to sincerely thank my co-supervisors Jennifer Couper and Barbara Lingwood for your involvement and feedback throughout my PhD.

Bev, thank you for being the most amazing primary supervisor anyone could ask for. In times of doubt you reassured me that everything was fine. I always felt comfort in the fact you were there if I needed you. Your support throughout my PhD has been constant, your never ending feedback has helped me grow and your love of science has inspired me in so many ways to what is possible. The excitement of receiving corgi stickers has never faded!

Evangeline, I thank you for your ongoing support and guidance throughout these last few years with your experience and honesty. You were always there to put me on the right track when things weren't going to plan. I loved being able to chat over a coffee, enjoy a laugh and have the opportunity to work together. You have not only been an incredible supervisor, but I value you as a mentor and a friend.

To my wonderful colleagues in the FOODplus Research group at Waite. Your support and friendship throughout this time has been incredible. I cannot name you all but you know who you are. In particular, a big thanks to Yichao Huang who has been there from the beginning, we have enjoyed many conversations about life and our PhD studies and you have always had the time to help me when I needed it. Liu Ge, for teaching and

explaining to me many statistical tests along the way and for your cheeky personality. Jing Zhou, who sat beside me for many years, thank you for being a beautiful friend. John Carragher, for your honesty, advice and sense of humour. I couldn't have asked for a more fantastic group of people to work with!

To the staff at WCHRI who helped me set up my clinic room, showed me how to measure children, assisted me when I needed it, your help along the way is greatly appreciated. To the DOMInO families who participated in this study, this research would not have been possible without you.

To the most important of all, my friends and family. To my parents for always being there unconditionally, always believing in me and moulding me into the person I am today. To my beautiful children, Lucy and Mitchell, you are my world, and I'm hoping that I have shown you that anything in life is possible. Reach for the stars!

To my husband Anthony, my world and my rock. I could not have done this without you. Juggling family and study and work – we did this together. You have never questioned my ability in anything, you told me I could do things when I said I couldn't possibly do them. You helped me get to the finish line in so many ways and I cannot express what that means to me.

This PhD would not be a thesis without all of the support I have received over the last few years and it represents something that I never dreamt possible. This experience has been life changing, challenging, and in the end, worth every moment.

## LIST OF ABBREVIATIONS

2C	Two compartment model
3C	Three compartment model
4C	Four compartment model
AA	Arachidonic acid
ADP	Air Displacement Plethysmography
AGHE	Australian Guide to Healthy Eating
AHS	Australian Health Survey
ALA	Alpha Linolenic Acid
BF	Body Fat
BIA	Bioelectrical Impedance Analysis
BIS	Bioelectric Impedance Spectroscopy
BMC	Bone Mineral Content
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
CHD	Coronary Heart Disease
CNRC	Child Nutrition Research Centre
CT	Computed Tomography
CV	Coefficient of Variation
Db	Body Density
DGI-CA	Dietary Guideline Index for Children and Adolescents
DHA	Docosahexaenoic acid
DOMInO	DHA for Optimising Mother and Infant Outcomes
DVD	Digital Video Disc
DXA	Dual energy x-ray absorptiometry
EAPM	European Association of Perinatal Medicine
EPA	Eicosapentaenoic acid
ESPEN	European Society for Clinical Nutrition
FFM	Fat Free Mass
FFQ	Food Frequency Questionnaire
FM	Fat Mass
FMC	Flinders Medical Centre
FSANZ	Food Standards Australia New Zealand

HDI	Healthy Diet Index
HDL	High-density lipoprotein
IOTF	The International Obesity Taskforce
IQR	Interquartile Range
ISSFAL	International Society for the study of Fatty Acids and Lipids
LA	Linoleic acid
LCPUFA	Long Chain Polyunsaturated Fatty Acids
LDL	Low-density lipoprotein
MRI	Magnetic Resonance Imaging
N-3	Omega 3
N-6	Omega 6
NEAF	National Ethics Application Form
NHMRC	National Medical and Research Council
NNPAS	National Nutrition and Physical Activity Survey
NNS	National Nutrition Survey
PUFA	Polyunsaturated Fatty Acids
RCT	Randomised Controlled Trial
SAA	Surface Area Artefact
SD	Standard Deviation
SFT	Skinfold Thickness
SSA	Site Specific Application
TBW	Total Body Water
TGV/V <sub>TG</sub>	Thoracic gas volume
V <sub>b<sub>raw</sub></sub>	Raw Body Volume
WCH	Women's and Children's Hospital
WCHN	Women's and Children's Health Network
WHO	World Health Organisation
WtHR	Waist:Height ratio