Early Mother-Child Relationships Influence Weight Regulation in Pre-School Children

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Abstract

While there has been significant historical interest in how the maternal-infant dyadic relationship shapes eating behaviour and obesity risk, only recently have systematic, longitudinal studies of this association been reported. The current thesis both replicates and extends this recent work using three studies based on the MAVAN developmental cohort: **Study 1** examined the association between 6 month maternal sensitivity scores and BMI z-scores measured at 48 months of age. As hypothesized, low maternal sensitivity early in life was associated with higher BMI z-scores and an increased likelihood of being at risk for overweight, overweight or obese in girls but not boys. These findings replicate recent work by Anderson SE et al (2012); we provide the first evidence of a possible sex difference in this relationship, and extend prior findings to the pre-school years. **Study 2** examined whether emotional overeating, food responsiveness, and/or enjoyment of food at 48 months as assessed using the Children’s Eating Behaviour Questionnaire (CEBQ) mediated the relationship between 6 month maternal sensitivity scores and BMI z-scores at 48 months. Results indicated that only emotional overeating was a significant mediator of this
association for girls but not for boys. Further analysis revealed that in girls only, low maternal sensitivity was associated with an increased likelihood of being at risk for overweight in connection with emotional overeating. **Study 3** examined whether exclusive breastfeeding at 6 months moderates the relationship between 6 month maternal sensitivity scores and BMI z-scores measured at 48 months of age, and whether the sex of the child might further moderate this association. The results supported the general working hypothesis that exclusive breastfeeding at age 6 months moderates the association between maternal sensitivity at 6 months and child BMI z-scores at 48 months. Overall these results demonstrated another highly novel developmental trajectory relevant to early weight regulation, and offered new support for current WHO recommendations for exclusive breastfeeding through 6 months of age.

Taken together, these three studies have demonstrated that early maternal sensitivity provides a significant influence on child weight regulation/BMI in the pre-school years, moderated by sex and exclusive breastfeeding and mediated by emotional overeating.
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I would like to dedicate this thesis to mothers and their children!

> There are only two lasting bequests we can hope to give to our children. One of these is "roots" and the other is "wings"…

> W. Hodder Carter
Contributions

Barbara Wendland (author) was solely responsible for preparation of this thesis, including planning, design, and analyses, and preparation of all manuscripts.

This thesis was based on data from the Maternal Adversity, Vulnerability, and Neurodevelopment (MAVAN) project, a multi-centre study with recruitment sites in Montreal, P.Q. and Hamilton, ON. I would like to thank the entire MAVAN team, with particular thanks to the individuals mentioned below:

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Abbreviations

ACTH – Adrenocorticotropic hormone
ADHD – Attention deficit/hyperactivity disorder
BMI – Body Mass Index
BMI z-score – WHO BMI z-scores
CRH – Corticotropin Releasing Hormone
CEBQ – Children’s Eating Behaviour Questionnaire
CORT - Cortisol
DEBQ – Dutch Eating Behaviour Questionnaire
DXA – Dual Energy X-ray Absorptiometry
EF – Enjoyment of Food
EO – Emotional Over-Eating
FBT – Family Based Behavioural Treatment
FR – Food Responsiveness
FU – Food Fussiness
GC – Glucocorticoid
GEN-R – Generation Rotterdam
GDM – Gestational Diabetes Mellitus
HPA – Hypothalamic-Pituitary-Adrenal Axis
IUGR – Intrauterine Growth Restriction
MAVAN – Maternal Adversity, Vulnerability, and Neurodevelopment
MBQS – Maternal Behavioural Q-Sort
OXT – Oxytocin
PRT – Prolactin
SES – Socioeconomic Status
SE – Slowness in Eating
SR – Satiety Responsiveness
WHO – World Health Organization
Chapter 1

Prologue
As I reflect on the journey that led to this dissertation it is clear that my clinical experience with families as a practising pediatric nutritionist was the primary inspiration. Over the 25 years of my clinical experience it became more and more evident that inter-personal and emotional factors were a critical aspect of the obesity puzzle, even in very young children. However, I did not have the knowledge base or tools from which to understand this systematically. This led me back to academia and an opportunity to study childhood obesity based on the maternal-infant dyadic relationship using an attachment theory/maternal sensitivity perspective.

As a clinician in major paediatric hospitals I was exposed to numerous stories about illness, relationships and family, and observed the tremendous stress on mothers who were dealing with one or more health issues in their children. I observed that some mothers were able to demonstrate warmth and security towards their children despite very difficult circumstances, while others exuded fear with what appeared to be less objective stress. Could these different coping styles influence the long term metabolic risk of the children and could interventions be developed to better educate and support the higher risk mothers in particular?

At the beginning of my doctoral degree there was a lack of published work using systematic scoring to assess the mother-child dyadic relationship as it relates to weight regulation. Subsequent to initiating my thesis work a few such studies began to emerge (Anderson SE et al, 2011; 2012). The current research both replicates and extends this recent work as described in more detail below.
I firmly believe that studying the early origins of weight regulation within the dyadic relationship in pre-school children will provide significant new insights on childhood obesity. At this stage in development children are exposed to highly palatable foods along with several other environmental cues. It is possible that the early feeding relationship within the dyadic relationship shapes several later behaviours relevant to weight regulation/obesity, including obesogenic food choices.

1.1 Statement of Purpose

The primary goal of the proposed research is to examine how systematic assessments of the mother-child dyadic relationship predict early overweight/obesity risk using an attachment theory/maternal sensitivity framework.

1.2 Primary Research Questions:

Study 1: Is there an association between maternal sensitivity measured at 6 months of age and child BMI z-scores at 48 months?

Study 2: Is the relationship between maternal sensitivity at 6 months and child BMI z-scores at 48 months mediated by CEBQ-eating styles i.e. emotional overeating, food responsiveness, and/or enjoyment of food?

Study 3: Does breastfeeding influence the relationship between maternal sensitivity at 6 months and child BMI z-scores at 48 months?
The theoretical model for this thesis begins with the relationship between maternal sensitivity at 6 months of age and child BMI z-scores at 48 months. Based on prior research by Anderson SE et al (2012), our first hypothesis was that low maternal sensitivity (at 6 months of age) would be associated with higher BMI z-scores (at 48 months of age) in the children. As the BMI trajectory of pre-adolescent girls is strongly influenced by environmental factors, while that of boys is more genetic in origin (Dubois L et al, 2012), we further hypothesized that the association between maternal sensitivity and BMI would be greater in girls.
The second study examines whether the relationship between maternal sensitivity at 6 months and BMI z-scores at 48 months is mediated by eating styles as assessed using the Children’s Eating Behaviour Questionnaire (CEBQ). We focused on three eating styles that are likely to contribute to overeating and weight gain on the one hand, and have a theoretical link with mood and affect regulation on the other i.e. emotional overeating, food responsiveness and enjoyment of food. We focused on eating styles with a mood/affective component based on the idea that low maternal sensitivity might lead to problems with emotion regulation in the children, and that consumption of highly palatable food could be used as a strategy to compensate for this (first based on mother’s choices, then learned by child over time).

The focus of the third study was to explore exclusive breastfeeding at 6 months as a second potential moderator of the association between maternal sensitivity at 6 months and BMI z-scores at 48 months. Given prior evidence that breastfeeding can protect from pathological weight gain, and given its potential overall benefit for the quality of the mother-child dyadic relationship, we hypothesized that breastfeeding would weaken the relationship between low maternal sensitivity and higher BMIs. We were most interested in determining whether exclusive breastfeeding at 6 months, which is the current WHO recommendation, would protect children exposed to low maternal sensitivity from developing higher BMIs.
Chapter 2

Review of the Literature
2.0. Introduction and Guide to the Literature Review:

The current thesis examines how systematic measures of the mother-child dyadic relationship, and maternal sensitivity in particular, predict early overweight/obesity risk. Given that obesity research and attachment/maternal sensitivity research are both vast in size, these sections of the literature review were limited to those topics of greatest relevance to this particular project.

As will be argued below, there is significant reason to believe that one or more of the processes under investigation would be expressed differently in girls vs. boys. In light of this, potential sex differences are discussed at various points in this review.

2.1. Review of Childhood Overweight-Obesity and Early Weight Regulation

2.1.1. Epidemiology and Economic Costs of Overweight/Obesity

Although we think of child overweight-obesity as a recent problem, North American children have exhibited steadily increasing body weights since the 1970s. It is only recently that public health interests have engaged in this dilemma, as serious over-weight and obesity have been escalating, along with complications such as insulin resistance and type 2 diabetes, which are occurring now in school-age children and adolescents (Ludwig DS, 2007; Whitaker RC et al, 1997).

While historically, child overweight-obesity was seen as a problem of developed countries (Shields M, 2006; Ogden CL et al, 2010; Roberts KC et al, 2012) it has now become a concern in developing countries as well (Wang Y and
Lobstein T, 2006; de Onis M, et al, 2010; Lobstein T, 2011). With respect to Canada, between 1981 to 1996, the prevalence of overweight status in young children increased from 15% to 28.8% in boys and from 15% to 23.6% in girls. Over this time, body mass indices (BMI) have increased at a rate of about 0.1 kg/m² for both boys and girls, reflecting a progressive upward trend in BMI measures over time (Tremblay MS and Willms JD, 2000). Strikingly, the 2009-2011 Canadian Health Measures Survey (CHMS) revealed that about a third of children between ages 5 and 11 years were overweight or obese, with obesity rates per se differing between boys (at 19.5%) and girls (at 6.3%) (Roberts KC et al, 2012).

Consistent with the Canadian data, American surveys from 1999-2010 indicate that 9.5 percent of infants and toddlers had weights above the 95th percentile of weight for length based on historical growth curves, while for children aged 2-19 years 11.9 percent were above the 97th percentile of BMI, and 31.7 percent were above the 85th percentile of BMI for age (Ogden CL et al, 2010). In the 2011-2012 survey 8.1% of infants to 2 years were found to have high weight for length, and 16.9% of children between 2 to 19 years and 34.9% of adults were identified as being obese. This survey indicated that there has been a plateau on obesity measures identified through 2003-2004 forward, however the prevalence of obesity continues to be at unacceptable levels (Ogden CL, 2014).

The gradual increase in overweight-obesity rates in developed countries such as Canada and the U.S. has brought with it diagnoses of type 2 diabetes in
adolescent and pre-adolescent children, with related complications such as metabolic syndrome starting in early adulthood in some individuals (Canadian Task Force on Preventive Health Care, 2015; Roberts KC et al, 2012). Quality of life and life expectancy will decrease in such cases (Canadian Task Force on Preventive Health Care, 2015) while associated healthcare costs will continue to escalate over time.

Definition of Overweight-Obesity in Children

Child overweight-obesity can be defined as the accumulation of high fat stores or adipose tissue in relation to lean body mass (WHO, 2006). Measurement of percentage body fat is the ideal approach to quantify adiposity, and in adults can be done using a variety of methods including assessment of skin-fold thickness, plethysmography, bio-impedance and/or imaging techniques such as Dual Energy X-ray absorptiometry (DXA). While useful in adults, implementation of these methods is impractical in young children, and for the most part lacks standardization (Katzmarzyk PT et al, 2007). This being the case, the majority of weight regulation studies in young children is based on body mass index (BMI), using standardized z-scores calculated separately for boys and girls.

While BMI is often thought to be a marker of body fatness, it is actually a measure of weight status, calculated using weight in kg divided by length in metres squared (BMI = weight (kg)/ length (m²)). BMI does not differentiate between excess fat, muscle, or bone mass, nor does it specify the distribution of fat within the body. Sex differences, age, and muscle mass can further change
the association between BMI and body fat (Gallagher D et al, 1996; Must A and Anderson SE, 2006). Given these limitations, some have argued that BMI is best used as a screening tool to monitor for overweight-obesity and health risk factors (Katzmarzyk PT et al, 2007). Others have suggested that BMI z-score changes can be a valid proxy for body fat evaluation, particularly when performed by skilled clinicians (Rudolf MC et al, 2012; Kakinami L et al, 2014).

2.1.2. Medical and Psychiatric Co-morbidity

It is well established that pathological weight gain early in life increases the risk of chronic overweight-obesity along with insulin resistance, type 2 diabetes and the metabolic syndrome (Weiss R et al, 2004; Baker JL et al, 2007; Tiroshi A et al, 2011). In addition to these early metabolic changes, a host of other conditions such as asthma, sleep apnea, and hypertension are associated with chronic overweight-obesity in many children (Singhal A, 2013). At a psycho-emotional level, many overweight children struggle with anxiety and/ or depression along with low self-esteem, which negatively influence early social relationships and overall functioning (Puhl RM and Heuer, CA, 2009). A recent study of children between six to ten years of age found that those who were overweight or obese were not able to activate the cognitive effort needed to inhibit involuntary responses and to switch between different mental operations (Blanco-Gomez E et al, 2015). Over time, these various co-morbid conditions contribute to a variety of complex obesity phenotypes that are challenging to treat.
effectively (Dietz WH, 1998; Biro FM and Wien M, 2010). This adds further to morbidity and mortality across the lifespan while adding yet more medical costs.

2.1.3. Early Life Factors Contributing to Childhood Weight Regulation

Causes of overweight status and obesity are complex and are likely to include a myriad of biological, psycho-social, psychological, and economic factors that operate at both an individual and societal level (Weiss R et al, 2004; Sinha R et al, 2002; Franks PW et al, 2010; D'Adamo E et al, 2009; Papadaki A et al, 2010). Dietz WH and Gortmaker SL (2001) point to three distinct critical periods for the development of obesity early in life i.e. the intrauterine environment into early infancy, the early preschool years, and adolescence. The following is a brief summary of the major factors that play a role in childhood weight regulation and obesity risk.

2.1.3.1. Genetic Factors

Extensive research in both adults and children has identified a strong role for genetics in anthropometric measures including BMI. Twin studies suggest that shared environmental factors also contribute significantly to BMI in early life and throughout childhood (Silventoinen K et al, 2009), though become less important in adulthood (Schousboe K et al, 2003).

A recent international study of over 12,000 twin pairs explored the relative importance of genetic and environment factors on child growth over early development (Dubois L et al, 2012). This study found that the heritability for body
weight, height, and BMI is low at birth (6.4 - 8.7% for boys and 4.8 - 7.9% for girls) but accounts for about half of the variance in body weight and BMI after just 5 months of age in both sexes (Dubois L et al, 2012). Genetics played an increasingly important role in explaining the variation in weight, height, and BMI from early childhood to late adolescence, particularly in boys. On the other hand, common environmental factors exerted their strongest and most independent influence in the pre-adolescent years and more significantly in girls. This work demonstrates that the role of genetics vs. environmental factors on weight regulation changes from birth through adolescence, and is different in the two sexes. As suggested by these authors, “these findings emphasize the need to target family and social environmental interventions in early childhood years, especially for females” (Dubois L et al, 2012).

2.1.3.2. Pre-Natal Factors and Fetal Development

Pre-natal factors that contribute to early over-weight/obesity risk in children include increased maternal BMI (both prenatally and during gestation e.g. Whitaker RC, 2004; Hillier TA et al, 2007), and gestational diabetes in conjunction with elevated weight (Crume TL et al, 2011; Catalano PM and Thomas A, 2007). Women who are significantly overweight before pregnancy have a greater risk of developing gestational diabetes mellitus (GDM), establishing both a genetic and environmental risk for obesity in their children (Nelson SM et al, 2010; Herring SJ and Oken E, 2011; Ludwig DS and Currie J, 2011). With the increasing prevalence of maternal obesity and gestational
diabetes mellitus (GDM), there is a need to understand the specific mechanisms that mediate their effect on child obesity risk.

Using a large retrospective cohort study among mother-nurse daughter dyads from the Nurses' Health Study data (N=35,826), Stuebe AM et al (2009) analyzed the relationship between recalled maternal pre-pregnancy BMI, gestational weight gain and obesity risk in daughters from adolescence into adult life. Mothers with a high pre-pregnancy BMI were more likely to have daughters with a high BMI at age 18; excessive maternal weight gain during pregnancy as well as high pre-pregnancy BMI was associated with adolescent and adult adiposity in the daughters. Reynolds RM et al (2010) examined how maternal parity, BMI and gestational weight gain influenced adiposity in the offspring in early adulthood. Results indicated that increased maternal BMI in pregnancy, increased gestational weight gain and primi-parity all contributed independently to this risk.

The effect of maternal pre-pregnancy BMI on offspring body composition may differ in the 2 sexes. For example, Andres A et al. (2015) found that boys born to obese mothers have higher body fat from 2-6 years compared to other boys, while no such relationship was found in girls.

Mothers who smoke cigarettes during gestation deliver more infants who are at a lower weight, lower height, and have a smaller head circumference than do other children. Despite this inhibitory effect of smoking on early growth, a disproportionate number of these children will develop abnormally high BMIs over time (Grzeskowiak et al, 2015). Low birth weight is often used as a non-
specific marker of in utero stress, and has been associated with both low and high extremes of BMI over time (Ludwig DS and Currie J, 2011; Barker DJP et al, 1993). While in modern developed societies, high birth weights are the more common cause of high childhood BMIs, the combination of low birth weight and very rapid catch-up growth can also be problematic in this regard (Martin A et al, 2016).

2.1.3.3. Early Post-Natal Factors: Breastfeeding

Children of mothers taking part in the Nurses’ Health Study II, who participated in the Growing-Up Today Study cohort (n= 7155 boys and n= 8186 girls) were surveyed to evaluate whether overweight in adolescence is associated with the type and duration of infant feeding. Children with greater frequency and/or duration of breastfeeding had a lower risk of overweight in childhood and adolescence (Gillman MW et, 2001). Armstrong and Reilly JJ, (2002), in a large cohort of children between 39-42 months, also found that the prevalence of obesity was significantly lower in children who were breastfed. Systematic reviews published since 2004 suggest that breastfeeding is associated with a small but consistent protective effect against obesity in later childhood (Arenz SD et al, 2004; Harder T et al, 2005). Some work suggests that the specific type and duration of breastfeeding may be important in moderating this obesity risk. For example, infants who are exclusively breastfed have a slightly lower mean BMI compared to those using substitute formula feedings (Owen CG et al, 2005). Bergmann KE et al (2003) showed that breastfeeding for
≥ 3 months afforded greater protection from child adiposity, while other work has shown that children with the highest risk for weight gain patterns in infancy may benefit the most from longer breastfeeding duration (Carling SJ et al, 2015).

While work to date suggests that breastfeeding has some protective effect on later obesity risk, methodological issues including inconsistent measurement of potential confounding variables, and a lack of understanding of the specific mechanisms that might account for findings to date, limit the impact of this work somewhat. The strongest finding to date is for an inverse relationship between breastfeeding duration and subsequent obesity risk in both observational and prospective studies. Unfortunately, several factors interfere with this protective effect of breastfeeding, including maternal overweight, maternal smoking habits during pregnancy, low social economic class, and the use of substitute formula feedings.

The Interaction of Maternal (BMI) and Breastfeeding on Child Obesity Risk

Baker JL et al (2004) studied the effects of maternal pre-pregnancy BMI, duration of breastfeeding, and timing of complementary food introduction on infant growth in a cohort of mother-infants dyads. Infant weight gain was associated with maternal pre-pregnant BMI and with an interaction between the duration of breastfeeding and the timing of complementary food introduction. In a follow-up paper (Baker JL et al, 2007) investigated how gestational weight gain related to both the pre-pregnant BMI and the duration of breastfeeding; they
found that the greater the pre-pregnant BMI, the earlier the termination of breastfeeding, even in a sociocultural context which strongly supports breastfeeding. A systematic review of maternal obesity and breastfeeding indicated that obese women were less likely to begin breastfeeding, and if they did start it would be for a shorter time compared to normal weight mothers – even after including covariates (Amir LH and Donath S, 2007).

Rasmussen KM and Kjolhede CL (2004) reported that overweight-obese women have a lower prolactin response to suckling from the infant, which would compromise the ability of the mother to produce milk, and suggests one specific biological mechanism that interferes with breastfeeding. Section 2.3.2. of this chapter will include recent work on hormones in breast milk that link with overweight-obesity risk.

### 2.1.3.4. Family Structure and Function

There are numerous ways by which the family environment influences eating behaviour and obesity risk. Longstanding family practices often influence food preferences and patterns of eating (Birch LL and Davidson KK, 2001; Faith MS et al, 2004; Moens E et al, 2007), which can be either protective or problematic in a given case. For example, if parents eat many 'fast food' meals throughout the day, their children tended to model this behaviour over time (Jansen PW et al, 2012). Given the important role of modelling in establishing long term eating patterns, education and simple interventions to guide parents
and their children is a fundamental aspect of obesity prevention (Jansen PW et al, 2012).

Parenting that is harsh and authoritarian is also a potential risk factor for childhood obesity, and may reflect issues with emotional regulation in the children (Decaluwe V et al, 2006; Moens E et al, 2007; Goossens L et al, 2009). While the natural response towards fear and stress is often reduced appetite (Macht M, 2008), many children will ultimately increase their food intake in response to negative moods while losing their sensitivity to more homeostatic hunger and satiety cues (van Strien T and Bazelier F, 2007).

The combination of single parenting, minimal education and financial strain can create a particularly challenging early environment that contributes to several negative health outcomes including childhood obesity (Suglia SF et al, 2012; Dubois L et al, 2006). In addition to their psychological effect, "social environments and experiences during sensitive periods in brain and biological development affect health for the balance of the life course through a process called biological embedding" (Hertzman C, 2013). Emerging evidence suggests that physiological systems critical for stress regulation and weight regulation, including the HPA-axis, may be affected in this way (e.g. Champagne F and Meaney M, 2001).

2.1.4. Broader Environmental Variables

The rapid increase in childhood obesity rates over a very short period of recent human history suggests the involvement of broad societal factors. The
widespread availability of highly palatable, high caloric foods in many developed and developing countries is a major contributor in this regard (Blundell JE and Cooling J, 2000). The evolutionary processes that promoted survival in pre-historic times during long periods of famine are not well suited to maintain a stable metabolic balance given a highly processed, high energy food environment (Mietus-Snyder ML and Lustig RH, 2008; Papadaki A et al, 2010). However, not all children are experiencing problems with weight management in this 'obesogenic' environment; understanding the factors that differentiate low and high risk children given this broader environmental context is thus a critical issue for the field going forward.

Another broad societal factor that has been linked to overweight and obesity, as well as low extremes of BMI in some cases, is psycho-social stress. The exposure of individuals to increasingly high stress environments (Twenge JM, 2000), combined with the ease of availability of highly palatable, high caloric foods which temporarily improve mood (“comfort food”), is likely to be a major contributor in this regard (Blundell JE and Cooling J, 2000; Dallman MF et al, 2003; Papadaki A et al, 2010). As mentioned above, the link between societal stress and increased rates of obesity is likely to have a strong intergenerational component, as parenting stress has major effects on several processes critical to obesity risk including food choices and the link between eating behaviour and emotion (Birch LL et al, 2001; Birch LL, 2006; Decaluwe V et al, 2006; Bosmans G et al, 2009). Understanding the specific mechanisms that link parenting stress
with early pathological weight gain, and developing novel interventions to address these mechanisms, is thus a high priority for child obesity research.

2.1.5. The Prevention and Treatment of Childhood Obesity

Prevention:

As discussed by Gillman MW and Ludwig DS (2013), the prevention of childhood obesity begins with pregnancy and the early post-natal environment. Monitoring higher risk mothers to control gestational weight gain, and supporting abstinence from smoking where possible are two common targets in this regard. Motivating mothers to breastfeed their infants for as long as 12 months, and to have infants sleep for 12 hours a day were identified as important steps in the early post-natal period. Public health approaches to early prevention have focused on the promotion of healthy eating patterns and physical activity, as well as limiting sedentary behaviour and screen time as the children reach the school-age years and beyond (Brown CL et al, 2015). Parental education and family support have also been a key concern. While the incidence rates of childhood obesity have stabilized somewhat, they remain at unacceptable levels in developed countries, suggesting that novel preventative strategies are needed going forward.

Treatment Approaches:

Recent reviews suggest that the best psychological and behavioural treatments for childhood obesity include family-based behavioral treatment (FBT)
and Parent-Only Behavioral Treatment for children (Altman M and Wilfley DE, 2015). Educational interventions toward healthy eating habits and physical activity at school have also shown significant though partial benefit (Verrotti A et al, 2014). Possibly efficacious treatments include Parent-Only Behavioral Treatment for adolescents and Behavioral Weight Loss treatment with family involvement for toddlers, children, and adolescents. As outlined by Altman and Wilfley, most treatments considered efficacious are multicomponent interventions that include dietary and physical activity modifications using a behavioral approach. Such treatments are further optimized if family members are specifically targeted in the treatment.

*While a very large number of factors contribute to normal and abnormal weight regulation as reviewed above, the current thesis focuses on the role of the dyadic relationship with a particular focus on maternal sensitivity in the first year of life. The next section provides an historical overview of prior work on the dyadic relationship ending with a summary of more recent studies using highly systematic measures of attachment and maternal sensitivity.*
2.2. The Mother-Child Dyadic Relationship
Early Maternal Influences

"From the moment of conception there is a dynamic interaction between our genetic and hereditary properties and our environment" (Hart S, 2008), creating and shaping each new life. Beginning in foetal development and continuing through birth and beyond, a variety of factors influence the early mother-child dyadic relationship. The following sections will review the factors most relevant to this process, at both a biological and psychological level.

2.2.1. Maternal stress

Pregnancy is a time of great change at both a physical and emotional level, and each mother will experience these changes in a highly personal way. Maternal distress throughout pregnancy can influence foetal development through the exposure of stress hormones, cortisol and corticotrophin releasing hormone (CRH) (Weinstock M, 2008). Recent evidence has indicated that factors such as maternal stress, excessive glucocorticoids, abnormal insulin secretion associated with gestational diabetes, and inadequate nutrients have the greatest capacity to influence the pre-natal environment in a way that can influence the developing foetus throughout life (Cottrell EC and Seckl JR, 2009). Foetal programming is the term that describes how the developing foetus modifies its physiology to adjust to a changing environment within the placenta (Barker DJP et al, 1993; Glover V et al, 2010; Harris A and Seckl JR, 2011). Effects associated with foetal programming vary at different sensitive points influencing
the structure and function of the brain as well as peripheral organ systems leading to long term outcomes on the foetus/child and parent that will influence physiology, behaviour, and long term health (Glover V et al, 2010).

2.2.2. Low birth weight

Low birth weight is thought to be a non-specific marker of fetal environmental adversity and has been the focus of numerous studies linking foetal development with prenatal stress (Harris A and Seckl JR, 2011). Much of this work has focused on fetal undernutrition and the long term risk of metabolic syndrome and cardiovascular disease in adulthood. According to the thrifty phenotype hypothesis (Barker DJP, 1993), an adverse nutritional environment during pregnancy promotes adaptive changes including insulin resistance in the developing foetus to help it survive if the environmental conditions remain strained. According to this model, if conditions change and nutrients become widely available, as usually occurs in modern developed societies, these same changes prove maladaptive and become a risk factor for type 2 diabetes and its associated complications over the lifespan.

2.2.3. Pre-Natal Stress, Foetal Glucocorticoid Exposure-Obesity Risk

During pregnancy the developing foetus is protected from high levels of maternal glucocorticoids within the placenta by the enzyme 11β-HSD2. Recent pregnancy studies using maternal and foetal cortisol (using amniotic fluid or placenta) have found that maternal anxiety can increase fetal exposure to cortisol, which might be an important mechanism associated with foetal
programming (Glover V et al, 2009; O’Donnell KJ et al, 2012). In some cases, maternal stress may limit the ability of 11β-HSD2 to perform its protective function (Cottrell EC and Seckl JR, 2009). As outlined below, one possible manifestation of this increased glucocorticoid exposure is long term obesity risk.

Consistent with this model, Hohwa L and colleagues (2014) demonstrated that males in the military born to mothers who had experienced severe stress before, during and after pregnancy (n= 4813) were found to have a significant increased risk of overweight or obesity as adults. This same group reported that in a normal European cohort (N=655 pregnancies), children of mothers who had a greater concentration of salivary cortisol during pregnancy, particularly during the second trimester, were at greater risk of overweight over a 10-20 follow-up period compared to other children. A smaller study by Entringer S et al. (2015) found that high maternal cortisol levels were associated with adiposity and fat gain from birth through age 6 months. These initial studies suggest an association between prenatal stress and obesity risk mediated in part by glucocorticoid levels.

2.2.4. Gestational Diabetes Mellitus (GDM)

Gestational Diabetes Mellitus (GDM), defined as glucose intolerance which develops or is initially recognized during pregnancy, affects between 1.1-14.3% pregnant women (Lapolla A et al, 2011). Given the explosion of GDM over some decades along with the escalation of childhood overweight-obesity, there have been concerns that maternal GDM, which is related to higher birth weights
and child BMIs, might be a major contributor to the childhood obesity epidemic (Crume TL et al, 2011).

Gillman MW et al (2003) studied a large cohort of children and their mothers to examine the independent roles of maternal BMI, gestational diabetes mellitus (GDM) and birthweight on adolescent BMI. High birth weight was found to predict an increased risk of overweight in the children between 9-14 years of age. While having been born to a mother with GDM was also associated with increased adolescent overweight, the overall pattern of results suggested only a partial causal role of altered maternal-foetal glucose metabolism in the genesis of obesity in the offspring. The authors further suggested that within the family eating patterns and physical activities might be the same, establishing both a shared environmental risk and genetic risk for these children (Gillman MW et al, 2003).

Prior to pregnancy increasing numbers of women now have a BMI > 30 kg/m² which is within the overweight-obesity range. Pre-pregnancy obesity along with a risk of GDM during pregnancy, and perhaps also a further risk for long term insulin resistance creates a trajectory whereby maternal weight may influence metabolic dysfunction in pregnancy (Herring SJ and Oken E, 2011).

Some ten years after the work of Gillman MW et al (2003), a within family study design of 42,133 mothers who had given birth to more than one child and 91,045 children was used to study pregnancy weight gain and childhood weight (Ludwig DS et al, 2013). High pregnancy weight gain was related to increased body weight in the children, but the effect was only partly mediated through
higher birth weight. Similar to Gillman MW et al, these authors concluded that shared environmental factors and genetics were also likely contributors to the association between pregnancy weight gain and child BMI.

2.3. Maternal Perinatal Behaviours and Maternal Sensitivity

2.3.1. Early mother-child relationship

“Maternal behaviours” refer to those actions that occur just before and after parturition that lead up to the arrival of the infant, along with “maternal responses to the infant such as affect, attention, perceptions, behavioural flexibility, and learning” (Fleming AS, 2006). In pregnant animals maternal responsiveness is focussed towards the latter part of pregnancy before birth, related to changes in absolute oestrogen or the ratio of oestrogen and progesterone combining responsiveness with parturition (Fleming AS et al, 1997). In line with evidence that mothers might experience feelings towards the developing foetus in the second trimester and on to the early post-partum period a study using oestrogen and/ or the ratio of oestrogen and progesterone was undertaken. Fleming and colleagues found that over time maternal feelings of nurturance towards the foetus were confirmed but hormones did not seem to influence feelings of attachment over the pregnancy. Mothers with higher postpartum attachment feelings showed an increase in the oestrogen/ progesterone ratio towards delivery suggesting that the effects of hormones may influence feelings of nurturance through maternal well-being, however, human maternal responsiveness did not match that of animals (Fleming AS et al, 1997).
Prior to delivery the first hints of synchrony between mother and child are usually apparent in the third trimester of pregnancy, when oscillatory systems mediating the foetal sleep-wake cycle begin to mature (Feldman R, 2007). Within the third trimester assessments of both the biological clock (sleep-wake cycles) and the cardiac pacemaker (controlling heart rhythms) have identified clear biological signals of synchrony within the mother-child dyad (Feldman R, 2006). This early synchronous relationship within the placenta signals towards maternal behaviour near to parturition and lactation implying that offspring and their needs will soon be present (Giardino MW et al, 2008). Sensitive maternal responsiveness is defined by timely, contingent and applicable behaviours that recognize the needs of the infant (Corter C and Fleming AS, 2002).

Mother-infant interactions begin immediately after birth (Fleming AS et al, 2009), progressing into mutually responsive behaviours that include an increased awareness of body odour and body rhythms, vocalizations, and various forms of non-verbal communication including tactile stimulation, eye gaze, body movements and affect (Feldman R, 2007; Krpan KM et al, 2005; Fleming AS et al, 2009). In this early phase of post-partum, the neuropeptide hormone, oxytocin plays a role in the bonding between mother and infant (Feldman R et al, 2013). Levine A et al (2007) found that in the first month of post-partum concentrations of oxytocin demonstrated that there was stability and correlations with both maternal behaviour and maternal bonding. The authors suggest that it is possible that the hormone prolactin might be engaged with the maternal bond, perhaps through maternal caregiving and possibly with attachment (Jansen J et al, 2008).
The mother-child dyadic relationship has been characterized as a primary regulator of the infant (Fonagy P, 2001). Internal homeostatic regulation, controlling the modulation of stress and emotions is a priority for the developing infant along with social connections (Harrist AW and Waugh RM, 2002; Feldman R, 2006; Feldman R, 2007). In these early months of life the primary caregiver modulates states of arousal and emotional reactions (Harrist AW and Waugh RM, 2002; Feldman R, 2007). The maternal contribution to the early bond is greater than that of her infant however the infant does demonstrate needs, suggesting a potential dual relationship. The dyadic relationship has often been described as a ‘dance’ (Harrist AW and Waugh RM, 2002; Feldman R, 2007), between mother as the leader, and infant as the follower, whereby mother acts as a regulator of stress and emotions, and guides social interaction. If the ‘dance’ reflects a positive partnership, the regulation of stress and emotions may be maximized. Responsive mothering requires a great deal of sensitivity to the cues of infants, recognizing when and how best to regulate stress reactivity, being prepared emotionally as well as being motivated to engage socially while using consistency and self-control when relating to the infant (Barrett J and Fleming AS, 2011). In sum, the early post-natal period is a time to build on developing relationships along with internal homeostatic regulation of stress and emotions within the dyadic bond.

Mothers who are teenagers or clinically depressed are at risk of providing disrupted interactions with their infants (Krpan KM et al, 2005) and to have increased levels of cortisol, which is associated with depression and linked with
additional negative maternal behaviours (Krpan KM et al, 2005). Another risk factor for young children is difficulties with socio-emotional interactions within the mother-child relationship.

2.3.2. Breastfeeding – Nutrition and Relationships

Nutrition and Hormones

From a biological perspective, breastfeeding offers a natural source of nutrients for infants as well as providing immune factors, antibodies, and enzymes which confer protection against infections. There is increasing evidence that human breastfeeding has another benefit, involving hormones which are recognized as protective towards glucose homeostasis and childhood obesity (Savino F et al, 2009). Human milk includes a wide variety of hormones that play a role in energy balance and the regulation of food intake including growth factors, adipokines, leptin and adiponectin, ghrelin, resistin and obestatin (Savino F et al, 2009). The arcuate nucleus of the hypothalamus has receptors for leptin and ghrelin, which play a major role in appetite and act as mediators between the adipose tissue, the gastrointestinal tract and the brain (Schwartz MW, Woods SC, Porte DJ et al, 2000). The pathways involved in appetite regulation develop early in postnatal life, and play a major role in shaping growth trajectories (Cripps RL et al, 2005). Early infant feeding has different effects on growth and body composition depending on whether breastfeeding or substitute formulas are used.- this is described in greater detail in Section 6.3.4. (e.g. Gale C et al, 2012).
Ghrelin is a gastrointestinal peptide which acts as a ‘hungry signal’; in the short-term ghrelin regulates food intake through stimulating appetite, while in the long term this hormone regulates weight and metabolism. In the long term ghrelin is associated with adipocytes, which are important for metabolic homeostasis: a tight regulation between insulin on one side and glucagon, ACTH, epinephrine to balance back into homeostasis (Cummings DE, 2006). The presence of this hormone in breast milk possibly underlines the importance of the early metabolic development of infants (Savino F et al, 2009). Leptin is a hormone which is created from adipocytes and regulates energy balance by ‘inhibiting hunger’ which is the opposite of ghrelin, which regulates energy balance is the ‘hunger hormone’ (Savino F et al, 2011).

The work of Miralles A et al (2006) demonstrates that breastfeeding for at least 6 months, by mothers who are not obese, could influence body weight gain in infants, acting as a protection to infants from additional weight gain. Unlike formula feedings, breast milk has leptin, a hormone that regulates food intake and balances energy; attaining leptin within breast milk might explain how the regulation of body weight in infancy on breastfeeding for 6 months could be protective compared to infants who are on formula feedings (Miralles A et al, 2006).

A recent systematic review on the relationship between maternal BMI, hormones and breast milk indicated a positive association between maternal BMI and breast milk leptin concentration in most studies, while no such relationship was found for breast milk adiponectin concentrations. The authors suggested
that there was a need for further research for the other hormones: insulin, ghrelin, resistin, obestatin, peptide YY and glucagon-like peptide-1, as most studies to date have had a narrow focus (Andreas NJ et al, 2014).

Lucas suggests that differences in growth and body composition between breastfeeding and substitute formulas “might be associated with a different endocrine response to feeding or to bioactive substances present in breast milk that could influence infants’ response to energy intake and metabolism” (Lucas, 1980).

Chapter 6, section 6.3.3. provides information on exclusive breastfeeding.

Breastfeeding and the Mother-Child Relationship

In addition to providing nutrition for health and development, breastfeeding has been identified as a key contributor to the early mother-infant relationship, although some aspects of this work remain controversial.

Harlow’s research on the rearing of infant rhesus macaque monkeys used two surrogate mothers constructed of wire, one covered with a comfortable soft cloth and the other with a nipple to enable feeding. This work demonstrated how the biological needs for feeding and the psychological needs for connection were quite different (Harlow H and Suomi S, 1970). The infant monkey behaviours revealed that the surrogate mother with a comfortable cloth was more desirable as a safe place rather than the one with the nipple for food, suggesting a need for a ‘secure base’ on which to regulate stress and emotions.

Recent advances in neurobiology using standardized assessments of mother-child interactions have provided novel insights on mechanisms underlying
breastfeeding and mother-child bonding. Compared with formula-feeding mothers, those who breastfeed show increased parasympathetic nervous system modulation, greater vascular stress response, lower perceived stress levels and fewer depressive symptoms (Kim P et al, 2011), which may facilitate the early bonding relationship. This same group studied maternal brain activity in response to her baby’s cry vs. that of an unfamiliar infant using MRI. Findings identified links between breastfeeding and greater response to infant cues mediated by brain regions such as the superior frontal gyrus, insula, striatum and amygdala that have been implicated in maternal-infant bonding and empathy (Kim P et al, 2011).

Britton JR et al (2006) tested the hypothesis that breastfeeding is associated with enhanced infant-mother attachment and maternal sensitivity. While no direct relationship between attachment security and breastfeeding was demonstrated, their data suggested that breastfeeding mothers may be more sensitive in responding to the cues of their infants than are non-breastfeeding mothers. As well, sensitive mothering was recognized among mothers who continued to exclusively breastfeed through 3 months postpartum (Britton JR et al, 2006).

Pearson RM et al (2011) tested whether breastfeeding is associated with sensitive maternal responses. These authors recruited 51 mothers in the latter phase of pregnancy, who were followed at 3 and 6 months post-partum, to evaluate how infant feedings (n=27 breastfeeding and n=24 formula) might relate to sensitive maternal responses. While there was no direct relationship between
sensitive maternal responses towards infants who were breastfed, their data suggested that breastfeeding mothers may have a greater attentional engagement with infant distress signals compared to infants who were not breastfed. The cohort of 51 mothers was relatively small, and as the authors indicated, it is possible that mothers who choose to use breastfeeding might be more sensitive than those who choose to not use breastfeeding (Pearson RM, 2011; Britton JR et al, 2006).

A recent study investigated whether breastfeeding duration through the first 6 months of life is associated with maternal sensitivity, attachment security and/or attachment disorganization in a large prospective birth cohort in the Netherlands i.e. Generation-Rotterdam (GEN-R). Dyads who completed 6 months of consistent breastfeeding had the highest ratings for maternal sensitivity and attachment security and the lowest ratings for attachment disorganization. Although breastfeeding predicted more harmonious interactions between mothers and their one-year old children, bottle feeding did not harm the infant-mother relationship. The authors did not find that maternal sensitivity mediated the relationship between breastfeeding duration and attachment security and maternal sensitivity was not related to attachment security in this cohort (Tharner A et al, 2012).

A review paper by Jansen J et al (2008) thoroughly explored whether the effect of breastfeeding was crucial for the mother-infant relationship. The authors concluded that there was a lack of convincing support that the mother-infant
relationship depends upon on breastfeeding to establish a bond within the dyad (Jansen J et al, 2008).

2.3.3. Mothering

The regulation of stress reactivity, internal homeostasis and emotions are a key aspect of early post-natal life. As indicated in section 2.3, mother-infant interactions play a critical role in shaping these regulatory processes.

Schore’s work (2005) suggests that the right brain of young infants is highly active and plays a critical role in social development. Mother-infant interactions shape neural circuits within the right brain that enable children to recognize and react to people in their environment, sensing safety and danger while enabling progressive emotional adjustment (Schore AN, 2001). Neurobiologists have identified differences in right and left brain growth over the first two years of childhood (Chiron C et al, 1997), suggesting that the complexity of the right brain develops in conjunction with the infant’s social environment. In addition to early socialization, the right brain is associated with homeostatic balance and the development of attachment behaviours, which play a further role in shaping social relationships and emotional regulation (Shore AN, 2005).

Emotional regulation

In infancy and early childhood, emotional regulation is shared and highly interactive within a mother-infant dyad. These interactions regulate states of arousal and emotions in response to various events and challenges (Schore AN,
Normal interactions between the mother and infant may start with a mismatching of goals (child turns to mother to show a book, while mother turns away) and/or emotions (child communicates negatively to mother who responds positively). Optimally, these mismatches are quickly repaired by the mother to establish matching interactions while minimizing negative emotions in the child (Tronick EZ and Reck C, 2009). These mother-child affect regulation interactions are particularly important in the early development and organization of emotion regulation pathways in the brain, particularly in the right hemisphere (Schore AN, 2000).

A critical developmental task during the pre-school years is the transition from dyadic regulation guided by the primary caregiver to progressive self-regulation by the child (Sroufe LA, 1997). This transition is best supported by sensitive caregivers who gradually assist the child in learning to self-regulate emotions independently (Sroufe LA, 1997). If the transition to self-regulation is not successful during this developmental period, social functioning may be compromised with long term implications for interpersonal functioning.

**Self-regulation**

Infants who have been supported with positive reinforcement from a sensitive and responsive primary caregiver will likely experience a reduced level of arousal and may feel comfortable adapting towards greater self-regulation of affect (Bell SM and Ainsworth MD, 1972). The early role of the mother/primary
caregiver is significant in the early months to guide the infant in modulating states of arousal and emotions (Harrist AW and Waugh RM, 2002; Feldman R, 2007).

As specific attachment relationships develop a transition towards greater dyadic regulation occurs, when the mother and child begin to work together as a dyad to begin the teaching of self-regulation over time. By the first year of life most children have identified a specific attachment relationship; the first signal is usually separation distress, another sign is ‘secure base’ behaviour, when the child remains close to the attachment caregiver, and also, when children are frightened or threatened they will turn to their attachment caregiver (Sroufe LA, 1997).

2.3.4. Attachment and maternal sensitivity

One systematic way of characterizing and studying the dyadic relationship is in the context of attachment theory, first proposed by the child psychiatrist and psychoanalyst John Bowlby. Bowlby suggested that attachment is a bio-behavioural system, shaped by natural selection, which facilitates protection and survival through proximity and a secure base between mammalian caregivers and their young (Bowlby J, 1969; 1973). The attachment behavioural system prompts infants to use vocalization, crying, approaching and following to enable greater proximity to a primary caregiver in periods of distress (Pederson DR, et al, 1998; Ainsworth MDS et al, (1978)/ 2015).

Bowlby emphasized the benefits for an infant of a warm and intimate relationship with a mother or permanent substitute and the need for mutual satisfaction in this relationship. His early clinical experiences working with young
children who were separated from their mothers revealed problems in personality
development in young children who were raised in environments of adversity
associated with lack of maternal care, maltreatment and neglect (Bowlby J,
1988). Bowlby’s concern about children who were ‘deprived’ of the attachment
from parents are mirrored by young animals who are separated from their
mothers. As demonstrated by Hofer in his animal studies, the longer a mother is
away the greater the impact on physiological and behavioural factors in the
offspring. His work provides a greater understanding of how behavioural
responses to loss, independent of emotions, are associated with a strong
physiological component (Hofer MA, 1995). Other work in rats suggests that
early separation can have long lasting inter-generational effects on maternal

Bowlby’s theory on attachment as a source of protection was highly
innovative (Goldberg S, 2000). He was certain that the ‘affectional tie’ between a
child and their mother had evolutionary significance (Bowlby J, 2005), and that
these biologically driven behaviours by adult caregivers towards their infants
were crucial to maximize the potential survival of the infant (Goldberg S, 2000;
Bowlby J, 2005).

While Bowlby developed the principle theory of attachment, Mary Ainsworth
was an equal partner in the development of Attachment Theory. She clarified the
importance of a secure base for a child’s emotional development and first used
the term ‘maternal sensitivity’ to reflect warm and timely responsiveness to infant
cues. Maternal sensitivity, termed by Ainsworth, refers to one specific aspect of
the attachment system; “warmth is not the same construct as sensitivity” (Ainsworth MDS and Marvin RS, 1995), sensitivity refers to timely and appropriate responsivity on the part of the mother toward the cues of her infant (Ainsworth MDS and Marvin RS, 1995).

Testing whether female rats would behave in a sensitive way to their pups, the Meaney lab found that ‘high quality mothering’ rats demonstrate high licking and grooming, along with arched back nursing, and that these behaviours modulated the stress reactivity of their young (Liu D et al, 1997). Of great interest, this maternal behaviour was found to be transferable to further generations (Champagne F et al, 2001).

2.4. Systematic Measurement of Attachment and Maternal Sensitivity

Ainsworth is best known for creating objective standardized assessments of parent-child interactions including the Strange Situation and Ainsworth Scales for maternal sensitivity which continue to be standards for the field (Ainsworth MDS et al, (1978)/ 2015).

Ainsworth Scales

Ainsworth developed an experimental procedure, the ‘strange situation’ protocol, to observe and categorize attachment relationships between mothers and children within a laboratory environment (Ainsworth MDS and Wittig B, 1969; Ainsworth MDS and Bell SM, 1970). In conjunction with Wittig, Ainsworth developed scales to systematically evaluate maternal sensitivity when observing

Coding of maternal sensitivity using the Ainsworth scales involves learning the details of each of the 4 scales, then observing maternal-child interactions on video-tapes, and systematically scoring maternal behaviour for each scale (Ainsworth MDS, et al 1969). Each scale has a maximum score of 9 points, with a range of 1 to 9. The maximum maternal sensitivity score would then be 36. Optimally, more than one coder scores each mother-child interaction, and scores are then correlated to evaluate reliability.

Maternal Behavioural Q-sort (MBQS)

Caregiver sensitivity can also coded using a tool called the maternal behaviour Q sort (MBQS), which was derived from the original Ainsworth scales (Pederson DR, Moran G et al, 1990). Coding with this system also requires viewing of video-tapes and then systematically identifying maternal behaviour, using descriptive cards arranging behaviour into 3 piles: most like, least like, and neither like or dislike. After working through all of the cards, the mother being studied is then compared to an 'ideal mother'; the calculated correlation is then used as the final maternal sensitivity score. The MBQS was originally developed using 90 cards, but has recently been revised to score using 25 cards (Tarabulsy GM et al, 2009).
2.5. The Role of Attachment and Maternal Sensitivity on Feeding Behaviour and Weight Regulation

Given the role of attachment and maternal sensitivity in self-regulation and emotional development, which are important contributors to eating behaviour and weight regulation, it is of interest to consider childhood obesity from this perspective. Early work in this area, based largely on unstructured clinical observation, emphasized how the shared social experience between mother and infant enabled a child to develop regulated feeding behaviour (Ainsworth MDS and Bell SM, 1969). Ainsworth found that sensitive mothers were able to connect feeding patterns with their children’s emotional and appetitive states, and limit feeding based on infant cues. Less sensitive mothers were unable to read the cues of their infants, and tended to over-feed them as a result. A third group of mothers, who were less interested in positive interaction with their babies, over-fed them to extend sleeping time and decrease attention from and interaction with themselves. Ainsworth noted that these three groups of mothers corresponded to the secure, anxious and avoidant categories respectively.

More recently, the association between attachment styles, maternal sensitivity and obesity risk has been studied systematically using large longitudinal studies of developing children. Anderson SE and Whitaker RC, (2011) studied a large cohort of young children in the general population to evaluate whether attachment styles measured at 24 months were related to the risk of obesity at 54 months. Logistic regression models were used to estimate odds ratios and 95% confidence intervals; key covariates including sex were
evaluated within these models. The odds of developing obesity in children identified with an insecure attachment were 1.30 times higher compared to those with a secure attachment (Anderson SE and Whitaker RC, 2011). A follow-on article by Anderson et al, 2012 evaluated the early mother-child relationship in association with obesity in adolescence. Mother-child interactions were measured at 3 time points (18, 24, and 36 months) for attachment and maternal sensitivity. Low maternal sensitivity and insecure attachment were associated with greater odds of obesity in adolescence. Children at 24 and 36 months with both insecure attachment and exposure to low maternal sensitivity were identified as having a particularly high risk of obesity in adolescence (Anderson SE et al, 2012), with low maternal sensitivity having the stronger effect.

Wu T et al, (2011) studied maternal sensitivity (sensitive or insensitive) and child temperament (easy, average, and difficult) as risk factors for the development of obesity in young children. Maternal sensitivity and temperament were measured at 6 months of age, while BMI was calculated from serial length and weight measures, taken over 4 years. Repeated measure and mixed effects models were used to clarify relationships between and within subjects, controlling for covariates including sex. Maternal sensitivity was found to influence the relationship between temperament and the risk of overweight-obesity in children who were at school age, with the combination of insensitive mothering and a difficult temperament being associated with the greatest risk (Wu T et al, 2011).
As alluded to earlier, sex differences may play a role in one or more aspects of the current investigation, and helped to inform our statistical approach. The next section discusses sex differences of greatest potential relevance to the current project, including growth trajectories, genetic vs. environmental effects on growth, eating behaviour and stress modulation. This is followed by a rationale for the current study and study aims and hypotheses.
2.6. Sex Differences in Early Growth: Gene vs. Environmental Effects on Growth, Eating Behaviour and Stress Modulation

There is evidence that boys and girls may have different growth trajectories early in life. At birth, boys tend to have a longer length and heavier weight compared to girls, and their growth trajectory differs compared to girls (WHO, 2006).

Recent work by Dubois L et al (2012) based on 12,000 twin pairs from four different countries found that genetics play an increasingly important role in explaining variation in weight, height, and BMI from early childhood to late adolescence, particularly in boys. Common environmental factors exert their strongest and most independent influence in the pre-adolescent years and more significantly in girls. This suggests that the role of genetics vs. environmental factors on weight regulation changes from birth through adolescence, and is different in the two sexes. Given that maternal sensitivity is an important environmental influence in early development, sex was included as a potential moderator in the current thesis.

Another line of research on sex differences in early growth looked at maternal pre-pregnancy BMI and offspring body composition from infancy to childhood (Andres A et al, 2015). They found that boys born to obese mothers have higher body fat from 2-6 years than do other boys, while no such effect was found in girls Following further on the placenta, a review paper by Clifton VL et al (2010) suggests that male and female foetuses behave quite differently within the placental environment. For example female placentas are responsive to maternal
adverse environments such as increasing glucocorticoid in pre-term and term pregnancies, and are able to adjust to additional cortisol and metabolic factors, while males seem to be glucocorticoid resistant and they do not respond to maternal adversity or metabolic factors signalled by cortisol. There is also literature indicating that boys and girls have different patterns of eating behaviour of potential relevance to obesity risk. For example, eating pathology was found to be shared with mothers and daughters but not by mothers and their sons (Elfhag K and Linne Y, 2005). It is important to note that emotion regulation and stress modulation differ markedly in the two sexes (Ordaz S and Luna B, 2012; Sontag LM and Graber JA, 2010; Weinberg MK et al, 1999). Furthermore, several authors have identified important sex differences associated with the mother–child relationship and the development of social interactions (Biringen Z et al, 1994, Hinde R and Stevenson-Hinde J, 1987; Goldberg S and Lewis M, 1969; Gunnar MR and Donahue M, 1980). These may be indirect contributors to sex differences in weight regulation and obesity risk.

Early life programming of the hypothalamic-pituitary-adrenal axis (HPA) axis has identified sex differences which point to a greater vulnerability in girls (Carpenter T et al, 2015). For example, girls tend to be more responsive to stress in both early and later life while exhibiting both increased diurnal cortisol secretion and HPA axis reactivity relative to boys. Compared to boys, girls show greater placental permeability of glucocorticoids in response to maternal stress with downregulation of the enzyme 11-β-hydroxysteroid dehydrogenase (which converts active cortisol to inactive cortisone) (Carpenter T et al, 2015). Given the
difference between the sexes this author suggests that possibly males have a greater risk of intrauterine growth restriction, pre-term delivery, or perhaps death in utero if there is further adversity during the pregnancy. Given that the females are able to adjust to the adverse maternal environment which would include many changes in protein and genes along with a decrease in growth without growth restriction, the author suggested that females may have greater preparation for survival in this context (Clifton VL et al, 2010).

2.7. Rationale for the Current Study:

Most strategies used to treat and/or prevent overweight-obesity in children create a regimen focussing on balancing energy intake, by limiting caloric dense foods and beverages in conjunction with increasing physical activity to release energy. Given that these strategies have been only partially successful for most children, there is a need to explore new approaches to this major public health problem.

This project focuses on early childhood weight regulation/ BMI as it relates to the mother-child dyadic relationship, and maternal sensitivity in particular. At the beginning of my doctoral studies there were no publications with this theme, however as outlined above, Anderson SE et al (2012) and Wu T et al (2011) have subsequently studied this in school age children and adolescents. The current study replicates and extends this prior work by examining:
1. potential links between 6 month maternal sensitivity scores and BMI z-scores at 48 months i.e. examining these measures at an earlier phase of life than did prior studies.

2. a possible mediating effect of eating styles on this association. No systematic studies to date have examined obesogenic eating styles as it relates to maternal sensitivity.

3. a potential moderating effect of sex and breastfeeding on this association - prior studies in this area treated these factors as co-variates rather than moderators.

The overall Theoretical Model is summarized again below:
2.8. Study Aims and Major Hypotheses

This project is comprised of three inter-related studies with goals and hypotheses summarized as follows:

**Study 1**: This study examined whether maternal sensitivity measured at 6 months of age predicts child BMI z-scores at age 48 months.

**Hypothesis**: Low maternal sensitivity at 6 months would predict higher child BMI z-scores at 48 months.

**Study 2**: The purpose of this study was to examine whether emotional overeating, food responsiveness, and/or enjoyment of food mediate the association between maternal sensitivity at 6 months of age and child BMI z-scores at 48 months.

**Hypothesis**: Emotional overeating, food responsiveness, and/or enjoyment of food mediates the relationship between maternal sensitivity at 6 months and child BMI z-scores at 48 months.

**Study 3**: This study examined whether breastfeeding influences the relationship between maternal sensitivity at 6 months of age and child BMI z-scores at 48 months.

**Hypothesis**: Breastfeeding would moderate the association between maternal sensitivity at 6 months and child BMI z-scores at 48 months.

Given significant evidence that weight regulation, eating behaviour and/or emotion regulation may develop differently in boys and girls, we examined potential sex differences in each of these relationships.

A detailed rationale for each of these hypotheses will be provided in chapters 4-6 respectively. The following sections describe the study sample and assessments used to test these main hypotheses.
Chapter 3

General Overview of Sample Recruitment and Methods
3.1. Sample Recruitment and Methodology

3.1.1 Data Source and Study Sample: the MAVAN project

The Maternal Adversity Vulnerability and Neurodevelopment (MAVAN) project is a longitudinal cohort study of developing children recruiting subjects from Montreal, Quebec and Hamilton, Ontario, Canada. The primary aim of the MAVAN study is to examine how various adversities influence brain development and child health. The most unique aspect of the MAVAN project is its detailed assessment of the early post-natal environment including standardized measures of maternal sensitivity done at both 6 and 18 months of age. The current thesis focuses on the role of maternal sensitivity in shaping weight regulation and obesity risk early in life.

3.1.2. Study Recruitment Procedures

Pregnant women were recruited between 13-20 weeks gestation in Montreal and Hamilton. Inclusion in the study required an age of ≥18 years, singleton gestation and fluency in French or English. Women with severe chronic illness, placenta previa, a history of incompetent cervix, impending delivery, or a foetus/infant affected by a major anomaly or born at a gestational age <37 weeks were excluded from the study. Birth records were obtained directly from the birthing units in Montreal, and either directly from mothers or from the medical records department of the birthing hospital for the Hamilton participants.

For the Montreal site approval for the MAVAN Project was obtained from obstetricians performing deliveries at the study hospitals and by the Institutional
Review Boards at hospitals and university affiliates: McGill University and l’Université de Montréal: the Royal Victoria Hospital, Jewish General Hospital, Centre Hospitalier de l’Université de Montréal, Hôpital Maisonneuve-Rosemont.

For the Hamilton site approval for the MAVAN Project was obtained from referring physicians at St. Joseph’s Hospital and McMaster University, Hamilton, Ontario, Canada. Informed consent was obtained from all participants.

The Montreal arm of MAVAN was initially inspired by The Montreal Prematurity Study funded by the March of Dimes (PI: Dr. Michael Kramer). The Prematurity Study has an outcome measure of gestational length, with predictor measures of psychosocial stress, nutrition, and family and community living conditions. The MAVAN Project was initially developed as a follow-on study derived from the Prematurity Study to take advantage of the multivariate assessment of prenatal adversity. The first phase of the MAVAN Project was designed to recruit two infants born at normal weight (controls, 3000-3500 g at birth) for each low-birth weight baby exhibiting evidence of intrauterine growth retardation (IUGR, 2200-2750 g at birth). Controls were recruited as close in time as possible to the low-birth weight babies. These groups were defined based on the published Canadian standards for foetal growth (Kramer MS, 2001), with a birth weight of 2,750 g representing the 10th percentile and 3750 g the 70th percentile. From the outset, the MAVAN Project has excluded extreme cases of growth retardation (i.e., < 2,200 g). All babies in this study were born at ≥ 37 weeks gestation to avoid the complication of prematurity and growth restriction. Recruitment of infants in Montreal was initially organized to enrol two normal
weight-for-age babies as controls born on the same or closest day to the birth of an IUGR baby.

While the very initial phase of MAVAN recruitment over-selected for low-birth weight babies in this way, this focus became less of a priority as the study progressed, and was not a major consideration for the Hamilton site. As a result, the final proportion of IUGR babies in MAVAN overall is only modestly higher than population norms. To help control for this, birthweight percentile was considered as a co-variante in all of the analyses described in this thesis.

For the Hamilton site approval for the recruitment of potential participants for the Healthy Pregnancy for Great Life Beginnings: MAVAN Project was obtained by designated medical staff from the Women’s Health Concerns Clinic (WHCC) at St. Joseph’s Healthcare associated with McMaster University, Hamilton, Ontario. In contrast to the Montreal site, the primary adversity oversampled at the Hamilton site is maternal anxiety and depression. The goal is to assess how these conditions affect early neurodevelopment, and whether effective treatment is protective in this regard.

Pregnant women presenting with symptoms of depression and/or anxiety are assessed in early pregnancy (12-18 weeks gestation) at the Women’s Health Concerns Clinic, SJHC. As part of the adversity group, they are offered a choice of treatments/interventions at the clinic. If they are already receiving treatment at the time of assessment, they can continue to receive care from their healthcare provider while participating in the study. In addition, accessing community services such as Public Health programs and postpartum support groups is
encouraged. Women can refer themselves to the clinic, or they can be referred by a caregiver. A control group of pregnant women who have no personal or family history of mental illness and who have no current symptoms of depression and/or anxiety are also recruited for comparison.

3.1.2.1. **Postnatal Assessments**

Postnatal assessment of the mother-child dyads are at 3, 6, 12, and 18 months and yearly from age 24 months onwards. Assessment of maternal health and well-being occurs each year using a questionnaire that is a composite of validated short versions of a number of measures, including standardized measures of maternal mental health focusing on mood and socio-economic status. Children are assessed with age-appropriate measures throughout the longitudinal study. Child assessments are duplicated at both sites at the same time point, and include both laboratory-based and home measures as appropriate.

3.2. **Measures and Methods**

3.2.1. **Measures of the Early Maternal-Infant Relationship**

Maternal-infant interactions are measured using a variety of approaches including validated coding of videotaped interactions under both normal conditions in the home environment and in response to minor challenges such as the Strange Situation in a laboratory setting.
Maternal sensitivity is systematically coded when the child is 6 months postpartum, using video-taped recordings of mother-child interactions within the home environment for a 20 minute interval, followed by a 10 minute interval when mothers complete questionnaires. Blinded trained scorer(s) study a free play time between mother and child, using a video tape taken in the family home. The blinded coder(s) observe videos at least 3 times before beginning to code the behaviour. A second assessment of maternal sensitivity was done at age 18 months, but was not a focus of this thesis.

3.2.2. Maternal Behaviour Question Sort (MBQS)

Caregiver sensitivity is also coded using a tool called the maternal behaviour Q sort (MBQS) which was derived from the original Ainsworth scales (Pederson DR, Moran G, et al, 1990). Coding with this system requires viewing of video-tapes and then systematically identifying maternal behaviour, using descriptive cards arranging behaviour into 3 piles: most like, least like, and neither like or dislike. After working through all of the cards, the mother being studied is then compared to an ‘ideal mother’; the calculated correlation is then used as the final maternal sensitivity score.

The MBQS was originally developed using 90 cards, but has recently been revised to score using 25 cards (Tarabulsy GM et al, 2009). A single coder (KL) systematically evaluated maternal behaviour at 6 months post partum using the maternal behaviour question sort (MBQS-25 rev; Ref: Pederson and Moran, et al, 1990).
3.2.3. Dependent Variables

3.2.3.1. Child Weight Measures

In addition to weight at birth, children are evaluated for gestational age and also categorized into birth size. Birth size in association with gestational age provides a more accurate understanding of growth for age (Kramer MS et al, 2001). Both high and low birth weights can increase the risk of overweight (Kajantie E et al, 2007) and using birth size rather than birth weight provides a clearer starting point for the growth trajectory.

Children are weighed and measured at birth and at each study visit using standard scales and measures. Beginning at 24 months, body mass index is calculated as (weight-kg)/ height in metres$^2$.

Boys and girls develop on different growth trajectories until young adulthood. When comparing BMI measures of boys and girls within a cohort it is important to use Z-scores, to provide normative information. This project uses the World Health Organization (WHO) guidelines for child growth using BMI Z-scores for children up to the age of 6 years.

Children were measured at clinic visits using standard equipment and methodology. Standing height, without shoes, was measured (to the nearest 0.1 cm) with the use of a stadiometer (Perspective Enterprises, PE-AIM-101, Portage, Michigan). Body weight, in light clothing, was measured (to the nearest 0.1 kg) with the use of a digital floor scale (TANITA BF625, Arlington Heights, Illinois). Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared (kg/m$^2$).
3.2.4. Intervening Variables (potential moderators and mediators)

3.2.4.1. Children's Eating Behaviour Questionnaire (CEBQ)

The Child Eating Behaviour Questionnaire (CEBQ) was developed to assess the eating styles of young children in an attempt to understand which eating styles might contribute to different trajectories of early weight gain (Wardle J et al, 2001). Parents participated in the development of the tool, through open discussions identifying eating styles of their children as well as verifying constructs identified in the earlier experimental publications. Parental input influenced the addition of two more constructs to the CEBQ, emotional under-eating and a constant desire to drink, providing a total of 8 subscales for the questionnaire.

A large pool of items was developed through modification of adult items and by creating new items based on behavioural testing. Items were then pared down for each construct of interest to create an internally consistent set of scales covering eight eating styles: food responsiveness, enjoyment of food, emotional overeating, desire to drink, satiety responsiveness, slowness in eating, emotional under-eating, and fussiness (Wardle J et al, 2001).
3.2.4.2. **Breastfeeding**

Mothers identified the frequency of breastfeeding for their infants-children, using a standardized questionnaire over the first two years of life. Within the dataset there is information on breastfeeding as a continuous variable for up to 24 months, and as a categorical variable (using yes or no) up to 12 months. Both exclusive and non-exclusive breastfeeding were assessed at each time point.

3.2.5. **Covariates: Blended Socioeconomic (SES) - Maternal Education**

To best reflect the composition of the MAVAN sample, a composite variable for maternal education and socio-economic status was initially generated based on the following three groupings: low income and low maternal education vs. (low income and high maternal education or high income and low maternal education) vs. high income and high maternal education. As relatively few mothers met criteria for both low education and low income, it was decided to use a bivariate factor for the subsequent analyses using high education-high SES versus all other combinations combined.

Based on Canadian norms, low SES was defined as income in the range of zero revenue to >$10,000.00/year. The MAVAN project over samples from low SES settings, thus the prevalence of families receiving income below the low income cut off (LICO, Statistics Canada) was near 30% compared to 15% in the general population (Statistics Canada, 2009). However, while education below 10 years was found in only 4% of the mothers of our sample, this number reaches 12% of adults in the provinces of Québec and Ontario (Statistics Canada, 2011).
In sum, SES status was relatively low but education relatively high, relative to Canadian population norms.

Maternal BMI

The mothers of children who were evaluated at the clinic at 48 months also had height and weight measures with the same equipment and following the same methods identified above. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared ($kg/m^2$). Not all mothers agreed to participate in the weight, height, and waist measures, which is a common problem with studies of this type, and is a study limitation i.e. one might expect that a disproportionate number of obese women refused to participate in the BMI measures, thus limiting the generalizability of findings somewhat. Notwithstanding this limitation, the distribution of maternal BMIs in the MAVAN cohort includes a significant number of overweight and obese women, and is highly consistent with other cohort studies of this type.

Birth Weight Percentile

Given the fundamental importance of birthweight on early growth trajectories, birthweight based on WHO- z scores (Oken E et al, 2003) was included as a co-variate in all key analyses.
3.3. Defining the Current Study Sample

One major issue that must be addressed when using secondary data from cohort studies such as MAVAN is whether to use case wise deletion of subjects to define a given study sample, or whether to use imputation. In the former case, only subjects with complete data for all of the key study variables are used, while imputation takes advantage of the full set of data available, including cases with partial missing data. In the case of MAVAN research, most of the initial studies have been based on the case-wise deletion approach. This in turn has been based on the reality that in the initial phases of an ongoing cohort study such as MAVAN, many children have incomplete data simply as a result of not yet having reached the age at which a given outcome is measured. In some cases, raw data has been collected but has not been coded for subsequent use. These factors were very much in play for the current studies over the period of my own research, and I chose to use the case wise deletion approach as a result. While imputation is likely to be used more often by MAVAN researchers going forward as the cohort and database mature, this was not the optimal approach possible when the current projects were undertaken.

MAVAN recruited new participants fairly consistently over the multi-year course of my work, and so the potential sample size for my work has fluctuated over time. The final sample size of N=223 children that I have ultimately studied reflects the state of affairs about 2 years ago when my initial analyses were completed. At that time, 223 children had complete data available for 48-month
BMI and maternal sensitivity at 6 months of age. The full MAVAN sample is now 
n=569 (n=323 children in Montreal and n=246 children in Hamilton).
Chapter 4

**Study 1**: This study examined whether maternal sensitivity measured at 6 months of age predicts child BMI z-scores at age 48 months.

**Hypothesis**: We hypothesized that Low maternal sensitivity at 6 months would predict higher child BMI z-scores at 48 months, with different effects in boys compared to girls.

This chapter is modified from the following:

4.1. Abstract

**Background:** Large population-based studies suggest that systematic measures of maternal sensitivity predict later risk for overweight and obesity. More work is needed to establish the developmental timing and potential moderators of this association. The current study examined the association between maternal sensitivity at 6 months of age and BMI z score measures at 48 months of age, and whether sex moderated this association. **Design:** Longitudinal Canadian birth cohort (the MAVAN project). **Methods:** This analysis was based on a dataset of 223 children (115 boys, 108 girls) who had structured assessments of maternal sensitivity at 6 months of age and 48-month BMI data available. Mother-child interactions were videotaped and systematically scored using the Maternal Behaviour Q-Sort (MBQS)-25 items, a standardized measure of maternal sensitivity. Linear mixed-effects models and logistic regression examined whether MBQS scores at 6 months predicted BMI at 48 months, controlling for other covariates. **Results:** After controlling for weight-relevant covariates, there was a significant sex by MBQS interaction \((p=0.015)\) in predicting 48 month BMI z. Further analysis revealed a strong negative association between MBQS scores and BMI in girls \((p=0.01)\) but not boys \((p=0.72)\). Logistic regression confirmed that in girls only, low maternal sensitivity was associated with the higher BMI categories as defined by the WHO (i.e. “at risk for overweight” or above). **Conclusions:** A significant association between low maternal sensitivity at 6 months of age and high body mass indices was found in girls but not boys at 48 months of age. These data suggest for the first
time that the link between low maternal sensitivity and early BMI z may differ between boys and girls.

**Keywords:** Maternal sensitivity, parent-child interaction, body mass index (BMI) WHO z scores, sex differences
4.2. Introduction

It has been argued that the very rapid increase in obesity rates over recent decades cannot be accounted for based on purely metabolic factors, and must relate in large part to one or more environmental factors (Suglia SF et al, 2012; Puder JJ and Munsch S, 2010; Lajunen HR et al, 2012; Vámosi M, et al, 2010; Gunderson C et al, 2011). As summarized in recent reviews (Ventura AK and Birch LL, 2008; Anzman SL et al, 2010; Sleddens EF et al, 2011; Mitchell GL et al, 2013), the quality of parent-child interactions has been a focus of obesity work over several decades. However, much of this work has been either cross-sectional in design, done in relatively small samples and/or focused on school-age children and adolescents, which may limit the interpretation and generalizability of results. A greater focus on large, longitudinal, population-based studies, including data from the first few years of life, may point the way to more effective interventions going forward (Anzman SL et al, 2010).

One systematic way of assessing the quality of early parental-child relationships is to measure maternal-infant attachment and maternal sensitivity based on direct observation, using standardized coding to score these interactions. Attachment can be defined as a bio-behavioural system to facilitate protection and survival through proximity and a secure base between mammalian caregivers and their infants (Bowlby J, 1973; Goldberg S, 2000). Maternal sensitivity refers to one specific aspect of the attachment system i.e. timely and appropriate responsivity on the part of the mother toward the cues of her infant (Ainsworth MDS and Marvin RS, 1995). In addition to providing a framework for
the objective and standardized assessment of parent-child interactions, attachment and maternal sensitivity have the further advantage of contributing to individual differences in emotion regulation (Waters SF et al, 2010; Sherman LJ et al, 2013) and stress responsivity (Champagne F and Meaney MJ, 2001; Walker CD, 2010; Fernald L and Gunnar MR, 2009; Loman MM and Gunnar MR, 2010). Increased consumption of highly palatable foods in the face of strong emotions, often triggered by daily stressors, is thought to be a major factor contributing to obesity over time (Dallman MF et al, 2003). Given these practical and theoretical advantages, standardized assessments of attachment and maternal sensitivity have recently been included in large, systematic population studies of obesity risk. For example, Anderson SE and Whitaker RC in 2011, using a version of the Attachment Q-sort (Waters E and Deane KE, 1985; van Ijzendoorn MH et al, 2004) in a large U.S. population sample, found that attachment insecurity measured at 24 months increased the risk of obesity at 54 months of age. This same team later showed that low maternal sensitivity in the pre-school years was an even stronger risk factor for the development of obesity in adolescence than was insecure attachment (Anderson SE et al, 2012). Wu T et al, (2011) showed that the combination of low maternal sensitivity and a difficult child temperament predicted an increased risk of overweight-or-obesity during school age, but not in earlier childhood.

While these initial studies suggest that insecure attachment and low maternal sensitivity in pre-schoolers is a risk factor for later obesity, much more work is needed to replicate these findings in independent samples and to
establish at what age these effects first come into play. For example, while Anderson et al report a link between 24 month attachment behaviours and later obesity risk, extending this finding to interactions measured at 6 months of age might inform a different interventional approach implemented at a very different time in the emerging dyadic relationship. Another important question for this area of work is whether sex moderates the link between attachment and/or maternal sensitivity behaviours and later obesity risk. Anderson SE and Whitaker RC (2011) reported that sex did not moderate the association between insecure attachment and childhood obesity, however they did not report on similar moderation effects related to maternal sensitivity and later weight gain (Anderson SE et al, 2012). Several authors have identified important sex differences associated with the early mother–child relationship and the development of social interactions (Biringen Z et al, 1994, Hinde R and Stevenson-Hinde J, 1987; Goldberg S and Lewis M, 1969; Gunnar MR and Donahue M, 1980). Furthermore, several aspects of eating behaviour and weight gain may develop differently in girls and boys (Suzuki K et al, 2012; Govindan M et al, 2013). Thus, it is reasonable to hypothesize that the link between maternal sensitivity and later obesity risk might differ in the two sexes.

The main goals of the current study were thus to: 1. examine the association between 6 month maternal sensitivity scores and body mass indices measured at 48 months of age in a new longitudinal study of developing children, thus extending the work of Anderson et al to an earlier developmental stage, and 2. assess whether sex might moderate this association. We hypothesized that
exposure to low maternal sensitivity at age 6 months would be associated with higher child BMIs at age 48 months, and that sex would moderate this association i.e. that girls would show this association more so than boys. The latter was based on recent work demonstrating a link between social adversity and obesity risk in girls but not boys at five years of age (Suglia SF et al 2012). Differences in parental expectations, perceived roles and maternal behaviours towards boys and girls might also be contributory in this regard (Goldberg S and Lewis M, 1969; Biringen Z et al, 1994; Carper JL et al, 2000; Elfhag K and Linné Y, 2005; Hinde R and Stevenson-Hinde J, 1987).

4.3. Participants and Methods

The current study sample included 223 children recruited in either Montréal, Québec (N= 105) or Hamilton, Ontario (N= 118), Canada as part of an established prospective birth cohort, the Maternal Adversity, Vulnerability and Neurodevelopment (MAVAN) project. For the current analysis, all available participants who had been enrolled in the MAVAN study at birth, been scored for maternal sensitivity at 6 months of age and who had participated in a laboratory visit to measure growth at 48 months of age were included. Eligibility criteria for mothers at study entry included age ≥18 years, singleton gestation, and fluency in French or English. Women with severe chronic illness, placenta previa, and history of incompetent cervix, impending delivery, or a foetus/infant affected by a major anomaly or born at a gestational age less than 37 weeks were excluded. Birth records were obtained directly from the birthing unit.
The current study sample was found to be comparable to the overall birth cohort in terms of maternal age at childbirth, gestational age, birth size, income categories, and maternal education. MAVAN is a multidisciplinary, collaborative study, recruiting pregnant women from obstetric clinics in hospitals located in Montréal, Québec and Hamilton, Ontario. All participants experienced identical home and laboratory based assessments. We excluded very low birth weight infants and included those born at 37 to 41 weeks gestation. The maternal age at childbirth was also comparable to the general population within Canada (study sample = 30.5 years; Québec =29.5 years, Ontario = 30.2 years), (Statistics Canada, 2012). The MAVAN project over-samples from low SES settings, thus the prevalence of families receiving income below the low income cut off (LICO, Statistics Canada, 2005) was near 30% compared to 15% in the general population (Statistics Canada, 2009). However, while education below 10 years was found in only 4% of the mothers of our sample, this number reaches 12% of adults in the provinces of Québec and Ontario (Statistics Canada, 2011). In sum, SES status was relatively low but education relatively high, relative to Canadian population norms.

Approval for the MAVAN project was obtained from obstetricians performing deliveries at the study hospitals and by the ethics committees and university affiliates (McGill University and l’Université de Montréal: the Royal Victoria Hospital, Jewish General Hospital, Centre hospitalier de l’Université de Montréal, and Hôpital Maisonneuve-Rosemont), and St. Joseph’s Hospital and McMaster University, Hamilton, Ontario, Canada. Details of the procedures are
available (Silveira PP et al, Pediatric Research 2012; 71(3): 293-298). Informed consent was obtained from all participants.

Measures

Mother-child interaction using video-taping

For the purposes of assessing maternal sensitivity (appropriately, and timely response to infant signals) at 6 months, 30 minutes of non-feeding mother-infant interactions were videotaped in the home. The 6 month videos were entirely free-play. The recordings were later coded by staff that were independent from the MAVAN study and had no awareness of the primary study hypotheses. The instrument used was the 25 item Maternal Behaviour Q-sort (MBQS revised-25) which has been shown to correlate with constructs central to infant development and attachment, including other measures of maternal sensitivity as well as infant attachment security and cognitive development (Pederson DR et al, 1990; Tarabulsy GM et al, 2009). Three MBQS revised-25 observers independently coded twenty eight 6 month tapes to obtain intra-class correlations between 0.82 and 0.94.

Growth Measures

At the 48 month visit children had length and weight measures taken. Standing height, without shoes, was measured (to the nearest 0.1 cm) with the use of a stadiometer (Perspective Enterprises, PE-AIM-101, Portage, Michigan). Body weight, in light clothing, was measured (to the nearest 0.1 kg) with the use of a digital floor scale (TANITA BF625, Arlington Heights, Illinois). BMI was calculated as weight in kilograms divided by height in metres squared (kg/m²).
BMI z-scores were calculated based on well established World Health Organization (WHO) growth curves for girls and boys (WHO, 2006).

**Covariates Related to BMI:**

Based on their established relationship with early growth and overweight-obesity risk, we included birth-weight (based on WHO- z scores; Oken E et al, 2003), maternal BMI and a blended variable for socio-economic status and maternal education in our analyses. Regarding the latter, bivariate low/high sub-groupings for both maternal SES and maternal education were first established based on Canadian norms (Statistics Canada, 2005). Maternal SES groupings were: “low” = total family income after tax <$21,359; “high” = total income after tax >$21,358 (Statistics Canada, 2005). Maternal education was defined as “low” if high school graduation was not achieved (Statistics Canada, 2011). A single composite variable for socio-economic status and maternal education was next generated based on the following three groupings: “low-low” identifies low income and low maternal education; “low/high” identifies low income and high maternal education or high income and low maternal education; “high/high” identifies high income and high maternal education. As relatively few mothers in this sample met criteria for both low education and low income, a bivariate factor for SES and maternal education was ultimately used for the statistical analyses i.e. high education-high SES (n= 156; 77.6%) versus all other subgroups combined (n= 45; 22.4%). No data for maternal SES and education was available for 22 other subjects. (See Table 1)
Statistical Methods

Analyses were conducted with IBM SPSS statistical software, version 21 (IBM SPSS Statistics for Windows, Amonk, N.Y.) and SAS version 9.2 software (SAS Institute, Cary, NC). The main goal was to investigate the relationship between maternal sensitivity measured at 6 months of age and BMI of the child measured at 48 months of age, and whether sex moderated this association. Data modelling using regression analysis and analysis of variance was used to evaluate the effects of covariates on the study results. To account for the relatedness of observations taken from the same study site (Montréal or Hamilton), linear mixed-effects models controlling for site, implementing the method of maximum likelihood were used to predict 48 month BMI z scores based on maternal sensitivity as reflected by the MBQS-25 score at age 6 months, sex, the MBQS by sex interaction and the BMI-relevant covariates listed above.

Variables that were focal components of the hypothesis, i.e., maternal sensitivity score (MBQS-25), sex and the MBQS by sex interaction, were entered into the multivariate regression model at each step. The random variable for site was kept in the model at each step because it is central to our methodology and our mixed model analyses. The decision to include other covariates was based on the following procedure: Firstly, we examined the simple bivariate associations between each of these covariates and BMI z-scores at 48 months, using a series of linear mixed-effects models (each including a random intercept to control for site – Montréal versus Hamilton). Covariates that were not
associated with BMI at p<0.05 were eliminated at this step. Next, a preliminary multivariate linear mixed model to predict 48 month BMI z scores was completed including all of the variables identified as central to our hypothesis, a random variable for site, and additional covariates that were significantly associated with 48 month BMI z scores in the bivariate analyses described above. For the covariates that were not central to our hypothesis, the basis to retain a given covariate in the final model was done using a “purposeful selection of covariates” procedure i.e. covariates that did not prove significant in the final multivariate regression model were eliminated until all remaining covariates were significant at p<0.05.

**Prediction of Higher BMI Categories**

In theory, the link between maternal sensitivity and body mass may operate at the lower and/or higher extremes of BMI, and this would not be discernable in the analysis described above. To more specifically determine whether maternal sensitivity at age 6 months was predictive of the higher BMI categories outlined by the WHO (i.e. at risk of overweight, overweight or obese), a logistic regression predicting membership in any of the higher weight categories considered together (yes/no) was performed using maternal sensitivity scores, sex, the sensitivity by sex interaction and maternal BMI as independent variables. The goal was to determine if maternal sensitivity was relevant to childhood overweight/obesity risk per se.
4.4. Results

Table 1 summarizes the sample characteristics including potential covariates and provides the simple bivariate associations between each independent variable and 48 month BMI z scores.

**Table 1: Sample Characteristics and Bivariate Association of Independent Variables with 48 month BMI z-Scores**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>N</th>
<th>Bivariate Association with 48 month BMI (WHO z-Scores)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Beta Estimate (SE)</td>
</tr>
<tr>
<td>Sex</td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td></td>
<td>115 (51.6%)</td>
<td>108 (48.4%)</td>
</tr>
<tr>
<td></td>
<td>0.18 (0.14)</td>
<td>223</td>
</tr>
</tbody>
</table>

| SES/Maternal Education Blended (high vs. other) | High | Other | | | |
| Sex | 156 (77.6%) | 45 (22.4%) | | | |
| 0.55 (0.17) | 201 | -3.14 | 0.002 |

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth Weight z-Score</td>
<td>-.12</td>
<td>.91</td>
</tr>
<tr>
<td>Maternal BMI</td>
<td>27.4</td>
<td>6.5</td>
</tr>
<tr>
<td>MBQS-25 score at 6 Months</td>
<td>0.41</td>
<td>0.43</td>
</tr>
</tbody>
</table>

**Notes:**
Discrepancies in sample size are due to missing/incomplete data

1High = high SES and high maternal education; Other = low SES and/or low maternal education

2MBQS-25 = Maternal Behaviour Q-Sort 25 -item (maternal sensitivity)
As shown, there was a significant bivariate association between the SES/maternial education variable and 48 month BMI z scores, with high SES/high maternal education status being associated with lower 48 month BMI. Higher birth weight z scores and higher maternal BMI were both positively associated with 48 month child BMI. Neither infant sex nor maternal sensitivity scores were significantly related to BMI z score at this step.

Final Model Predicting BMI z scores at age 48 months:

After implementing the purposeful selection of covariates methodology as outlined above, maternal BMI was retained as a significant covariate in the final multivariate model (at p<0.001), while birth weight and SES/maternial education were not. Notably, the sex by MBQS interaction was also significant in this model (p=0.015). To explore this interaction in more detail, two separate mixed effects models were completed in boys and girls.

Table 2 indicates that after controlling for maternal BMI, there was a negative association between maternal sensitivity at age 6 months and BMI z scores at age 48 months in girls (at p=0.01), while in boys there was no significant association between maternal sensitivity at 6 months and 48 month BMI z scores (p=0.72).
Table 2. Final models, split by sex, predicting 48 month BMI z-scores

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta Estimate (SE)</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBQS-25 Score at 6 Months</td>
<td>0.07 (.20)</td>
<td>0.85 (.32)</td>
<td></td>
</tr>
<tr>
<td>P = .72</td>
<td>P = .01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal BMI</td>
<td>0.06 (.01)</td>
<td>0.05 (.02)</td>
<td></td>
</tr>
<tr>
<td>P &lt; .001</td>
<td>P = .002</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

MBQS-25 = Maternal Behaviour Q-Sort 25 item (Maternal Sensitivity)

Prediction of Higher BMI Categories

Of the 223 children included in the current sample, a total of 60 (26.9%) would be considered as “at risk of overweight”, “overweight” or “obese” based on WHO criteria. The logistic regression predicting membership in any one of these categories at age 48 months (yes/no), controlling for maternal BMI, was highly significant (chi-square = 21.9, df = 4, p<0.001). Consistent with the mixed model analysis described earlier, the maternal sensitivity by sex interaction was significant (Wald = 6.75, df = 1, p = 0.009, odds ratio = 10.73 (95% confidence interval = 1.79 – 64.26). Separate logistic regressions done in girls and boys revealed that after controlling for maternal BMI, lower maternal sensitivity was associated with membership in a higher BMI category in girls (Wald = 6.66; df=1, p=0.01; odds ratio = 7.18, 95% CI= 1.61- 32.12) but not in boys (Wald = 0.66; df=1, p = 0.42; odds ratio = .67, 95% CI = .25-1.78).
4.5. Discussion

The main goals of the current study were to: 1. examine the association between 6 month maternal sensitivity scores and body mass indices measured at 48 months of age in a new longitudinal study of developing children, thus extending the work of Anderson et al to an earlier developmental stage, and 2. assess whether sex might moderate this association. After controlling for covariates known to have a strong relationship with child BMI, we found a significant negative association between maternal sensitivity at 6 months of age and body mass indices in 48 month old girls, but not their male peers. Further analysis revealed that in girls only, low maternal sensitivity was associated with an increased likelihood of being at risk for overweight, overweight or obese based on established WHO cut-offs. This suggests for the first time that the link between maternal sensitivity and early markers of obesity risk may in fact differ between the two sexes.

While the prior literature linking parent-child interactions with obesity risk is substantial, recent reviews have highlighted several potential limitations of this work (Ventura AK and Birch LL, 2008; Anzman SL et al, 2010; Sleddens EF et al, 2011; Mitchell GL et al, 2013), including a heavy reliance on cross-sectional designs, relatively small samples and with a primary focus on school-age children and adolescents. Only recently has objective, systematic scoring of early mother-child interactions been used in the context of large population-based studies (Anderson SE and Whitaker RC, 2011; 2012). In these latter studies, children at 24 and 36 months with both insecure attachment and exposure to low
maternal sensitivity had a particularly high risk of obesity in adolescence (Anderson SE. et al, 2012). In their 2011 paper, Anderson and Whitaker tested sex as a moderator of the association between attachment categories and the risk of obesity, reporting no significant effect. However their subsequent paper looking at maternal sensitivity and obesity risk did not include sex as a potential moderator. A smaller study by Wu T et al (2011) found that maternal sensitivity influenced the relationship between temperament and the risk of overweight-obesity in children who were at school age, with the combination of insensitive mothering and a difficult temperament being associated with the greatest risk (Wu T et al, 2011); again, sex was not considered as a potential moderator of this association. Thus, in linking low maternal sensitivity with higher BMIs in girls but not boys, the current findings both replicate and extend the work of Wu et al (2011) and Anderson SE, et al (2012).

The current findings suggest that 6 months of age may encompass a significant period of development when human infants are highly sensitive to maternal signals, with implications for early prevention and management of childhood obesity risk. However, low maternal sensitivity has also been associated with feeding problems and failure to thrive in some children (Hagekull B et al, 1997; Drotar D et al, 1990; Ward MJ et al, 1993; Feldman R et al, 2004; Block RW et al, 2005), suggesting that the link between early maternal sensitivity and weight regulation may be bidirectional. Understanding the moderators of these two different growth trajectories in response to low maternal sensitivity is an important question for future research.
Infant feeding disorders are relatively common in the early years of children. While there are many factors leading towards feeding disorders, inadequate nutrition and problems with the mother-child relationship are primary features (Block RW et al, 2005; Hagekull B et al, 1997). Ward MJ et al (1993) worked with young children between 12 to 25 months comparing how those with failure to thrive (FTT) related to those who were normally growing children. FTT children were less likely to be securely attachment, with only 35% and 46% who experienced disorganized attachments; while the controls tended to be securely attached with caregivers at 64% and with a lower degree of disorganized in children, at 7%. Disordered relationships creating stressful environments for FTT children within families were identified as a primary factor to focus on including medical and psychological treatments (Ward MJ et al, 1993). Another group studying FTT infants with a healthy control cohort of infants found that mothers of the FTT children tended to be less adaptive towards their infants around social interactions and affective behaviours, and they were inclined to stop the feeding time of their infants in a very arbitrary way, compared to the behaviours of the control mothers (Drotar D et al, 1990).

Feldman R et al (2004) has been studying how mother-child touch patterns in are linked with feeding disorders in infants. Children with feeding disorders have been found to experience less maternal affection, more negative touch, and also more rejection from maternal touching, which together signals that the early mother-child relationship is at risk for infants who have eating disorders. Touch and proximity have been identified to be markers of
relationships which are linked to feeding behaviours; opportunities to educate parents might benefit many of these developing infants (Feldman R et al, 2004).

Important meta-analyses reported from Europe suggest that maternal sensitivity and attachment behaviours can be modified through learning; early preventive interactions focussing on maternal sensitivity have been effective in enhancing maternal sensitivity as well as promoting child attachment security (Bakermans-Kranenburg MJ et al, 2003; Bakermans-Kranenburg MJ et al, 2005. If low maternal sensitivity is in fact causal of early weight gain, such interventions should make an impact on limiting childhood obesity over time. The current findings suggest that girls might benefit disproportionately in this regard.

Several potential strengths and limitations of the current study merit consideration. Strengths include our use of a population-based sample with highly structured and standardized assessments of maternal sensitivity done in the first year of post-natal life, when plasticity effects are likely to be significant. The longitudinal aspect of our findings is also a potential strength. On the other hand, our current sample size is much smaller than that reported by Anderson SE et al (2012), which limits statistical power. While the current data suggest that boys will not show an association between maternal sensitivity and BMI even with a much larger sample size, similar studies in other cohorts will be needed to assess this more fully. The generalizability of the current findings is another potential limitation, given the large number of mothers with low SES but high educational status. The latter could in theory limit the impact of social adversity on the outcome under consideration.
While the detailed phenotyping of the MAVAN sample is a major long term strength, we do not have sufficient data at this time to explain the mechanistic basis of our main finding, though this will be a goal of future work. Several potential variables have been linked to maternal-infant interactions on the one hand and obesity on the other, including HPA-axis activity (Lumeng JC et al, 2014; Hillman JB et al, 2012), emotion regulation (Harrist AW et al, 2013; Vandewalle J et al, 2014) and brain reward processes (Sinha R and Jestreboff AM, 2013; Berthoud HR et al, 2011).

4.6. Acknowledgements

This manuscript is dedicated to the memory of Dr. Susan Goldberg, our cherished friend and colleague who made a significant contribution to the work described in this manuscript. The MAVAN research is supported by multiple grants from the Canadian Institutes for Health research (to RDL, MJM, and ASF), as well as private support from the Faculty of Medicine, McGill University and the Norlien Foundation (Calgary, Alberta) and the WOCO Foundation (London, Ontario). In addition, this research has been supported by the SRC Travel Grant, Faculty of Community Services, Ryerson University (to BEW). We would like to thank Kimmi Labbett for her commitment to the behavioural coding of the maternal sensitivity component of the MAVAN project. As well, we would like to thank Jessica Grummitt for her commitment to managing the MAVAN Data Base associated with the work of Dr. Robert Levitan at CAMH, Toronto. In addition, we would like to thank Patricia Szymkow and Carmen
MacPherson for their commitment to co-ordinating the MAVAN project in Hamilton, Ontario.
Chapter 5

Study 2: This chapter examines whether the CEBQ sub-scales for emotional overeating, food responsiveness, and/or enjoyment of food mediate the relationship between maternal sensitivity at 6 months and child BMI z-scores at 48 months of age described in study 1.

Hypothesis: The association between maternal sensitivity at 6 months and BMI z-scores at 48 months in girls is mediated by one or more of emotional overeating, food responsiveness, and/or enjoyment of food.

“...For many obese children deprived of other outlets and satisfying contacts, the intake of food had gained an inordinate importance....”

Dr. Hilde Bruch, 1940
5.1. Abstract

**Background:** Study 1 demonstrated a significant association between low maternal sensitivity at age 6 months and higher BMIs at age 48 months in girls but not boys. The current study examines whether Childhood Eating Behaviour Questionnaire (CEBQ) subscale scores for emotional overeating (EO), food responsiveness (FR), and/or enjoyment of food (EF) mediate this association.

**Methods:** This analysis was based on a dataset of 223 children (115 boys, 108 girls) who had complete data for maternal sensitivity and BMI z-scores. Based on the work of Hayes (Hayes PROCESS, 2013) we explored whether each of the thee CEBQ sub-scales listed above mediates the relationship between low maternal sensitivity at 6 months and high child BMI z-scores at 48 months of age. Following from our earlier findings, we further examined whether sex moderates this putative mediation effect (moderated-mediation using Hayes model 58).

**Results:** The overall moderated-mediation model was significant only when emotional overeating was used as the potential mediator ($\beta = -0.30$, S.E.= 0.21, CI = -0.87 to -0.01). Extending from our initial finding, this mediation effect was significant in girls ($\beta = -0.30$, S.E.=.21, CI= -.85 to -.01) but not boys ($\beta = .004$, SE=.03, CI= -0.04 to.12).

**Conclusions:** Emotional overeating at 48 months of age mediates the association between maternal sensitivity at 6 months and BMI z-scores at age 48 months in girls but not boys. Given that the 48-month CEBQ measures are based on maternal reports, further testing of this model using other measures of emotional eating as the children reach later childhood will be of great interest.
Keywords: Maternal sensitivity, body mass index (BMI) WHO z scores, Children’s Eating Behaviour Questionnaire (CEBQ), emotional regulation, emotional overeating, sex differences
5.2. Overview

Study 1 (Chapter 4) demonstrated a significant association between low maternal sensitivity at age 6 months and higher BMI at age 48 months in girls but not boys.

Study 2 (Chapter 5) examines whether this association is mediated by the CEBQ sub-scales for emotional overeating, food responsiveness and/or enjoyment of food. We limited these analyses to only three CEBQ subscales in part to avoid the problem of multiple testing. Another reason to focus on these particular CEBQ subscales was that:

1. emotional overeating, food responsiveness, and enjoyment of food are all related to mood and emotion in some way, and all contribute to overeating and obesity
2. mood and emotional regulation are strongly shaped by the early dyadic relationship
3. the link between maternal sensitivity and BMI might thus be mediated by one or more of these CEBQ measures
Given our prior finding that sex moderates the association between maternal sensitivity and BMI z-scores (Wendland BE et al, 2014), and prior research showing that the link between eating behaviour and emotions may be different in females than in males (e.g. Galloway et al, 2010; Halliday et al, 2014), we used Hayes PROCESS Model 58, which tests moderated-mediation, for this purpose. We hypothesized that one or more eating styles based on the CEBQ would mediate the relationship between maternal sensitivity at 6 months and child BMI z scores at 48 months, moderated by the sex of the child:

The next sections will review prior work on emotional eating in children, and are followed by a more detailed description of the methods and results for study 2.
5.3. Introduction and Overview

5.3.1. An Historical Perspective on Emotional Eating: The pioneering work of Dr. Hilde Bruch

Emotional eating can be defined as eating in response to emotional stimuli rather than internal signals of hunger. Our current understanding of emotional eating can be traced back to the mid-1930s with the pioneering work of Dr. Hilde Bruch, a paediatrician who had emigrated from Europe to New York. Bruch was strongly motivated to apply systematic, scientific methods to diagnose and treat young clinic patients who presented with overweight-obesity. Hormone replacement treatment for an underactive thyroid was seen as the primary solution for weight problems in children in America at that time. However, based on her own careful observations, Bruch was among the first to treat weight problems with modified food choices and portions as well as physical activity (Bruch H, 1940). To her surprise she found that many mothers felt threatened by her prescribed diet and activity regimens, while at the same time exhibiting ambivalent feelings towards their overweight-obese children (Bruch H, 1940). Bruch described these mothers as apathetic, lacking healthy emotional feelings towards their children, along with a lack of supportive behaviours toward healthier food choices (Bruch H, 1940).

Despite these challenges, Bruch pressed forward with her treatment approach while carefully documenting each child’s weight, caloric intake, food preferences and cholesterol levels, as well as ethnic background, income information, and family size. It was these careful clinical observations that first led
to the conclusion that weight gain in children resulted from increased caloric intake and lack of physical activity rather than an underactive thyroid gland.

The frequent observation of emotional indifference in mothers of overweight children was an ongoing concern to Bruch, who turned to the psychiatric literature in the hope of understanding it. This proved difficult at first, as most psychiatric journals in the 1930s focussed on individual rather than family dynamics (Bruch H, 1941). However, her tremendous drive motivated her to leave her clinical practice in New York to qualify in psychiatry and psychoanalysis in Baltimore. Following her training Bruch returned to New York in the early 1940s to further elucidate the link between emotions, eating behaviour and overweight-obesity in children.

In her ongoing work with overweight children, Bruch observed an emotional tension which was not related to hunger for food, but rather a sense that “I need food now” (Bruch H, 1940). She observed that food intake driven by negative emotions was providing a means to control feelings of anxiety and depression in these children (Bruch H, 1940). In sum, she believed that child overweight-obesity was largely mediated by overeating resulting from psycho-emotional processes that involved the child, parents, and the overall atmosphere within the family (Bruch H, 1940, 1941).

Bruch had a strong interest in the dyadic feeding relationship associated with overweight and obese children. Her psychoanalytic training led her to focus on how infants used body language and crying to signal their needs and desires to caregivers (Bruch H, 1940,1953). Bruch observed that “an alert mother quickly
learns to read the cues of her baby’s crying… but a confused over-anxious mother, who turns to experts for advice rather than relying on her own competency is likely to continue to misread cues, masking insecurity by indiscriminately offering food…” (Bruch H, 1940). She further suggested that mothers who were unable to read the cues of their children would confuse them, promoting helpless feelings which made it difficult for the children to differentiate hunger from other uncomfortable feelings (Bruch H, 1940).

Around the same time that Bruch was documenting her concerns about the mother-child relationship, feeding behaviour and obesity, other psychiatrists such as David Levy and Renee Spitz were examining the effect of strained early relationships on the lower extremes of weight regulation. Based on observations from his own clinical practice, Levy wrote that "the child had an emotional hunger for maternal love and those other feelings of protection and care implicit in the mother–child relationship" (Levy D, Maternal Overprotection, 1943). In another city, Spitz studied infants who were raised in physically well-kept orphanages which provided sufficient nutrition but lacked caregivers to develop enduring emotional bonds with the children. In many cases, this led to a failure to thrive, and even death from a lack of caloric intake despite satisfactory food availability (Spitz R, 1945, 1965). Taken together with Bruch’s findings, this suggested that the early dyadic relationship influences feeding behaviours in a bidirectional way, in some cases leading to obesity and in others a lack of normal weight gain.

The emerging construct of attachment theory in the late 1960s and 1970s stimulated a second wave of work on emotions and eating behaviour. Similar to
Bruch, Ainsworth MDS and Bell SM (1969) noted marked differences in how mothers would cue their infants when feeding. Sensitive mothers were able to gratify their infants using well timed emotional cues and attention, while less sensitive mothers tended to over-feed their babies in the hope of gratifying them. A third group of mothers overfed their babies with the intention of having them sleep longer and demanding less maternal attention (Ainsworth MDS and Bell SM, 1969).

**Summary of early work on emotions and eating behaviours**

In sum, Bruch’s excellence in systematic observation and documentation, and her intensive training in psychiatry and psychoanalysis, enabled her to achieve several major conceptual advances in understanding links between the dyadic relationship, emotion regulation and feeding behaviour. She was likely to have been the first to introduce the term “emotional eating” in the form that we now recognize (Bruch H, 1940, 1941). One limitation of her work, which reflected the state of the field at that time, was the absence of validated instruments to assess eating behaviour more objectively and allow testing of her hypotheses more empirically. This important development came many years later, as summarized briefly in the next several paragraphs.
5.3.2. Emotional Eating in the Modern Era: The Development of Standardized Rating Scales to Evaluate Eating Behaviours:

While Bruch excelled at systematic observation and documentation, the availability of standardized and validated rating scales to evaluate eating behaviours came decades later. van Strien took a leading role in this regard in the early 1980s with the development of the tri-scale Dutch Eating Behaviour Questionnaire (DEBQ) which assesses emotional, external, and restrained eating behaviours (van Strien T et al, 1986).

5.3.2.1. The Dutch Eating Behaviour Questionnaire (DEBQ)

Prior to the development of the DEBQ, while there were several theories on the phenomenology and etiology of abnormal eating behaviour, the relative dearth of validated rating scales limited the interpretation and progression of this work on a broader scale (van Strien T et al, 1986). The DEBQ was developed to measure core aspects of eating behaviour that were based on three major theoretical frameworks: psychosomatic theory (Bruch H, 1964), externality theory (Schachter S and Rodin J, 1974), and the construct of restrained eating (Herman CP and Polivy J, 1980; Braet C and van Strien T, 1997). The corresponding items on the DEBQ were emotional eating, externally induced eating (eating in response to food related stimuli, regardless of the states of hunger and satiety), and restrained eating (attempts to refrain from eating). Creating this instrument would provide a greater understanding of eating patterns across three different dimensions for those who were vulnerable to overweight-obesity and/or eating disorders.
To establish the final items for the DEBQ, a longitudinal survey was initiated in 1980 testing potential items for the tri-scale questionnaire, using volunteer subjects from regions in the Netherlands. The study started with 100 items from three existing questionnaires; the Eating Pattern Questionnaire (EPQ), (Wollersheim JP, 1970), the Fragenbogen fur Latente Adipositas (FLA), (Pudel V, et al, 1975), and the Eating Behaviour Inventory (EBI). The EPQ contained items related to emotional eating, the FLA provided items related to restrained and external eating, and the EBI offered a series of statements on behaviour that was related to the assessment of external stimulus control (van Strien T et al, 1986).

The final DEBQ that emerged from this survey was a 33-item self-assessment with scales for restrained, emotional, and external eating patterns. Factor analyses indicated that all items on restrained and external eating scales had high loadings on one factor while the emotional eating scale was found to have two loadings- either eating in relation to diffused emotions or eating in relation to obvious emotions. Early papers confirmed that emotional, external, and restrained eating behaviours act as independent constructs (van Strien T and Schippers GM, 1995; Wardle J, 1987). Since their implementation, these scales have demonstrated high consistency and validity (van Strien T et al, 1986).
5.3.2.2. The Dutch Eating Behaviour Questionnaire-Child (DEBQ-C)

The Dutch Eating Behaviour Questionnaire - Child (DEBQ-C), was developed to create a questionnaire that could be used for children in the age range of 7 to 12 years (van Strien T et al, 2007). Like the original DEBQ, the version for children also has the three scales for emotional, external, and restrained eating behaviours: the wording of questions was been adjusted for the needs of children, and the number of questions reduced from 33 to 20 items.

5.3.2.3. The Children’s Eating Behaviour Questionnaire (CEBQ)

While the DEBQ-C is oriented towards school-age children, obesogenic eating behaviour may have its origins even earlier in life. The Child Eating Behaviour Questionnaire (CEBQ) was developed to evaluate eight dimensions of eating behaviour in young children in an attempt to understand which eating styles might contribute to different trajectories of early weight gain (Wardle J et al, 2001). Given its focus on pre-school children, parents provide the reports on child eating behaviours when using the CEBQ.

The creation of the CEBQ was based on the literature of adult and child eating styles, and on interviews with parents about their children's eating behaviours (Wardle J et al, 2001). A large pool of items was developed through modification of adult items and by creating new items based on behavioural testing. Items were then pared down for each construct of interest to create an internally consistent set of scales covering eight eating styles: food responsiveness, enjoyment of food, emotional overeating, desire to drink, satiety
responsiveness, slowness in eating, emotional under-eating, and fussiness (Wardle J et al, 2001). Subsequent to its initial development, the CEBQ has been translated into several languages and shown consistent validity throughout the world (Carnell S and Wardle J, 2007; Viana V et al, 2008; Sleddens EFC et al, 2008; Santos JL et al, 2011; Mallan KM, 2014).

5.3.3. Studies of High–Risk Eating Behaviours in Children based on the DEBQ and CEBQ

Given the high prevalence of overweight-obesity in both developed and developing countries around the world, and the high morbidity associated with obesity and eating disorders starting early in life, there has been significant interest in using structured rating scales to characterize high risk eating behaviours in children and adolescents. Prior to the development of the CEBQ or the DEBQ-child version, the adult DEBQ was used to characterize high risk eating behaviours in adolescents. One such study by Wardle J et al (1992) evaluated the connection between eating styles, attitudes towards food and food intake in a large, community-based sample. Adolescents scoring highly on the restrained eating subscale were found to have negative feelings towards food, avoidance of fattening foods and guilt around eating. On the other hand, adolescents scoring most highly on external and emotional eating reported positive feelings towards food without the guilt characteristic of restrained eaters (Wardle J et al, 1992). Subjects who scored highly on emotional eating were also more likely to report binge eating, though a relationship between emotional eating and increased energy intake was not identified. The authors suggested
that had measures of 'emotional state' been included in this study it might have
provided a clearer association between emotional eating, energy intake and
weight. Notwithstanding this limitation, this was among the first large scale
studies to validate the utility of the DEBQ subscales in an adolescent population,
and to demonstrate unique subgroups of adolescents with highly distinct profiles

While restrained eaters tend to exhibit a highly unique profile on the DEBQ
that makes them stand out as a distinct subgroup, the distinction between
emotional and external eaters is often less clear. In the Wardle J et al (1992)
study, similar to emotional eaters, adolescents who scored highly on external
eating were also positively indulgent towards food, suggesting one way that
external eating overlaps with emotional eating (Wardle J et al, 1992). van Strien
T et al (1995) studied this further in a cohort of female university students, and
showed that emotional eating was significantly associated with emotional distress
and day to day interpersonal relationship issues, while external eating was not,
suggesting that these scales do represent independent constructs.

**Eating Styles in Pre-Adolescent and Younger Children:**

Given increasing evidence that eating behaviours are established early in
life, there has been growing interest in studying eating styles in younger children
and how this relates to distinct parenting practices which could be a target of
intervention. For example, van Strien T and Bazelier FG, (2007) studied 596
children aged 7-12 years using the DEBQ for children (DEBQ-C) to evaluate how
parental control of food intake (‘pressure to eat’ and ‘restriction of eating’) might influence child eating behaviours. The key finding was that for boys only, perceived pressure to eat was associated with emotional and external eating, while for both sexes, perceived restriction to eat was positively associated with restrained eating and inversely related to emotional and external eating. Children who were overweight had significantly higher scores on dietary restraint, and perceived more parental restriction associated with eating. Overall, the unexpectedly high ratings of external and restrained eating for both boys and girls in this study was identified as “alarming” by these authors. They suggested that these eating styles were likely to reflect inadequate self-regulation and lack of responsiveness to normal hunger and satiety cues in a much larger proportion of children than previously thought (van Strien T and Bazelier FG, 2007).

Another important role of parenting for eating behaviour and weight regulation in children relates to modelling of parental feeding practices. In a recent large cross-sectional study in Europe, feeding patterns of parents were shown to correlate highly with the eating behaviours of their children. For example, if parents ate many ‘fast food’ meals throughout the day their children tended to model this behaviour over time. Based on these findings, the authors stressed the potential utility of education and simple interventions to guide parents and thus their children towards healthy long term trajectories of food intake (Jansen PW et al, 2012).

As reviewed in section 5.3.2.3 above, studying eating behaviours in the youngest children requires maternally-reported questionnaires specifically
designed for this purpose, given the unique aspects of this age group. The CEBQ assesses eight eating behaviours most relevant to early weight regulation (Wardle J et al, 2001). Four sub-scales measure food approach behaviours indicating positive interest in eating by children: food responsiveness (FR), enjoyment of food (EF), emotion-overeating (EO) and desire to drink (DD) while the other four sub-scales demonstrate food avoidant behaviours indicating a lack of interest in eating by children: slowness in eating (SE), satiety responsiveness (SR), emotional-under eating (EU), and fussiness (FU).

A large community based study of young Canadian children age 4-5 years (n=1730) compared individual eating behaviours using the CEBQ in overweight, normal, and underweight groups (Spence JC et al, 2011). Significant differences (p<0.01) were identified between weight status groups for six of the sub-scales: food responsiveness (FR), emotional over-eating (EO), enjoyment of food (EF), satiety responsiveness (SR), slowness in eating (SE), and food fussiness (FU). Linear trend analysis showed significant positive linear patterns by weight for FR, EO, and EF, and significant negative linear patterns by weight for SR, SE, and FU. Overweight children were found to have greater food approach behaviours compared to normal weight and underweight children. Similar findings were reported by Webber L et al (2009) and Santos JL et al (2011) in the 6-12 age range.

These and many other studies based on structured eating behaviour questionnaires such as the CEBQ have demonstrated highly consistent results in obese samples using cross-sectional research designs. Studies based on the
food approach-related and food avoidance-related appetitive traits have consistently demonstrated a profile of responsiveness to and enjoyment of food, with more emotional eating, as well as rapid eating along with lower responsiveness to internal satiety cues, and lower fussiness towards food associated with increased risk of pathological weight gain.

**Summary and Rationale for the Current Study**

As outlined above, descriptive studies using the DEBQ and CEBQ suggest that there are clear differences in eating styles between overweight/obese and normal weight populations across the lifespan, including children. However, most of these studies have been cross-sectional in design, making it difficult to discern cause and effect, although some work using more prospective longitudinal designs has begun to emerge (e.g. Parkinson KN et al, 2010). Improving our understanding of the specific mechanisms that promote the high risk eating behaviours that lead to pathological weight gain is a key priority for this area of work.

The current study implements a longitudinal strategy in examining a potential mechanism through which emotional overeating might increase overweight/obesity risk. Study 1 (Chapter 4) found a relationship between low maternal sensitivity at 6 months and higher BMI-z scores at age 48 months in girls but not boys. The current study 2 (Chapter 5) examines whether emotional overeating, food responsiveness, and/or enjoyment of food at 48 months mediate this association. Our working hypothesis was that the association between
maternal sensitivity at 6 months and BMI z-scores at 48 months in girls is mediated by emotional overeating, food responsiveness, and/or enjoyment of food. The following is a detailed summary of this work.

5.4. Participants and Methods

5.4.1. Study Participants

The current study sample included 223 children recruited in either Montréal, Québec (N= 105) or Hamilton, Ontario (N= 118), Canada as part of an established prospective birth cohort, the Maternal Adversity, Vulnerability and Neurodevelopment (MAVAN) project (O’Donnell K et al, 2015). For the current analysis, all available participants who had been enrolled in the MAVAN study at birth, been scored for maternal sensitivity at 6 months of age, and who had participated in a laboratory visit to measure growth at 48 months of age were included. Eligibility criteria for mothers at study entry included age ≥18 years, singleton gestation, and fluency in French or English. Women with severe chronic illness, placenta previa, and history of incompetent cervix, impending delivery, or a foetus/infant affected by a major anomaly or born at a gestational age less than 37 weeks were excluded. Birth records were obtained directly from the birthing unit.

The current study sample was found to be comparable to the overall birth cohort in terms of maternal age at childbirth, gestational age, birth size, income categories, and maternal education. MAVAN is a multidisciplinary, collaborative study, recruiting pregnant women from obstetric clinics in hospitals located in
Montréal, Québec and Hamilton, Ontario. All participants experienced identical home and laboratory based assessments. We excluded very low birth weight infants and included those born at 37 to 41 weeks gestation. The maternal age at childbirth was also comparable to the general population within Canada (study sample = 30.5 years; Québec =29.5 years, Ontario = 30.2 years), (Statistics Canada, 2012). The MAVAN project has families receiving income below the low income cut off (LICO, Statistics Canada, 2005) was near 30% compared to 15% in the general population (Statistics Canada, 2009). However, while education below 10 years was found in only 4% of the mothers of our sample, this number reaches 12% of adults in the provinces of Québec and Ontario (Statistics Canada, 2011). In sum, SES status was relatively low but education relatively high, relative to Canadian population norms.

Approval for the MAVAN project was obtained from obstetricians performing deliveries at the study hospitals and by the ethics committees and university affiliates (McGill University and l’Université de Montréal: the Royal Victoria Hospital, Jewish General Hospital, Centre hospitalier de l’Université de Montréal, and Hôpital Maisonneuve-Rosemount), and St. Joseph’s Hospital and McMaster University, Hamilton, Ontario, Canada. Informed consent was obtained from all participants.
5.4.2. Measures

5.4.2.1. Mother-child interaction using video-taping

For the purposes of assessing maternal sensitivity (appropriately, and timely response to infant signals) at 6 months, 30 minutes of non-feeding mother-infant interactions were videotaped in the home. The 6 month videos were entirely free-play. The recordings were later coded by a highly trained rater (KL) who was independent from the MAVAN study and had no awareness of the primary study hypotheses. The instrument used was the 25 item Maternal Behaviour Q-sort (MBQS revised-25) which was based on the earlier Ainsworth scales (Ainsworth SE et al, 1978/2015) and has been shown to correlate with constructs central to infant development and attachment, including other measures of maternal sensitivity as well as infant attachment security and cognitive development (Pederson DR, Moran G et al, 1990; Tarabulsy GM et al, 2009). To verify reliability three other experts in the field independently coded twenty eight 6 month tapes to obtain intra-class correlations between 0.82 and 0.94.

5.4.2.2. Growth Measures

At the 48 month visit children had length and weight measures taken. Standing height, without shoes, was measured (to the nearest 0.1 cm) with the use of a stadiometer (Perspective Enterprises, PE-AIM-101, Portage, Michigan). Body weight, in light clothing, was measured (to the nearest 0.1 kg) with the use of a digital floor scale (TANITA BF625, Arlington Heights, Illinois). BMI was
calculated as weight in kilograms divided by height in metres squared (kg/m²).

BMI z-scores were calculated based on well established World Health Organization (WHO) growth curves for girls and boys (WHO, 2006).

5.4.2.3. Child Eating Behaviour Questionnaire (CEBQ)

The CEBQ is described in section 5.3.2.3 above. Based on the current hypothesis, three CEBQ sub-scales: emotional overeating (EO), food responsiveness (FR), and the enjoyment of food (EF) of the Childhood Eating Behaviour Questionnaire (CEBQ), assessed at age 48 months, was used in the mediation model.

5.4.2.4. Covariates Related to BMI

Based on their established relationship with early growth and overweight-obesity risk, we included sex, birth-weight (based on WHO- z scores; Oken et al, 2003), maternal BMI and a blended variable for socio-economic status and maternal education in our analyses. Regarding the latter, bivariate low/high sub-groupings for both maternal SES and maternal education were first established based on Canadian norms (Statistics Canada, 2005). Maternal SES groupings were: “low” = total family income after tax <$21,359; “high” = total income after tax >$21,358 (Statistics Canada, 2005). Maternal education was defined as “low” if high school graduation was not achieved (Statistics Canada, 2011). A single composite variable for socio-economic status and maternal education was next generated based on the following three groupings: “low-low” identifies low
income and low maternal education; “low/high” identifies low income and high maternal education or high income and low maternal education; “high/high” identifies high income and high maternal education. As relatively few mothers in this sample met criteria for both low education and low income, a bivariate factor for SES and maternal education was ultimately used for the statistical analyses i.e. high education-high SES (n= 156; 77.6%) versus all other subgroups combined (n= 45; 22.4%). No data for maternal SES and education was available for 22 other subjects. (See Table 1)

Site was also included as a possible covariate to control for possible differences in the Montreal and Hamilton samples.

5.5. Statistical Methods

For the current analyses we used IBM SPSS statistical software version 21 (IBM SPSS Statistics for Windows, Amonk, N.Y.) supplemented by Hayes PROCESS for mediation and moderation modelling (Hayes AF, 2013). The PROCESS software developed by Hayes was specifically designed to study more complex moderation and/or mediation effects. The PROCESS menu includes 76 potential modelling templates for moderation, mediation, and combined analyses (http://www.afhayes.com/spss-sas-and-mplus-macros-and-code.html).
5.5.1. Testing the Current Hypothesis using PROCESS:

When implementing Hayes PROCESS for mediation and/or moderation analyses, one must first establish which of the several models available will be tested. For the current analyses, the goal was to study the CEBQ sub-scales associated with both mood and increased eating (food responsiveness, enjoyment of eating, and emotional overeating) as potential mediators of our previous finding linking low maternal sensitivity at age 6 months with higher BMI z-scores at age 48 months in girls but not in boys (Wendland BE et al, 2014). While it might be argued that the current mediation analysis could be limited to girls, we included boys to best elucidate the sex moderation effect. According to Hayes, moderated mediation can be constructed through a conditional process model, which allows the direct and/ or indirect effects of an independent variable X on a dependent variable Y through a mediator M to be moderated.

Figure 1, which is based on Hayes PROCESS model 58 adapted for the current variables, demonstrates this moderated-mediation strategy.

![Diagram](image.png)
To support mediation, one must demonstrate an indirect path from the independent variable X (maternal sensitivity) to the dependent variable Y (BMI z-score at 48 months) through the putative mediator variable (CEBQ subscale). To demonstrate moderated mediation using a dichotomous moderator, one must show that this indirect path is significant at one level of the moderator but not the other. Based on our earlier findings, the current goal was to show that the indirect path was significant in girls but not boys.

Analysis of variance and regression analysis were used to evaluate the effects of covariates (site, sex, SES-maternal education, birth weight, maternal BMI at 48 months and emotional overeating at 48 months) on the study results.

5.6. Results

5.6.1. The Study Sample:

Table 1 summarizes the sample characteristics including potential covariates and provides the simple bivariate associations between each independent variable and 48 month BMI z scores. As shown, there was a significant bivariate association between the SES/maternal education variable and 48 month BMI z scores, with high SES/high maternal education status being associated with lower 48 month BMI. Higher birth weight z-scores, higher emotional overeating, food responsiveness and enjoyment of eating scores and higher maternal BMI were all positively associated with 48 month child BMI.
Neither infant sex nor maternal sensitivity scores were significantly related to BMI z-score in the univariate analysis.

Table 1a: Descriptive statistics for categorical variables across all subjects (n=223)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Categories</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td>105</td>
<td>Montréal</td>
<td>47.1</td>
</tr>
<tr>
<td></td>
<td>118</td>
<td>Hamilton</td>
<td>52.9</td>
</tr>
<tr>
<td>Sex</td>
<td>115</td>
<td>Boys</td>
<td>51.6</td>
</tr>
<tr>
<td></td>
<td>108</td>
<td>Girls</td>
<td>48.4</td>
</tr>
<tr>
<td>Income Maternal Education</td>
<td>156</td>
<td>High income/ high education</td>
<td>77.6</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>Other</td>
<td>22.4</td>
</tr>
</tbody>
</table>

**Notes: Discrepancies in sample size are due to missing/incomplete data.**

1High = high SES and high maternal education; Other = low SES and/or low maternal education
MBQS-25 = Maternal Behavior Q-Sort 25-item (maternal sensitivity)
Table 1b: Descriptive statistics for continuous variables across all subjects (n=223)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child BMI 48 months-z-score</td>
<td>223</td>
<td>-.136</td>
<td>5.00</td>
<td>.50</td>
<td>1.06</td>
</tr>
<tr>
<td>MBQS-25 item (maternal sensitivity at 6 months)</td>
<td>223</td>
<td>-.70</td>
<td>.94</td>
<td>.41</td>
<td>.43</td>
</tr>
<tr>
<td>Birth weight z-score</td>
<td>223</td>
<td>-2.58</td>
<td>2.58</td>
<td>-0.12</td>
<td>0.09</td>
</tr>
<tr>
<td>+Maternal BMI (at 48 months)</td>
<td>185</td>
<td>17.46</td>
<td>51.86</td>
<td>27.4</td>
<td>6.54</td>
</tr>
<tr>
<td>CEBQ (Emotional Overeating) at 48 months</td>
<td>209</td>
<td>1.00</td>
<td>3.75</td>
<td>1.65</td>
<td>0.61</td>
</tr>
<tr>
<td>CEBQ (Food Responsiveness) at 48 months</td>
<td>204</td>
<td>1.00</td>
<td>5.00</td>
<td>2.33</td>
<td>0.81</td>
</tr>
<tr>
<td>CEBQ (Enjoyment of Food) at 48 months</td>
<td>210</td>
<td>1.75</td>
<td>5.00</td>
<td>3.63</td>
<td>0.76</td>
</tr>
</tbody>
</table>

+Discrepancies in sample size are due to missing/incomplete data

*Maternal Behaviour Q-sort (MBQS) is scored between -1.0 to 1.0; the most sensitive mother will score close to 1.0 while the least sensitive mother will score close to -1.0.

5.6.2. Correlation matrix: Predictor and Outcome Variables and Covariates

Tables 2a, 2b and 2c are a series of correlation matrices for the key study variables across both sexes (table 2a) and in girls and boys considered separately (tables 2b and 2c respectively). As shown in table 2a, across all children, there was a significant negative association (at p<.05) between two of the putative mediators (emotional overeating and food responsiveness) and the main predictor variable (MBQS score) and a significant positive association (at
p<.01) between all three putative mediators and the main outcome variable (BMI z score at age 48 months).

**Table 2a: Correlation Matrix Across all Children (n=223)**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBQS 6mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI-WHOz-score 48mo</td>
<td>-0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SES-ED</td>
<td>0.01</td>
<td>-0.20**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight z-score</td>
<td>0.06</td>
<td>0.17**</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal BMI 48mo</td>
<td>-0.12</td>
<td>0.37**</td>
<td>-0.14</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ - Emotional Overeating 48 mo</td>
<td>-0.15*</td>
<td>0.21**</td>
<td>-0.15*</td>
<td>0.08</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ – Food Responsiveness 48 mo</td>
<td>-0.15*</td>
<td>0.25**</td>
<td>-0.08</td>
<td>0.08</td>
<td>0.02</td>
<td>0.56**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ - Enjoyment of Food 48 mo</td>
<td>0.07</td>
<td>0.21**</td>
<td>0.06</td>
<td>0.09</td>
<td>-0.04</td>
<td>0.14*</td>
<td>0.50**</td>
<td></td>
</tr>
</tbody>
</table>

* p<= 0.05; ** p<=0.01

Table 2b indicates that in girls considered separately, the pattern of results was highly similar to the overall results, except for food responsiveness which was not significantly correlated with MBQS scores in this case.

**Table 2b: Correlation Matrix in Girls only (n=108)**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBQS 6mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI-WHOz-score 48mo</td>
<td>-</td>
<td>0.25**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SES-ED</td>
<td>0.12</td>
<td>-0.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight z-score</td>
<td>0.06</td>
<td>0.13</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal BMI 48mo</td>
<td>-0.19</td>
<td>0.35**</td>
<td>-0.17</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ - Emotional Overeating 48 mo</td>
<td>-</td>
<td>0.29**</td>
<td>-0.20</td>
<td>-0.07</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ – Food Responsiveness 48 mo</td>
<td>-0.14</td>
<td>0.38**</td>
<td>-0.07</td>
<td>0.04</td>
<td>-0.08</td>
<td>0.63**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ - Enjoyment of Food 48 mo</td>
<td>-0.07</td>
<td>0.27**</td>
<td>0.05</td>
<td>0.06</td>
<td>-0.08</td>
<td>0.07</td>
<td>0.07</td>
<td>0.51**</td>
</tr>
</tbody>
</table>

* p<= 0.05; ** p<=0.01
As shown in table 2c where boys are considered separately, there was no significant associations between emotional overeating, food responsiveness, or enjoyment of food and either MBQS scores or 48-month BMI z scores.

Table 2c: Correlation Matrix in Boys only (n=115)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBQS 6mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI-WHOz-score 48mo</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SES-ED</td>
<td>-0.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight z-score</td>
<td>0.08</td>
<td>0.20*</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal BMI 48mo</td>
<td>-0.07</td>
<td>0.40**</td>
<td>-0.11</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ - Emotional Overeating 48 mo</td>
<td>-0.04</td>
<td>0.11</td>
<td>-0.11</td>
<td>0.30**</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ - Food Responsiveness 48 mo</td>
<td>-0.16</td>
<td>0.12</td>
<td>-0.08</td>
<td>0.10</td>
<td>0.12</td>
<td>0.55**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEBQ - Enjoyment of Food 48 mo</td>
<td>-0.06</td>
<td>0.12</td>
<td>0.08</td>
<td>0.10</td>
<td>-0.01</td>
<td>0.23*</td>
<td>0.44**</td>
<td></td>
</tr>
</tbody>
</table>

* p<= 0.05; ** p<=0.01
Table 3. Univariate Associations - predicting 48 month BMI (n=223)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta estimate</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBQS at 6mo</td>
<td>-0.26</td>
<td>0.16</td>
<td>-1.59</td>
<td>0.11</td>
</tr>
<tr>
<td>Site</td>
<td>0.18</td>
<td>0.14</td>
<td>1.30</td>
<td>0.20</td>
</tr>
<tr>
<td>Sex (female vs male)</td>
<td>-0.18</td>
<td>0.14</td>
<td>-1.31</td>
<td>0.19</td>
</tr>
<tr>
<td>SES-maternal education (high vs. low)</td>
<td>-0.55</td>
<td>0.17</td>
<td>-3.14</td>
<td>0.002</td>
</tr>
<tr>
<td>Birth weight z-score</td>
<td>0.20</td>
<td>0.08</td>
<td>2.56</td>
<td>0.011</td>
</tr>
<tr>
<td>Maternal BMI 48mo</td>
<td>0.06</td>
<td>0.01</td>
<td>5.43</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CEBQ - Emotional Overeating 48mo</td>
<td>0.21</td>
<td>0.12</td>
<td>3.07</td>
<td>0.002</td>
</tr>
<tr>
<td>CEBQ - Food Responsiveness 48mo</td>
<td>0.33</td>
<td>0.09</td>
<td>3.76</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CEBQ - Enjoyment of Food 48mo</td>
<td>0.30</td>
<td>0.10</td>
<td>3.11</td>
<td>0.002</td>
</tr>
</tbody>
</table>

5.6.3. Hayes PROCESS Modelling of Moderated-Mediation

When using Hayes PROCESS model 58, to demonstrate a significant mediation effect, the confidence intervals for the indirect pathway must not cross 0. To demonstrate a moderated-mediation effect, one must further show an indirect path from the independent variable X (MBQS score) to the dependent variable Y (48-month BMI z-score) at one level of the moderator (sex) but not the
other. Results using Hayes model 58 indicated that the overall index of moderated–mediation, which assesses the significance of the full model across the two sexes while controlling for covariates, was significant when emotional overeating was the mediator ($\beta = -0.301$, $SE=0.21$, CI= -0.87 to -0.01), but not when either food responsiveness or enjoyment of food was used. Table 3 summarizes the conditional indirect effect of maternal sensitivity on BMI z scores in girls and boys respectively, using emotional overeating as the mediating variable. As shown, the results confirm that the indirect path from maternal sensitivity to BMI z-scores through emotional overeating was significant in girls but not boys.

**Table 4. Conditional Indirect effect of X on Y at different values of the moderator:**

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>Beta effect</th>
<th>Boot standard error</th>
<th>Boot LLCI</th>
<th>Boot ULCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional overeating</td>
<td>Girls</td>
<td>-0.30</td>
<td>0.21</td>
<td>-0.85</td>
<td>-0.01</td>
</tr>
<tr>
<td>Emotional overeating</td>
<td>Boys</td>
<td>0.004</td>
<td>0.03</td>
<td>-0.04</td>
<td>0.12</td>
</tr>
</tbody>
</table>

To further examine the indirect pathway from X to Y across the 2 sexes, we next examined the two sides of the indirect pathway considered separately. Firstly, we examined pathway A from the independent variable (maternal sensitivity) to the mediator (emotional overeating), controlling for covariates. This indicated a significant maternal sensitivity by sex interaction in predicting emotional eating: ($\beta = -0.55$, $SE= 0.23$, $p=0.02$). There was a significant negative
association between maternal sensitivity and emotional over-eating in girls (β = -0.30, SE=0.21, CI= -0.85 to -0.01) but not boys (β = 0.004, SE=0.03, CI= -0.04 to 0.12). Next we examined pathway B from the mediator variable to the dependent variable. The emotional overeating by sex interaction was not a significant predictor of BMI z-scores (β=0.42, SE 0.26), although it did approach a trend (p=0.11).

These results, which are summarized in Figure 2, suggest that the significant moderated-mediation effect was primarily attributable to the negative association between maternal sensitivity and emotional overeating in girls but not boys, while the association between emotional overeating and BMI-z-scores was not different across the sexes.
Figure 2. Summary findings for the moderated-mediation effect based on the Hayes model 58.

As shown, the MBQS by sex interaction predicting Emotional Overeating was significant, while the Emotional Overeating X sex interaction predicting Child BMI z scores was not.

These results suggest that the association between maternal sensitivity and Emotional Eating was different in girls and boys, while the association between Emotional Eating and BMI-z-scores was not different across the sexes.
Post-Hoc Testing of the Mediator Pathway in Girls – only

As a further elucidation of these findings, we tested a basic mediation model in girls considered separately using Process model 4. In girls, the association between maternal sensitivity at 6 months and emotional overeating at 48 months was significant at p=0.015, while the relationship between emotional overeating at 48 months and BMI-z scores at 48 months was significant at p=0.004; the direct effect of X on Y was significant at a trend level of p=0.059: These results, with the corresponding β weights, can be summarized as follows:

MODEL 4 - only girls

** p < .01; * p< .05; ^ p< .10
The results of the HAYES PROCESS modelling, in girls only was as follows:

### Total effect of X on Y

<table>
<thead>
<tr>
<th></th>
<th>Beta estimate</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.86</td>
<td>0.32</td>
<td>-2.68</td>
<td>0.009</td>
</tr>
</tbody>
</table>

### Direct effect of X on Y

<table>
<thead>
<tr>
<th></th>
<th>Beta estimate</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
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<td></td>
<td>-0.60</td>
<td>0.32</td>
<td>-1.88</td>
<td>0.06</td>
</tr>
</tbody>
</table>

### Indirect effect of X on Y

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<th></th>
<th>Beta estimate</th>
<th>Boot standard error</th>
<th>Boot LLCI</th>
<th>Boot ULCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional overeating</td>
<td>-0.27</td>
<td>0.18</td>
<td>-0.78</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

In summary, there was a significant inverse relationship between maternal sensitivity and emotional overeating, and a significant positive association between emotional eating and BMI Z-scores when the girls were considered separately. The direct path from X to Y was at a trend level of significance only, as would be expected with a mediation effect.

**Summary of Results:**

Taken as a whole, the current results suggest that emotional overeating at 48 months mediates the association between maternal sensitivity at 6 months and BMI z-scores at 48 months for girls but not boys. Food responsiveness and enjoyment of food were not significant mediators of this association. The detailed analysis of the indirect pathway based on emotional overeating suggests that the differential relationship between maternal sensitivity and emotional overeating in girls but not boys was the main contributor to this moderated-mediation effect.
5.7. Discussion

Study 1 demonstrated an association between low maternal sensitivity at age 6 months and higher BMI z scores at age 48 months in girls but not boys. The current study examined whether emotional overeating, food responsiveness, and/or enjoyment of food measured at 48 months mediated this relationship. After controlling for key covariates we found that emotional overeating in the children, as reported by their mothers based on the CEBQ, was the only significant mediator of the link between maternal sensitivity and BMI z scores in girls but not boys. Further follow-up of the cohort in later childhood and adolescence will determine whether self-report measures of emotional eating show this same mediating effect. These findings extend prior work on the dyadic relationship, eating behaviour and weight regulation and may have significant implications for the understanding and preventing of various disorders characterized by emotional eating including many forms of obesity, mood and/or eating disorders.

The work of Dubois L et al (2012) suggests that common environmental factors exert their strongest influence in the pre-adolescent years and more significantly in girls compared to boys. One of the traits of females tends to be the socializer of infants, children, and families – perhaps this relates to the longer period that nature provides in the environmental phase for females. If so, this might indicate that the role of genetics versus environment influences how weight regulation changes from birth towards adolescence, and that there are differences for boys and girls (Dubois L et al, 2012; Silventoinen K et al, 2007). Perhaps for boys
there is an earlier period within genetics, whereby their birth weight is a marker of how their future weight/ BMI might develop.

The current results in my thesis supports Dubois’s model for both sexes, i.e. emotional eating is linked to an environmental factor in girls (sensitivity) and a more biological/ genetic factor in boys (birthweight). This is the first study to demonstrate a specific behavioural mechanism that might account for the sex difference in BMI risk based on environment versus genetics.

Several authors have suggested that the marked increase in childhood obesity rates in recent decades is due in part to greater parenting stress (e.g. Birch LL et al, 2001; Birch LL, 2006; Decaluwe V et al, 2006; Bosmans G et al, 2009; Goossens L et al, 2011; Vandewalle J et al, 2014). Understanding factors that link parenting stress with early pathological weight gain, and developing novel interventions to address these mechanisms, is thus a high priority for child obesity research. An emerging line of research suggests that emotional stress is associated with 'comfort food' choices (high density calories, using fat and carbohydrates) (Dallman MF et al, 2003) and that emotional stress may act as an appetitive stimulant to those at risk of obesity (Braet C and van Strien T, 1997). Persistent emotional stress is associated with a cascade of events overwhelming the ability to function in a normal way, together with glucocorticoids and insulin which activate both the desire for 'comfort foods' and facilitate the storage of abdominal fat leading to pathogenic obesity (Dallman MF et al, 2003; Tomiyama AJ et al, 2011).
Evidence continues to accumulate that certain patterns of family functioning contribute to child overweight-obesity risk (Rhee KE, 2008; Zeller MH et al, 2007; Moens E et al, 2007; Goossens L et al, 2012; Vandewalle J et al, 2014). Halliday et al (2014) recently reviewed twenty-one such studies published between 1990-2011. Some early findings from this review are as follows: 1. the relationship between strained family functioning and overweight risk is greater for girls than it is for boys; 2. families lacking authoritative parenting styles were associated with an increased risk of childhood overweight-obesity; 3. the majority of family functioning measures used in these studies were self-reported, reducing reliability. The authors further recognized the need for more longitudinal studies and randomized controlled trials where possible (Halliday JA et al, 2014).

As reviewed earlier, Anderson SE et al (2011;2012) used a large cohort of developing children for this purpose, and found that both insecure attachment and low maternal sensitivity were associated with a high risk of obesity in adolescence (Anderson SE. et al, 2012; Anderson SE and Whitaker RC, 2011). While these authors proposed that, “attachment and maternal sensitivity may be linked to obesity through the development of children’s capacity to modulate their responses to internal emotional states such as those that occur with stress”, they did not test this empirically in these papers. The current findings thus extend this work significantly in finding a mediation effect of emotional eating on a similar association. As mentioned in chapter 4, the current finding of a sex difference in this relationship and the current focus on pre-school children are also highly novel.
Strengths and Limitations

Several methodological strengths and limitations of the current study merit consideration. Strengths include our use of a population-based sample with highly structured and standardized assessments of maternal sensitivity done in the first year of post-natal life, when developmental programming effects in general, and those related to eating behaviour in particular, may be at their peak. The longitudinal aspect of our findings is also a major strength, although does not prove causality given the lack of a randomized design.

On the other hand, our current sample size is smaller than those reported in Anderson et al, 2012 and Wu et al, 2011, which limits statistical power. As alluded to above, the CEBQ is based on maternal reports of emotional overeating in the children, which may reflect maternal biases. While some of this can be controlled for by using maternal BMI as a study covariate, further follow-up of the cohort in later childhood and adolescence, using more direct measures of emotional eating, will be needed to more fully elucidate the importance and robustness of the current results over time.

Our current findings of the large number of mothers with low SES but high educational status may not be generalizable. The high educational status could in theory limit the impact of social adversity on the outcome under consideration.

Future Translational Considerations:

Meta-analyses reported from Europe (Bakermans-Kranenburg MJ et al, 2003; Bakermans-Kranenburg MJ et al, 2005) and a recent Canadian study
(Moss et al. 2013) suggest that maternal sensitivity and attachment behaviours can be modified through basic video-based instruction. Whether this same strategy can be used to prevent at least some cases of childhood obesity and/or eating disorders is an important question for future work. Based on the current findings assessing whether maternal sensitivity interventions limit the development of emotional eating will be of particular interest in this regard.
Chapter 6

**Study 2:** The purpose of this study was to examine whether breastfeeding at age 6 months moderates the association between maternal sensitivity measured at 6 months and child BMI measured at 48 months.

**Hypothesis:** Breastfeeding at age 6 months will moderate the association between maternal sensitivity measured at 6 months and child BMI measured at 48 months. More specifically, breastfeeding at 6 months will protect children from overweight-obesity risk when exposed to low maternal sensitivity at 6 months.
6.1 Abstract

**Background**: Study 1 demonstrated a significant association between low maternal sensitivity at age 6 months and higher BMIs at age 48 months in girls but not boys. The current study examined whether breastfeeding further moderated this association. **Methods**: This analysis was based on a dataset of 223 children (115 boys, 108 girls) who had complete data for maternal sensitivity at 6 months and BMI measures at 48 months. Based on the work of Hayes (Hayes PROCESS, 2013), two separate moderation models of the relationship between low maternal sensitivity and higher BMIs were tested. The first model considered breastfeeding as a second moderator interacting with the sex of the child, while the second model considered breastfeeding as a separate moderator acting independently from the sex of the child. In light of current WHO recommendations for exclusive breastfeeding through to six months of age, exclusive breastfeeding at age 6 months was the key moderating variable in our primary analysis. However, as exclusive breastfeeding at six months was relatively uncommon in girls in the current sample, we also performed secondary analyses using any breastfeeding at six months as the putative moderator variable. **Results**: Consistent with model two above, exclusive breastfeeding at age 6 months was a significant moderator of the association between maternal sensitivity at 6 months and BMI at 48 months (at p=.004), but did not moderate the moderation effect of sex found in study one. The overall pattern of results suggested that exclusive breastfeeding at age 6 months limited the effect of low maternal sensitivity on higher BMIs at age 48 months. When any breastfeeding
at six months was used as the moderator variable, no moderation effect was found. **Conclusions:** Exclusive breastfeeding at age 6 months moderates the association between maternal sensitivity experienced at age 6 months and BMI status at age 48 months. This moderation effect appears to be the same for girls and boys.

**Keywords:** maternal sensitivity, exclusive breastfeeding, parent-child interaction, body mass index (BMI) WHO z scores
6.2 Overview

Study 1 (Chapter 4) demonstrated a significant association between low maternal sensitivity at age 6 months and higher BMI at age 48 months in girls but not boys:

Summary of Findings from Study 1 (Adapted from Statistical modelling of moderation by Hayes AF, 2013)

Study 3 (Chapter 6) extends this work by examining whether breastfeeding acts as a second moderator of the relationship between maternal sensitivity at 6 months of age and child BMI at 48 months. Breastfeeding was chosen as a potential second moderator for two reasons: 1. breastfeeding provides a natural source of nutrition to the developing infant; and 2. breastfeeding has recently been identified as a potential protective factor for future overweight-obesity in children. At a statistical level, we examined two possible ways in which breastfeeding might be operative in this regard: (diagrams adapted from Hayes AF, 2013):
1. as a second moderator *interacting* with sex:

![Diagram 1](image1)

2. as a second moderator *distinct* from sex:

![Diagram 2](image2)

The next sections will review prior work on breastfeeding and child health, including possible protective effects for childhood obesity in particular, followed by a description of study 2.
6.3 Introduction and Hypothesis

6.3.1 Breastfeeding and Health: An Historical Perspective

The fundamental importance of optimal infant nutrition for child health and survival has been a primary research focus for centuries (Lucas A, 1998). The earliest studies in this area focussed on the potential benefits of milk whether through maternal breastfeeding if available or substitute sources where needed. Over the centuries, these substitute sources of milk have varied, starting with ‘wet nurses’ as early as 2000 B.C. (Stevens EE et al, 2009), later attempts to use direct nursing on the teats of animals, and more recently the use of feeding vessels that contained animal milk along with cereals or starches (Stevens EE et al, 2009; Obladen M, 2014). Until the development of sterilization processes in recent times, these various modes of milk delivery were associated with impurities and risk of infection, at times compromising rather than protecting infant health and survival (Stevens EE et al, 2009).

By the late 19th century the quality and availability of substitute milk products provided in sterilized containers improved, resulting in fewer infants dying of infectious diseases and starvation. In the early 20th century a national movement in the UK advocated “clean pure milk for babies” to improve the wellbeing of mothers and babies who needed consistently safe substitute milk (Weaver LT, 2006). Recognizing that quality substitute formula feedings were now available, mothers with healthy babies who were able to breastfeed, began to turn to substitute formula feedings (Weaver LT, 2006).
In the second part of the 20th century significant work was centred on the optimization of the macro-and micro-nutrient content of milk and the use of standardized growth charts to evaluate potential differences in the growth of infants fed through breastfeeding or substitute milk products.

In the first part of the 21st century infant nutrition research has broadened further, with a major focus on how early nutritional experiences beginning as early as foetal development establish long term trajectories for health and disease (Lucas A 1990, 2005; Koletzko B, 2011; Weaver LT, 2006). There continues to be significant work on nutritional practices in the early post-natal period, which also has a major effect on long-term feeding behaviour and health. This work focuses on the more specific ways that breastfeeding might promote health, the optimal duration of breastfeeding for a given child, and direct comparisons of breastfeeding versus substitute formula feedings (WHO, 2001; Kramer MS and Kakuma R, 2002; Kramer MS et al, 2008; Duijts L et al, 2009).

This brief review of the history of infant feeding practices has emphasized that while breastfeeding has been the norm for a significant percentage of women for centuries, there have always been mothers who have not been able to breastfeed for many reasons, and have used a variety of approaches to provide infants with a source of nutrition.
6.3.2. The emergence of substitute infant formula feedings

While breastfeeding has been the norm for a significant percentage of women for centuries, there have always been mothers who have not been able to breastfeed, or have chosen not to breastfeed for a variety of reasons. From a biological perspective breastfeeding offers a natural source of nutrients for infants as well as providing immune factors, enzymes, and antibodies, conferring protection against infections for the infant. While substitute formula feedings offer a source of nutritional benefits, they cannot safeguard the immune system in the way that breastfeeding does. Despite the unique advantages of breastfeeding and its role in overall health in early life (WHO, 2001, 2009; Critch JN, 2014), mothers across the globe are increasingly turning to the substitute formula feeding products rather than breastfeeding. This likely reflects on the perception that substitute formula feedings are equivalent to breastfeeding, often supported by paediatricians in the 20th century (Weaver LT, 2006), and the desire of many mothers to share the feeding experience, allowing them to have more flexibility to engage in other activities.

The evolution of breastfeeding substitutes began in earnest following the Second World War, when the manufacturing, and selling of these products began to escalate rapidly in developed countries (WHO,1995). By the early 1970s members of the World Health Assembly identified concerns regarding the reduction of breastfeeding and increasing use of formula feedings by mothers throughout the world (WHO,1995). By 1980 it became obvious that many infants were not thriving on substitute formula feedings. The WHO in conjunction with
United Nations International Children’s Emergency Fund (UNICEF) held discussions regarding infant death rates associated with malnutrition and lethal infections, primarily occurring in developing countries (WHO, 2006). Marketing strategies by large multi-nationals using substitute infant formula feedings within developing countries was on the agenda at the WHO (2002) and led to the boycott of products marketed by large multi-nationals, particularly in North America.

In response to the aggressive marketing strategies of multi-national corporations, the WHO along with UNICEF created a global health programme, called the International Code of Marketing of Breast-milk Substitutes that prioritized the needs of infants and young children (WHO, 1995). As well, the UNICEF Baby Friendly Initiative and the WHO Innocenti Declaration were developed to spell out the importance of breastfeeding for child health (WHO, 2005). In conjunction with these broader societal initiatives, the framework for thinking about infant nutrition practices changed from a food processing approach to one of empirical biological studies (Weaver LT, 2009).
6.3.3. Exclusive breastfeeding

In the mid 1990’s the WHO recommended exclusive breastfeeding for infants until 4 to 6 months, after which the inclusion of complementary foods would be introduced (WHO, 1995). In May 2001, the World Health Assembly changed this recommendation slightly in promoting exclusive breastfeeding for a full 6 months. This change was based on a 2001 report by a WHO Expert Consultations Group (WHO, 2001) along with a systematic review by Kramer M and Kakuma R, (2002) which compared outcomes to exclusive breastfeeding for 4 versus 6 months (WHO, 2002). While most of the studies included in this review were observational in design and done in the developed world, two randomized intervention studies in a developing country [Honduras] were also included (WHO, 2002).

Subsequent work by Kramer has examined the more specific health benefits that might emanate from exclusive breastfeeding practices. For example, the largest randomized trial of breastfeeding to date (n=13,889) found that prolonged and exclusive breastfeeding improves cognitive development as measured by I.Q. and teacher ratings in children at 6.5 years of age. This finding takes on added significance in that it is based on a randomized trial, while prior studies associating breastfeeding and cognition have tended to be observational only (Kramer MS et al 2008). Not all studies on this topic have produced unequivocal results however. Kramer MS et al (2009) compared infants who were exclusively breastfed at 3 months (n=2947) versus 6 months (n=524) and found little difference in health outcomes in the two groups; indeed, the children
who were exclusively breastfed at 6 months unexpectedly had higher adiposity measures than the comparison group. The authors suggested that this association might have been due to reverse causality rather than a causal effect of prolonged exclusive breastfeeding on adiposity per se.

A systematic review by Duijts L et al (2009) assessed the protective effect of breastfeeding on infections of infants living in developed, industrial countries. The authors concluded that breastfeeding protects infants against infections, particularly related to the respiratory tract and gastrointestinal system. A subsequent paper by this group (Duijts L et al, 2010) indicated that exclusive breastfeeding until 4 months followed by partial breastfeeding was associated with a significant reduction in respiratory and gastrointestinal infections. While exclusive breastfeeding until 6 months had some incremental benefit in this regard, the small percentage of subjects practising exclusive breastfeeding at 6 months precluded meaningful statistical information (Duijts L et al, 2010).

The WHO and UNICEF continue to recommend exclusive breastfeeding until 6 months of age, followed by the introduction of complementary foods and suggest that continuation of breastfeeding up to two years of age may be optimal in some cases (WHO, 2006). There is literature that for some years has suggested that exclusive breastfeeding may not be able to provide adequate energy for all developing infants (Reilly JJ et al, 2005; Reilly JJ and Wells JC, 2005). More recent work by this team has found that exclusive breastfeeding to 6 months has adequate energy intake for normal infant development (Nielson SB et al, 2011), with further validation of energy requirements for exclusively
breastfed infants suggests that more studies on these infants to understand how growth influences energy requirements (Nielson SB et al, 2013).

**6.3.4. Breastfeeding and the risk of childhood overweight-obesity**

Given the recent epidemic of obesity in both developed and developing countries around the world, a significant body of work has focussed on the potential protective effects of breastfeeding on overweight and obesity risk.

The first suggestion of a relationship between breastfeeding and child overweight-obesity was based on a case-control study of children between 12-18 years of age (Kramer MS, 1981), some 20 years before large-scale studies began to emerge (von Kries et al, 1999; Poulton R and Williams S, 2001; Gillman MW et al, 2001; Hediger ML et al, 2001; Armstrong J and Reilly JJ, 2002; Arenz S et al, 2004; Harder T et al, 2005; Owen CG et al, 2005b). Kramer’s initial research suggested that breastfeeding provides a significant protective effect against subsequent obesity that persists at least through adolescence (Kramer MS, 1981).

Children of mothers who are subjects of the Nurses’ Health Study II, who participated in the Growing-Up Today Study cohort (n= 7155 boys and n= 8186 girls) and were offered a survey to evaluate whether overweight in adolescents is associated with the type of infant feeding (breastfeeding or infant formula) along with the duration of breastfeeding. They found that children who had used breastfeeding more than those who used infant formula, and if the duration of
breastfeeding was longer than their peers there was a lower risk of overweight in childhood and on to adolescence (Gillman MW et, 2001).

Bergmann KE et al (2003) showed that breastfeeding for ≥ 3 months in a cohort of (n=1314) afforded greater protection from child adiposity, however several factors interfered with this protective effect, including maternal overweight, maternal smoking habits during pregnancy, low social economic class, and the use of substitute formula feedings. Gillman MW et al (2006) studied breastfeeding effects in non-twin sibling pairs aged 9-14 years (n=5614), and found that a greater duration of breastfeeding was associated with a protective effect against later obesity.

A systematic review and meta-analysis undertaken by Arenz S et al (2004) was a major step toward for the field in being the first review of breastfeeding and childhood obesity that was limited to well-designed prospective studies that controlled for confounding variables. Findings from this review included: 1. strong evidence for an inverse association between breastfeeding duration and obesity risk, 2. evidence that the protective effect of breastfeeding was more pronounced in studies that adjusted for less than seven potential covariates. Overall, the authors concluded that breastfeeding was associated with a small but consistent protective effect against obesity risk in later childhood (Arenz S et al, 2004).

Another meta-analysis by Harder T et al (2005) focussed on duration of breastfeeding and risk of overweight using observational studies only. In sum, the majority of study subjects used partial breastfeeding, and the duration of
breastfeeding was inversely and linearly associated with the risk of overweight in these individuals. The risk of overweight was reduced by 4 percent for each month of breastfeeding, with this effect being found to up to 9 months of age.

Owen CG et al (2005) did a systematic review of published studies examining the link between infant feeding and continuous measures of BMI or adiposity. Analyses were based on mean differences in BMI between subjects who were exclusively breastfed or exclusively fed with substitute formula feedings. Breastfeeding was associated with a slightly lower mean BMI when compared to substitute formula feedings. The mean difference in BMIs appeared to be larger in smaller studies, and smaller in larger studies. Adjustment for covariates abolished the effect of breastfeeding on BMI for many of the studies.

Recent work studying risk factors for overweight-obesity in children explored whether short duration of breastfeeding would influence infant weight gain patterns among children with differing risk for future obesity. Children with the highest risk for weight gain patterns in infancy were found to benefit longer breastfeeding duration (Carling SJ et al, 2015). Hopkins D et al (2015) examined the intake of various types of milk being consumed at the latter time of infancy (n=1112) along with the effects of energy intake, growth, and BMI. They found that unlike breastfeeding, high volumes of formula (>=600 mL/day) is related to increased length and weight, but high volumes of cow milk (>=600 mL/day) is more concerning when used in infants given that increased length, along with weight and BMI that persists through childhood.
Another line of research is comparing differences in body composition of infants who were breastfed or using substitute formula feedings to explore whether infant feeding might influence overweight-obesity into adult life (Gale C et al, 2012). The systematic review and meta-analysis findings, which included 15 studies and more than 1000 healthy term infants who were fed by breast or substitute formula, indicated that compared to breastfed infants (exclusive or predominant), those on substitute formula feedings (exclusive or predominant) from birth to 12 months developed a different body composition (Gale C et al, 2012). More specifically, the infants on substitute formula were found to have higher fat-free mass at 3-4 months, 8-9 months, and at 12 months; lower fat mass was identified in 3-4 months and 6 months in the infants with substitute formula compared to the breastfed infants. However, at 12 months fat mass was found to be higher in the substitute formula infants compared to the breastfed infants suggesting that an underlying significant factor might be influencing these changes in body composition by the first year of life. Information on body composition might be providing a different approach compared to BMI when evaluating risk of overweight-obesity in children.

Early eating practices might influence health in later life (Anzman SL et al, 2010). Further research is needed to clarify implications and potential mechanisms of these results.

Chapter 2 Section 2.1.3.3. discusses additional information on maternal pre-pregnancy and body mass index (BMI) – Breastfeeding.
Chapter 2 Section 2.3.2. discusses the breastfeeding relationships in further detail, including recent work on hormones in breast milk that link with overweight-obesity risk.

**Summary of literature review and rationale for the current study**

Taken as a whole, work to date offers moderate but incomplete support for the basic hypothesis that breastfeeding has a protective effect on later obesity risk. The strongest finding so far is for an inverse relationship between breastfeeding duration and subsequent obesity risk in both observational and prospective studies. However, methodological issues including incomplete consideration of potential confounding variables, and a lack of understanding of the specific mechanisms that might account for findings to date, limit the impact of this work somewhat.

The current study examines one potential mechanism through which breastfeeding might limit obesity risk. Study 1 (Chapter 4) found that sex moderates the relationship between low maternal sensitivity at 6 months and higher BMI at age 48 months. Extending this work, study 3 (Chapter 6) examines whether breastfeeding at 6 months acts as a second moderator of the association between low maternal sensitivity at 6 months and high child BMI at 48 months. In doing so, we considered breastfeeding in its interaction with sex, and independently from sex, in the moderation models described below. Our general working hypothesis was that breastfeeding at 6 months would protect
children from overweight-obesity risk when exposed to low maternal sensitivity at 6 months.

Given that exclusive breastfeeding at 6 months is the current WHO recommendation, and to maximize the translational value of this work, exclusive breastfeeding at 6 months was the primary breastfeeding variable used in the analyses that follow. However, given that non-exclusive breastfeeding was common in our sample, we also performed secondary analyses using any breastfeeding at six months as the putative moderator variable. The following is a detailed summary of this work.

6.4. Participants and Methods

6.4.1. Study Participants

The current study sample included 223 children recruited in either Montréal, Québec (n= 105) or Hamilton, Ontario (n= 118), Canada as part of an established prospective birth cohort, the Maternal Adversity, Vulnerability and Neurodevelopment (MAVAN) project. For the current analysis, all available participants who had been enrolled in the MAVAN study at birth, been scored for maternal sensitivity at 6 months of age, and who had participated in a laboratory visit to measure growth at 48 months of age were included. Eligibility criteria for mothers at study entry included age ≥18 years, singleton gestation, and fluency in French or English. Women with severe chronic illness, placenta previa, and history of incompetent cervix, impending delivery, or a foetus/infant affected by a
major anomaly or born at a gestational age less than 37 weeks were excluded. Birth records were obtained directly from the birthing unit.

The current study sample was found to be comparable to the overall birth cohort in terms of maternal age at childbirth, gestational age, birth size, income categories, and maternal education. MAVAN is a multidisciplinary, collaborative study, recruiting pregnant women from obstetric clinics in hospitals located in Montréal, Québec and Hamilton, Ontario. All participants experienced identical home and laboratory based assessments. We excluded very low birth weight infants and included those born at 37 to 41 weeks gestation. The maternal age at childbirth was also comparable to the general population within Canada (study sample = 30.5 years; Québec =29.5 years, Ontario = 30.2 years), (Statistics Canada, 2012). The MAVAN project over-samples from low SES settings, thus the prevalence of families receiving income below the low income cut off (LICO, Statistics Canada, 2005) was near 30% compared to 15% in the general population (Statistics Canada, 2009). However, while education below 10 years was found in only 4% of the mothers of our sample, this number reaches 12% of adults in the provinces of Québec and Ontario (Statistics Canada, 2011). In sum, SES status was relatively low but education relatively high, relative to Canadian population norms.

Approval for the MAVAN project was obtained from obstetricians performing deliveries at the study hospitals and by the ethics committees and university affiliates (McGill University and l’Université de Montréal: the Royal Victoria Hospital, Jewish General Hospital, Centre hospitalier de l’Université de
Montréal, and Hôpital Maisonneuve-Rosemont), and St. Joseph’s Hospital and McMaster University, Hamilton, Ontario, Canada. Informed consent was obtained from all participants.

6.4.2. Measures
6.4.2.1. Mother-child interaction using video-taping

Maternal sensitivity was systematically coded based on video-taped recordings of mother-child interactions within the home environment, at 6 months post-partum. This included a 20 minute period of semi-structured play and a 10 minute interval when mother completed questionnaires. The latter divides the mother’s attention and indicates how she interacts with her child when distracted.

The actual scoring of maternal sensitivity was done by a highly trained rater (KL) who demonstrated consistent reliability with experts in the field using the 25-item revised Maternal Behaviour Q-sort (MBQS) (Tarabulsy GM et al, 2009; Pederson DR, Moran G, et al, 1990). The MBQS was originally developed using a pool of descriptors of maternal behaviour based on the writings of Ainsworth (Ainsworth MD et al, 1971, 1974). Some of these behaviours associate with attachment security while others describe insensitive mothering (Pederson DR, Moran G, et al, 1990). This Q-sort was originally developed using 90 cards, but has recently been revised based on 25 cards (Tarabulsy GM et al, 2009). Coding with this system requires viewing of video-tapes and then systematically identifying maternal behaviours using descriptive cards arranged into 3 piles: most alike, least alike, and neither alike nor unalike. After working through all of
the cards, the rater compares the mother being studied to an ‘ideal mother’; the calculated correlation is then used as the final maternal sensitivity score.

6.4.2.2. Growth Measures

At the 48 month visit children had length and weight measures taken. Standing height, without shoes, was measured (to the nearest 0.1 cm) with the use of a stadiometer (Perspective Enterprises, PE-AIM-101, Portage, Michigan). Body weight, in light clothing, was measured (to the nearest 0.1 kg) with the use of a digital floor scale (TANITA BF625, Arlington Heights, Illinois). BMI was calculated as weight in kilograms divided by height in metres squared (kg/m²). BMI z-scores were calculated based on well established World Health Organization (WHO) growth curves for girls and boys (WHO, 2006).

6.4.2.3. Breastfeeding:

Breastfeeding questionnaires originated by the MAVAN Study Team, 'Health and Well Being of Mothers and Their Newborns' and the 'Child's Health Questions' were completed shortly after birth and at 3, 6, and 12 months postpartum. An example of questions was: 'At what age did you stop breastfeeding your baby?' With each question the mother indicates whether breastfeeding has stopped or continues. If continued there are further questions regarding duration and whether breastfeeding is exclusive or supplemented by other sources of feeding. If breastfeeding has stopped there is a question on
what other modes of feeding are being provided. Within the dataset breastfeeding variables are categorized using “yes” or “no” prompts.

As described above, to maximize the translational value of this work as it relates to current WHO guidelines, we initially focused on exclusive breastfeeding at age 6 months as our key moderating variable. However, as non-exclusive breast-feeding at age 6 months was common in this sample, we also performed a secondary set of analyses based on any breast-feeding at six months.

6.4.2.4. Covariates Related to BMI:

Based on their established relationship with early growth and overweight-obesity risk, we included site, sex, a blended variable for socio-economic status (SES) and maternal education, birth-weight (based on WHO- z scores; Oken E et al, 2003), and maternal BMI in our analyses. Regarding SES-maternal education, bivariate low/high sub-groupings for both maternal SES and maternal education were first established based on Canadian norms (Statistics Canada, 2005). Maternal SES groupings were: “low” = total family income after tax <$21,359; “high” = total income after tax >$21,358 (Statistics Canada, 2005). Maternal education was defined as “low” if high school graduation was not achieved (Statistics Canada, 2011). A single composite variable for socio-economic status and maternal education was next generated based on the following three groupings: “low-low” identifies low income and low maternal education; “low/high” identifies low income and high maternal education or high income and low
maternal education; “high/high” identifies high income and high maternal education. As relatively few mothers in this sample met criteria for both low education and low income, a bivariate factor for SES and maternal education was ultimately used for the statistical analyses i.e. high education-high SES (n=156; 77.6%) versus all other subgroups combined (n= 45; 22.4%). No data for maternal SES and education was available for 22 other subjects. (See Table 1a)

6.5. Statistical Methods

6.5.1. Moderation Modelling: Overview and Challenges

In the early phase of most scientific investigations, the first priority is to demonstrate a significant association between two or more variables. As research evolves, the direction of interest moves from testing for the existence of an association to considering mechanisms by which it functions. Researchers from the behavioural sciences use two regression-based models, moderation and mediation analyses, which determine evidence or to test hypotheses in relation to these mechanisms. Considering questions of 'how' (associated with mediation) and 'when' (associated with moderation) an association provides a more meaningful awareness of the process being studied, thus enabling further reflection on longer term goals (Hayes AF, 2012).

Moderation analysis examines whether the effect of a presumed causal variable X on outcome Y depends on a moderator variable or variables. For example, in chapter 4, an association between low maternal sensitivity and high BMI was found, but depended on the sex of the child i.e. this association was
found in girls but not boys. In statistical terms, we conclude that sex moderated the association between low maternal sensitivity and high BMI. The current chapter explores whether breastfeeding also influences the relationship between maternal sensitivity and child BMI. One simple statistical approach to this question would be to simply replicate the methodology described in Chapter 4, using “breast-feeding” instead of “sex” as a unique moderating variable. However, having previously found a significant moderating effect of sex on the relationship between low maternal sensitivity and higher BMIs, an optimal statistical approach would include sex, breast-feeding and their interaction as potential moderators of this association. While several modelling software packages are available for this purpose, they typically require highly specialized programming skills and adaptation of coding to a given dataset. To help address this issue, Hayes AF (2012) created a tool called PROCESS, which is a computational procedure for SPSS and SAS specifically designed to study more complex moderation and/or mediation effects. PROCESS is a tool that brings moderation or mediation analyses or groupings into an integrated conditional process model, for example moderated mediation and mediated moderation (Hayes AF, 2012). Using a path analysis framework similar to the approach described by Hayes AF, (2012) PROCESS provides many of the capabilities of existing programs and tools while expanding the number and complexity of models that combine different types of moderation and/or mediation (Hayes AF, 2012). The PROCESS menu, including 76 potential modelling templates for
moderation, mediation, and combined analyses, is available from Hayes without cost at: http://www.afhayes.com/spss-sas-and-mplus-macros-and-code.html

6.5.2. Testing the Current Hypothesis using PROCESS:

Based on the above, for the current analyses we used IBM SPSS statistical software version 21 (IBM SPSS Statistics for Windows, Amonk, N.Y.) supplemented by Hayes PROCESS for moderation modelling (Hayes AF, 2012, 2013). The goal was to examine whether breastfeeding moderates the relationship between maternal sensitivity measured at 6 months and child BMI measured at 48 months (see Chapter 4). Analysis of variance and regression analysis were used to evaluate the effects of covariates (site, sex, SES-maternal education, birth weight, maternal BMI at 48 months, breastfeeding at 6 months) on the study results.

When implementing Hayes PROCESS software for moderation analyses, one must first establish which of the several moderation models available will be tested. For the current analysis, the goal was to build on the previous finding of a significant association between low maternal sensitivity at age 6 months and higher BMI at age 48 months in girls but not boys:
To build on this earlier finding, the first model chosen was moderated moderation (Hayes model 3), whereby breastfeeding would act as a second moderator interacting with sex:

![Diagram](image)

To account for the possibility that breastfeeding might act as a second moderator independently from sex, we also tested a second model in which sex and breastfeeding each have independent moderating effects on the relationship between maternal sensitivity and child BMI (Hayes model 2):

![Diagram](image)

Given that exclusive breastfeeding at 6 months is the current WHO recommendation, and to maximize the translational value of this work, exclusive breastfeeding at 6 months was the primary breastfeeding variable used in the analyses that follow. However, given that non-exclusive breastfeeding was
common in our sample, we also performed secondary analyses using any breast-feeding at six months as the putative moderator variable.

6.6. Results

6.6.1 Sample Description and Demographics: Tables 1a and 1b summarize the categorical and continuous variables respectively that describe the current sample. As shown, 11.5 % of the sample experienced exclusive breastfeeding at 6 months including 10/106 girls (9.4%) and 15/113 boys (13.4 %). The experience of “any breastfeeding” at 6 months was found in 63.6 % of the sample, including 67/106 girls (63.2%) and 71/113 boys (64.0 %).

Table 1a: Descriptive statistics of the categorical variables for all subjects (n=223)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Categories</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td></td>
<td>Montréal</td>
<td>47.1</td>
</tr>
<tr>
<td></td>
<td>105</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>118</td>
<td>Hamilton</td>
<td>52.9</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td>Boys</td>
<td>51.6</td>
</tr>
<tr>
<td></td>
<td>115</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>108</td>
<td>Girls</td>
<td>48.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Income Maternal Education</strong></td>
<td>156</td>
<td>High income/ high education</td>
<td>77.6</td>
</tr>
<tr>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**</td>
<td></td>
<td>Other</td>
<td>22.4</td>
</tr>
<tr>
<td>**</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Exclusive Breastfeeding 6months</strong></td>
<td>193</td>
<td>No</td>
<td>88.5</td>
</tr>
<tr>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**</td>
<td></td>
<td>Yes</td>
<td>11.5</td>
</tr>
<tr>
<td>**</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ANY Breastfeeding 6 months</strong></td>
<td>79</td>
<td>No</td>
<td>36.4</td>
</tr>
<tr>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**</td>
<td></td>
<td>Yes</td>
<td>63.6</td>
</tr>
<tr>
<td>**</td>
<td>138</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Discrepancies in sample size are due to missing/incomplete data
Table 1b: Descriptive statistics of the continuous variables for all subjects (n=223)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Child BMI 48 months-z-score</td>
<td>223</td>
<td>-1.36</td>
<td>5.00</td>
<td>.50</td>
<td>1.06</td>
</tr>
<tr>
<td>*MBQS-25 item (maternal sensitivity at 6 months)</td>
<td>223</td>
<td>-.70</td>
<td>.94</td>
<td>.41</td>
<td>.43</td>
</tr>
<tr>
<td>Birth weight z-scores</td>
<td>223</td>
<td>-2.58</td>
<td>2.58</td>
<td>-0.12</td>
<td>0.091</td>
</tr>
<tr>
<td>**Maternal BMI (at 48 months)</td>
<td>185</td>
<td>17.46</td>
<td>51.86</td>
<td>27.4</td>
<td>6.54</td>
</tr>
</tbody>
</table>

* Child BMI 48 months is always measured in z-scores

*Maternal Behaviour Q-sort (MBQS) is scored between -1.0 to 1.0; the most sensitive mother will score close to 1.0 while the least sensitive mother will score close to -1.0.
**Discrepancies in sample size are due to missing/incomplete data

6.6.2. Correlation matrix: Predictor and Outcome Variables and Covariates

Table 2 summarizes a correlation matrix with the predictor variable maternal sensitivity at 6 months of age, the outcome of child BMI at 48 months, breastfeeding variables that varied in exclusivity and duration, as well as the covariates: income-maternal education, child birth weight, and maternal BMI at 48 months. Exclusive breastfeeding (r=0.163*, p=0.05) and any breastfeeding at 6 months (r=0.199*, p=0.05) are the only breastfeeding variables associated with maternal sensitivity. Maternal BMI is negatively associated with infant breastfeeding variables (range of r= -0.199 to -0.277**, p=0.01); only infants on exclusive breastfeeding at 6 months (r= -0.029) lack significance. Maternal BMI
also has a significant but positive relationship with child BMI 48 months

(r=0.371**, p=0.01).

**Table 2: Correlation Matrix (n=223) - ALL Children**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBQ5 6mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI-48 mo WHO-z</td>
<td>-.106</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SES-ED</td>
<td>0.006</td>
<td>-.203*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth wt z-score</td>
<td>0.057</td>
<td>.169*</td>
<td>0.028</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal BMI 48mo</td>
<td>-.121</td>
<td>.371**</td>
<td>-.139</td>
<td>0.094</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF-EX 3mo</td>
<td>.108</td>
<td>-0.037</td>
<td>0.074</td>
<td>0.092</td>
<td>-.203**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF_EX 6mo</td>
<td>.163*</td>
<td>-.101</td>
<td>.126</td>
<td>0.078</td>
<td>-0.029</td>
<td>.370**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF_3mo A</td>
<td>.093</td>
<td>-0.091</td>
<td>.115</td>
<td>0.018</td>
<td>-.277**</td>
<td>.539**</td>
<td>.199**</td>
<td></td>
</tr>
<tr>
<td>BF_6mo A</td>
<td>.135*</td>
<td>-.112</td>
<td>.127</td>
<td>-0.003</td>
<td>-.199**</td>
<td>.503**</td>
<td>.273**</td>
<td>.733**</td>
</tr>
</tbody>
</table>

* Indicates p<= 0.05; ** Indicates p<= 0.01

6.6.3 Univariate Associations of Co-Variates with BMI z-Scores at 48 months.

Table 2 summarizes the univariate associations between the study co-variates and 48-month BMI z-scores. As shown, SES-maternal education, birth weight z-score and maternal BMI were all significant predictors of BMI z-scores at age 48 months (at p<0.05).
Table 3.  **Univariate Associations - predicting 48 month BMI (n=223)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta estimate</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBQS at 6 months</td>
<td>-0.26</td>
<td>0.17</td>
<td>-1.58</td>
<td>0.12</td>
</tr>
<tr>
<td>Site</td>
<td>0.18</td>
<td>0.14</td>
<td>1.30</td>
<td>0.20</td>
</tr>
<tr>
<td>Sex (female vs male)</td>
<td>-0.19</td>
<td>0.14</td>
<td>-1.31</td>
<td>0.19</td>
</tr>
<tr>
<td>SES-maternal education (high vs. low)</td>
<td>-0.51</td>
<td>0.17</td>
<td>-2.93</td>
<td>0.004</td>
</tr>
<tr>
<td>Birth weight z-score</td>
<td>0.20</td>
<td>0.08</td>
<td>2.55</td>
<td>0.012</td>
</tr>
<tr>
<td>Maternal BMI</td>
<td>0.06</td>
<td>0.01</td>
<td>5.40</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Exclusive Breastfeeding 6 months</td>
<td>-0.34</td>
<td>0.23</td>
<td>-1.49</td>
<td>0.14</td>
</tr>
<tr>
<td>Any Breastfeeding 6 months</td>
<td>-0.25</td>
<td>0.15</td>
<td>-1.65</td>
<td>0.10</td>
</tr>
</tbody>
</table>

**6.6.4 Graphical Summary of the Main Study Results based on Exclusive Breastfeeding:**

Figure 1 below plots the relationship between maternal sensitivity at six months and BMI Z scores at age 48 months in all children with and without exclusive breast-feeding at age 6 months.
Figure 1A. The relationship between maternal sensitivity at age 6 months and BMI $z$-scores at age 48 months in children with and without exclusive breast-feeding at age 6 months.

Figure 1B. The influence of maternal sensitivity on BMI $z$-scores at 48 months for girls and boys with or without exclusive breastfeeding at age 6 months.
The statistical analyses of these raw data are as follows:

### 6.6.5. Hayes PROCESS Modelling

As outlined above, two separate moderation models based on breastfeeding at 6 months were used. The first considered breastfeeding as a second moderator interacting with sex (using PROCESS model 3):

We chose PROCESS Model 3 as our first model given to extend the prior finding that sex moderates the association between low maternal sensitivity and higher BMIs. In essence, PROCESS Model 3 evaluates moderated moderation i.e. whether breastfeeding interacts with sex to influence the association between maternal sensitivity and BMI. To support a significant moderation effect of this type, one would need to demonstrate a significant three-way interaction between maternal sensitivity, sex and exclusive breastfeeding at 6 months in predicting child BMI z-scores. As shown below, while the maternal sensitivity by sex interaction described in chapter 4 remained significant in this slightly larger sample, the three-way-interaction including exclusive breastfeeding at 6 months was not significant, and did not approach significance in the model:
Hayes Model 3: Regression Model Predicting 48 month BMI z-scores
Including Exclusive Breastfeeding at 6 months (BFEx_6m) and its Interaction with MBQS scores and sex as Predictor Variables

<table>
<thead>
<tr>
<th></th>
<th>Coeff</th>
<th>SE</th>
<th>t-statistic</th>
<th>p-value</th>
<th>LLCI</th>
<th>ULCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.835</td>
<td>0.211</td>
<td>3.954</td>
<td>0.000</td>
<td>0.418</td>
<td>1.252</td>
</tr>
<tr>
<td>Sex</td>
<td>0.282</td>
<td>0.239</td>
<td>1.183</td>
<td>0.238</td>
<td>-0.189</td>
<td>0.754</td>
</tr>
<tr>
<td>MBQS_6</td>
<td>-0.077</td>
<td>0.239</td>
<td>-0.320</td>
<td>0.749</td>
<td>-0.550</td>
<td>0.396</td>
</tr>
<tr>
<td>MBQS_6 x sex</td>
<td>-0.846</td>
<td>0.399</td>
<td>-2.123</td>
<td>0.035</td>
<td>-1.634</td>
<td>-0.059</td>
</tr>
<tr>
<td>BFEx_6mo</td>
<td>-1.156</td>
<td>0.748</td>
<td>-1.546</td>
<td>0.124</td>
<td>-2.633</td>
<td>0.321</td>
</tr>
<tr>
<td>MBQS_6 x BFEx_6mo</td>
<td>1.640</td>
<td>1.111</td>
<td>1.477</td>
<td>0.142</td>
<td>-0.554</td>
<td>3.835</td>
</tr>
<tr>
<td>Sex x BFEx_6mo</td>
<td>0.328</td>
<td>1.129</td>
<td>0.290</td>
<td>0.772</td>
<td>-1.902</td>
<td>2.557</td>
</tr>
<tr>
<td>MBQS_6 x Sex x BFEx_6mo</td>
<td>-0.730</td>
<td>1.904</td>
<td>-0.383</td>
<td>0.702</td>
<td>-4.491</td>
<td>3.032</td>
</tr>
<tr>
<td>Site</td>
<td>-0.018</td>
<td>0.162</td>
<td>-0.110</td>
<td>0.913</td>
<td>-0.338</td>
<td>0.302</td>
</tr>
<tr>
<td>SES-education</td>
<td>-0.284</td>
<td>0.184</td>
<td>-1.543</td>
<td>0.125</td>
<td>-0.647</td>
<td>0.079</td>
</tr>
<tr>
<td>Birthwt-z</td>
<td>0.267</td>
<td>0.174</td>
<td>1.536</td>
<td>0.127</td>
<td>-0.076</td>
<td>0.610</td>
</tr>
<tr>
<td>MatBMI_48mo</td>
<td>0.059</td>
<td>0.012</td>
<td>4.920</td>
<td>0.000</td>
<td>0.035</td>
<td>0.082</td>
</tr>
</tbody>
</table>

These results can be summarized diagrammatically as follows:
Hayes Model 3: Lack of Effect of BFEx6 as Moderator
Maternal Sensitivity X Sex Interaction

Model 2: PROCESS Model 2 evaluates whether the association between maternal sensitivity and BMI z-scores is moderated by breastfeeding independently from sex. In Model 2 sex and breastfeeding act as discrete moderators. To demonstrate this moderating effect of breast-feeding, a significant maternal sensitivity by breast feeding interaction in predicting 48 month BMI z-scores is required. As shown in the table below, the maternal sensitivity by exclusive breastfeeding interaction was highly significant in the model (at p=0.004). In this model, the maternal sensitivity by sex interaction described in Chapter 4 dropped to a trend level of significance.
Hayes Model 2: Regression Model Predicting 48 month BMI z-scores Using Exclusive Breastfeeding at 6 months (BFEx_6m) and Sex as Non-Interactive Independent Variables

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE</th>
<th>t-statistic</th>
<th>p-value</th>
<th>LLCI</th>
<th>ULCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant</td>
<td>0.834</td>
<td>0.214</td>
<td>3.894</td>
<td>0.0001</td>
<td>0.411</td>
<td>1.258</td>
</tr>
<tr>
<td>Sex</td>
<td>0.291</td>
<td>0.298</td>
<td>0.979</td>
<td>0.329</td>
<td>-0.296</td>
<td>0.879</td>
</tr>
<tr>
<td>MBQS_6mo</td>
<td>-0.063</td>
<td>0.236</td>
<td>-0.268</td>
<td>0.789</td>
<td>-0.529</td>
<td>0.403</td>
</tr>
<tr>
<td>MBQS_6 x Sex</td>
<td>-0.883</td>
<td>0.470</td>
<td>-1.878</td>
<td>0.062</td>
<td>-1.812</td>
<td>0.046</td>
</tr>
<tr>
<td>BFEx_6mo</td>
<td>-1.050</td>
<td>0.277</td>
<td>-3.791</td>
<td>0.0002</td>
<td>-1.597</td>
<td>-0.503</td>
</tr>
<tr>
<td>MBQS_6 x BFEx_6mo</td>
<td>1.413</td>
<td>0.484</td>
<td>2.922</td>
<td>0.004</td>
<td>0.458</td>
<td>2.369</td>
</tr>
<tr>
<td>Site</td>
<td>-0.019</td>
<td>0.175</td>
<td>-0.110</td>
<td>0.913</td>
<td>-0.366</td>
<td>0.327</td>
</tr>
<tr>
<td>SES-education</td>
<td>-0.283</td>
<td>0.201</td>
<td>-1.411</td>
<td>0.160</td>
<td>-0.680</td>
<td>0.113</td>
</tr>
<tr>
<td>Birthwt-z</td>
<td>0.268</td>
<td>0.195</td>
<td>1.373</td>
<td>0.172</td>
<td>-0.117</td>
<td>0.653</td>
</tr>
<tr>
<td>MatBMI_48mo</td>
<td>0.058</td>
<td>0.017</td>
<td>3.370</td>
<td>0.0009</td>
<td>0.024</td>
<td>0.092</td>
</tr>
</tbody>
</table>

The findings based on model 2 can be summarized as follows.
Summary and Discussion of Results based on Exclusive Breastfeeding at 6 months:

Taken as a whole, the current results support the general working hypothesis that exclusive breastfeeding at age 6 months moderates the association between maternal sensitivity at 6 months and child BMI at 48 months. The results supported model 2, which considers exclusive breastfeeding as a separate moderator acting independently from the sex of the child, but did not support model 3 based on moderated moderation (a three way interaction between breastfeeding, sex and maternal sensitivity). While it was further hypothesized that the moderating effect of exclusive breastfeeding would protect children from overweight/obesity, further examination of figures 1A and 1B suggest a more complex interpretation of these data. Figure 1A shows that across the full sample, there was no relationship between maternal sensitivity scores at age 6 months and BMI z-scores at age 48 months in children who were not exclusively breast-fed at age 6 months ($R^2=.013$). On the other hand, there was a positive relationship between maternal sensitivity scores and BMI in
children who were exclusively breastfed at six months of age ($R^2=0.119$). A closer examination of figure 1A suggests that the moderation effect of exclusive breast-feeding on the relationship between maternal sensitivity and BMI was not related to obesity risk, but rather to risk of being at a very low BMI at age 48 months i.e. at the lower extreme of maternal sensitivity, the regression line approached a BMI z-score of -2, which is pathologically low, while at the higher extreme of maternal sensitivity, the regression line was close to zero. This suggests that in children who were exclusively breast-fed at six months, higher maternal sensitivity offered protection from very low BMIs, but did not protect from overweight/obesity.

Figure 1B, which plots these same data in girls and boys separately, suggests why there was no significant 3-way interaction between breastfeeding, sex and maternal sensitivity in predicting BMI at 48 months i.e. the lack of support for moderation model 3. As shown, the relative distance between the regression lines for exclusively breastfed and non-exclusively breast-fed children appears to be the same in boys and girls. For there to be a significant three-way interaction effect, one would expect to see a different relationship between these regression lines in girls and boys. Notwithstanding the lack of a three-way interaction, there did appear to be a fundamental difference in boys and girls in the clinical interpretation of the results. In boys, children who were exclusively breastfed exhibit the same pattern described above for the full sample i.e. in this case maternal sensitivity protects boys from being at a very low BMI, with limited effects at the higher extremes of BMI. In girls, while the difference in the
regression lines between exclusively breastfed and non-exclusively breastfed children appears to be the same as in boys, the data are shifted vertically upwards, and thus operate at a higher range of BMI. In this case, it appears that exclusive breastfeeding at six months mitigates the previously described relationship between low maternal sensitivity and higher BMIs which is evident in the non-breastfed girls. In this case, exclusive breastfeeding appears to protect girls exposed to low maternal sensitivity from developing abnormally high BMIs, but does not protect them from very low BMIs. This suggests that the effect of exclusive breastfeeding on the relationship between maternal sensitivity and 48 month BMIs may in fact be of the same magnitude and same direction in boys and girls, but differ in biological relevance across the two sexes.

In interpreting these results it should be noted that only 11.5% of children were exclusively breast-fed at age 6 months, including only 10 girls. Given this limitation, the statistical power available for the analyses was highly limited, and the results must be considered as only preliminary in nature. Should they be replicated in a larger sample, this would have major implications for our understanding of how exclusive breastfeeding might influence growth in the pre-school years.

**Secondary analysis based on any breast-feeding at age 6 months:**

Given the relatively small number of children who were exclusively breastfed at age 6 months in this sample, we repeated the above analyses using “any breast-feeding” at six months as the key moderator variable. Results indicated no
significant moderation effect of “any breastfeeding” in either model 2 or model 3. Given that the distribution of children who were and were not breastfed at 6 months was much more balanced for any vs. exclusive breastfeeding, this lack of effect could not simply be attributable to low statistical power. This suggests that the moderating effect of breastfeeding on the maternal sensitivity - BMI link may be limited to children who experience exclusive breastfeeding at 6 months only.

6.7. Discussion

Study 1 demonstrated a significant association between low maternal sensitivity at age 6 months and higher BMI at age 48 months in girls but not boys.

Study 3 (Chapter 6) extends this work by examining whether breastfeeding acts as a second moderator of the relationship between maternal sensitivity at 6 months of age and child BMI at 48 months. Breastfeeding was chosen as a potential second moderator for two reasons: 1. breastfeeding provides a natural source of nutrition to the developing infant; and 2. breastfeeding has recently been identified as a potential protective factor for future overweight-obesity in children. At a statistical level, we examined two possible ways in which breastfeeding might be operative in this regard: (diagrams adapted from Hayes, 2013):

We examined whether exclusive breastfeeding at 6 months acting as a second moderator interacting with sex influences the relationship between low
maternal sensitivity at 6 months and abnormal child BMI at 48 months in girls but not boys.

We had hypothesized that exclusive breastfeeding at 6 months interacting with sex would protect children from overweight-obesity risk when exposed to low maternal sensitivity at 6 months. Exclusive breastfeeding at 6 months was found to be a robust moderator of the association of maternal sensitivity at 6 months and BMI at 48 months. However, this association between maternal sensitivity at 6 months and BMI 48 months z-scores moderated by exclusive breastfeeding at 6 months was only linked with infants who were exclusively breastfed. These data suggest that the effect of exclusive breastfeeding at 6 months of age is to lessen the association of low maternal sensitivity and high BMI, with the effect being the same for girls and boys. These data add further support for the current WHO recommendation to implement exclusive breast-feeding through the first six months of life where possible.

The work of Miralles A et al (2006) supports my hypothesis that breastfeeding is an important factor that might influence BMI z-scores at 48 months. As well, studies of breastfeeding have shown that there is a connection with alterations in the hypothalamic-pituitary-adrenal (HPA) axis in the postpartum phase. The reduced activity of endocrine stress reactivity might be due to breastfeeding itself or other factors such as skin-on skin and suckling which might also be significant in this early mother-infant relationship (Heinrichs M et al, 2001; Handlin L et al, 2009). Heinrichs M et al created a study using lactating mothers who were randomly providing breastfeeding or holding their
infants 30 minutes before the mothers were exposed for a short psychosocial stressor which activated the HPA-axis (Trier Social Stress Test). While the baseline endocrine hormones taken one minute before the stressor were equivalent (p< 0.01), after the stressor it was found that breastfeeding (but not holding infants) was found to decrease the levels of salivary free cortisol and total plasma cortisol responses ( p<=0.001).

The studies of Handlin L et al were exploring factors that associated with breastfeeding as well as hormones linking with skin-to-skin and suckling to further understand how these influences act on adrenocorticotropic hormone (ACTH) and cortisol. Breastfeeding was found to decrease the levels of ACTH and cortisol in conjunction with skin-on-skin contact between the mother-infant dyad; as the duration of the skin-on-skin contact increased the levels of cortisol decreased and as the duration of suckling increased the ACTH levels began to decrease. These authors provide evidence that breastfeeding offers reductions of cortisol and ACTH which can lessen stress which might be positive for the developing mother-infant dyad.

A recent paper on breastfeeding and the mother-infant relationship is also focussed on cortisol, where the mother-infant dyad is providing salivary cortisol at three time points (awakening, 30 minutes later, and at bedtime) (Neelon SEB et al, 2015). These children were fully or partially breastfeeding or using bottled formulas; only mother-infant breastfeeding dyads were correlated with cortisol and only at bed time suggesting that they are attuned at the end of the day (Neelon SEB et al, 2015).
Prior research (Arenz S et la, 2004; Harder T et al, 2005; Owen CG, et al, 2005a, 2005b) has provided moderate but incomplete support for the hypothesis that breastfeeding acts as a protective factor on later overweight-obesity risk. Methodological issues that include details on incomplete consideration of confounding of variables, as well as a lack of understanding of specific mechanisms that might be integral to further our understanding of how breastfeeding might relate to the risk of overweight-obesity in young children have been problematic. Taken together these issues limit the impact of this work. Our results indicated that exclusive breast-feeding at age 6 months limited the effect of low maternal sensitivity on higher BMIs at age 48 months, which provides important new information.

Recently large population-based studies in which systematic scoring of early mother-child interactions identified that insecure attachment and low maternal sensitivity were associated with a high risk of obesity in adolescence (Anderson SE. et al, 2012). In their 2011 paper, Anderson and Whitaker included breastfeeding and infant feeding as a covariate but did not test either of these variables as a moderator of the association between attachment categories and the risk of obesity. Their subsequent paper studying maternal sensitivity and obesity risk did not include breastfeeding as a covariate nor was breastfeeding tested as a potential moderator (Anderson SE. et al, 2012). In a smaller study school age children found to have the greatest risk of overweight-obesity were those who had a difficult temperament and insensitive mothering (Wu T et al 2011). Breastfeeding was not included or considered as a potential moderator of
this association. Thus, in connecting low maternal sensitivity at 6 months with higher BMIs at 48 months moderated by exclusive breastfeeding at 6 months the current findings extend the work of Wu et al (2011) and Anderson SE, et al (2012).

In summary our findings of a robust interaction between maternal sensitivity at 6 months and exclusive breastfeeding at 6 months is important, with the effect of exclusive breastfeeding at 6 months lessening the association of low maternal sensitivity and high BMI for girls and boys. This work suggests that children who have not been exclusively breastfed have a higher risk for overweight-obesity in the future. There is a need to further explore this work in larger population-based studies.

**Strengths and Limitations**

Several potential strengths and limitations of the current study are worth considering. Strengths include our use of a population-based sample with highly structured and standardized assessments of maternal sensitivity done in the first year of postnatal life, when plasticity effects are likely to be significant. The longitudinal aspect of our findings is also a potential strength. On the other hand, our current sample size is much smaller than the large scale studies (Anderson SE et al, 2012; Wu T et al, 2011; Arenz S et al, 2004; Harder T et al, 2005; Owen CG et al, 2005a, 2005b), which limits statistical power.

Our previous paper (Chapter 4) indicated that the relationship between maternal sensitivity at 6 months and BMI at 48 months was manifest in girls only.
We anticipated that this sex difference would translate into a significant three way interaction when breastfeeding was added as a further moderating variable in the current study, but found that sex and breastfeeding acted independently as distinct moderators. One possible statistical explanation for the lack of a significant three-way interaction is that a low percentage of children (11.5%) had exclusive breastfeeding at 6 months in our cohort, with an imbalance in the numbers of boys (two-thirds) to girls (one-third). This compares to the current Canadian average of 26 percent (Statistics Canada, 2012). A further limitation was that the children recruited in Hamilton had more exclusive breastfeeding at 6 months compared to the Montreal site.

*Future Considerations*

The current data add to previous arguments at governmental and public health policy levels that novel approaches be used to encourage exclusive breastfeeding up to 6 months of age. Highlighting novel scientific findings to support this practice, including findings from the current study, could be of help in this regard. Recent systematic reviews have identified that the provision of education and support by health professionals in the early postpartum period and beyond has been successful in assisting mothers to breastfeed their infants (Meedya S et al, 2010; Sikorski J et al, 2003).
Chapter 7

Integrative Discussion of Thesis
7.1. Overview

Child overweight-obesity continues to be a major public health issue on a world-wide basis, with major costs at a personal, familial and societal level. As a qualified clinical dietitian working with parents and children who were struggling with overweight-obesity it was evident that conventional diet therapy and physical activity were only one part of the solution. Over the 25 years of my clinical experience it became more and more evident that inter-personal and emotional factors were also critical pieces of this puzzle. This led me back to academia and an opportunity to study relationships based on the maternal-infant dyadic relationship using an attachment/maternal sensitivity perspective.

In exploring how the early maternal-child relationship might influence child weight regulation in the pre-school years, three studies were conducted. The summary of major findings is as follows:

Study 1

In study 1 the main goals were: 1) to examine the association between 6 month maternal sensitivity scores and body mass indices measured at 48 months of age in a longitudinal study of developing children, thus extending the work of Anderson SE et al (2012), to an earlier developmental stage, and 2) to assess whether sex might moderate this association. We hypothesized that exposure to low maternal sensitivity at age 6 months would be associated with higher child BMIs at age 48 months, and that sex would moderate this association i.e. that girls would show this association more so than boys. The latter was based on known differences in parental expectations, perceived roles
and maternal behaviours towards boys and girls that might be contributory in this regard (Goldberg S and Lewis M, 1969; Biringen Z et al, 1994; Carper JL et al, 2000; Elfhag K and Linné Y, 2005; Hinde R and Stevenson-Hinde J, 1987), as well as recent work demonstrating a link between social adversity and obesity risk in girls but not boys at five years of age (Suglia SF et al 2012). Other recent work has further demonstrated that girls are more susceptible than are boys to environmental influences as it relates to weight regulation early in life (Dubois L et al, 2012).

After controlling for covariates known to have a strong relationship with child BMI (SES-maternal education, child birth weight, maternal BMI), we found a significant negative association between maternal sensitivity at 6 months of age and body mass indices in 48 month old girls, but not their male peers. Further analysis revealed that in girls only, low maternal sensitivity was associated with an increased likelihood of being either at risk for overweight, overweight or obese based on established WHO cut-offs. This suggests for the first time that the link between maternal sensitivity and early markers of obesity risk may in fact differ between the two sexes:

In sum, study 1 demonstrated a significant association between low maternal sensitivity at 6 months and the risk of higher BMI at 48 months in girls
but not boys:

Hayes PROCESS model 1

**Study 2**

In study 2 the main goals were to: 1. examine whether CEBQ subscales scores for emotional overeating, food responsiveness and enjoyment of food at 48 months mediate the relationship between 6 month maternal sensitivity scores and body mass indices measured at 48 months of age, and 2. assess whether sex might moderate this association. After controlling for covariates known to have a strong relationship with child BMI 48 months, using conditional PROCESS analyses with a moderated mediation approach, we found that the CEBQ-scale of emotional over-eating mediated a negative association between maternal sensitivity at 6 months of age and body mass indices at 48 month for girls but not boys. Further analysis revealed that in girls only, low maternal sensitivity was associated with an increased likelihood of being at risk for overweight in relation with emotional overeating. This suggests that risk for emotional eating may be established earlier in life than previously thought, although the fact that the CEBQ is maternally reported is a natural limitation in this regard.
Summary of Study 2 results:

Hayes PROCESS model 58

MODEL 4 – girls only

** p < .01; * p < .05; ^ p < .10
Study 3

In study 3 the main goals were to: 1. examine whether exclusive breastfeeding at 6 months of age moderates the relationship between low maternal sensitivity at 6 months and higher child BMI at 48 months and 2. assess whether sex might act as a moderator of this association. We hypothesized that exclusive breastfeeding at 6 months would protect girls in particular from overweight-obesity risk when exposed to low maternal sensitivity at 6 months.

The current results supported the general working hypothesis that exclusive breastfeeding at age 6 months moderates the association between maternal sensitivity at 6 months and child BMI at 48 months. However, the results supported PROCESS model 2, which considers exclusive breastfeeding as a separate moderator acting independently from the sex of the child. Another unexpected finding was that the effect of exclusive breastfeeding at 6 months of age was to enable infants who were underweight to move towards normal BMI, with the effect being the same for boys and girls.

Hayes PROCESS model 2
7.2. Relevance of Study Findings

1. The early mother-infant relationship - weight regulation/ BMI

   While the literature linking parent-child interactions with obesity risk is substantial, recent reviews have highlighted several potential limitations of this work, including strong reliance on cross-sectional designs, limited direct assessment of parent-child interactions, relatively small samples and with a primary focus on school-age children and adolescents (Ventura AK and Birch LL, 2008; Anzman SL et al, 2010; Sleddens EF et al, 2011; Mitchell GL et al, 2013). The current project, with its use of highly systematized assessments of maternal sensitivity done very early in life in a well characterized developmental cohort, addresses many of these issues “head-on”.

   Recently, objective systematic scoring of early mother-child interactions been used in the context of large population-based studies (Anderson SE et al, 2012). In these studies, children at 24 and 36 months with both insecure attachment and exposure to low maternal sensitivity had a particularly high risk of obesity in adolescence (Anderson SE. et al, 2012). While our early evolving longitudinal study does not reach the subjects found by Anderson SE et al (2012) we have replicated their study and also extended their results. We found a significant negative association between maternal sensitivity at 6 months of age and body mass indices in 48 month old girls, but not their male peers. Further analysis revealed that in girls only, low maternal sensitivity was associated with an increased likelihood of being at risk for overweight, overweight - obese based on established WHO cut-offs. This suggests for the first time that the link
between maternal sensitivity and early markers of obesity risk may in fact differ between the two sexes. Moreover current findings suggest that 6 months of age, when plasticity effects are likely to be significant (Vohr BR et al, 2008), may encompass a significant period of development when human infants are highly sensitive to maternal signals, with implications for early prevention and management of childhood obesity risk. However, low maternal sensitivity has also been associated with feeding problems and failure to thrive in some children (Hagekull B et al, 1997; Drotar D et al, 1990; Ward MJ et al, 1993; Feldman R et al, 2004; Block RW et al, 2005), suggesting that the link between early maternal sensitivity and weight regulation may be bidirectional.

2. Sex differences

Our finding that boys and girls may have different relationships with mothers (or primary female caregivers) is interesting but perhaps not surprising. Several authors have identified important sex differences associated with the early mother-child relationship and the development of social interactions (Biringen Z et al, 1994; Hinde R and Steven-Hinde J, 1987; Goldberg S and Lewis M, 1969; Gunnar MR and Donahue M, 1980). Furthermore, several aspects of eating behaviour and weight gain may develop differently in girls and boys (Elfhag K and Linne Y, 2005; Suzuki K et al, 2012; Govindan M et al, 2013). Thus, it is reasonable to hypothesize that the link between maternal sensitivity and later overweight-obesity risk might differ in the two sexes.
3. Emotional overeating at 48 months of age

Emotional eating is eating in response to emotions rather than normal appetitive signals. Emotional eating is also portrayed as a disordered eating pattern described as "an increase in food intake in response to negative emotions" (Spoor ST, Bekker MH, van Strien T, van Heck GL, 2007).

The Children’s Eating Behaviour Questionnaire (CEBQ) was developed for pre-school children, with an instrument that was systematically developed with eight scales and 35 items to evaluate eight dimensions of eating styles of young children in an attempt to understand which styles might contribute to the development of body weight (Wardle J et al, 2001). Given the early age of children using this tool, parents provide the reports on child eating behaviours.

Using the CEBQ instrument the current study examined whether three sub-scales: emotional overeating, food responsiveness and enjoyment of food at 48 months would mediate the relationship the relationship between 6 month maternal sensitivity scores and body mass indices measured at 48 months of age.

We found that only emotional overeating mediated a significant negative association between maternal sensitivity at 6 months of age and body mass indices in 48 month old girls, but not their male peers. Further analysis revealed that in girls only, low maternal sensitivity was associated with an increased likelihood of being at risk for overweight related with emotional overeating. This suggests that eating behaviours such as emotional overeating may occur earlier
in life than we had anticipated, and that the link between maternal sensitivity and early markers of obesity risk may in fact differ between the two sexes.

While the findings in chapter 5 are highly provocative in demonstrating a mediating effect of emotional overeating on the association between low maternal sensitivity and higher BMI z-scores in girls, the fact that this data was based on maternal reports rather than self-reports is an important limitation as eluded to above. Ultimately, the best test of this hypothesis will occur as the children reach the preadolescent years and beyond, when self-report measures and other objective assessments of emotional regulation in general, and emotional overeating in particular, will be possible. This is a high priority for future MAVAN work given the major role that Emotional Overeating plays in both obesity and eating disorders including binge eating disorder and bulimia nervosa.

4. **Exclusive breastfeeding at 6 months of age**

To maximize the translational value of this work as it relates to current WHO guidelines, we initially focused on exclusive breastfeeding at age 6 months as our key moderating variable. However, as non-exclusive breast-feeding at age 6 months was common in this sample, we also performed a secondary set of analyses based on any breast-feeding at six months ‘any time’.

Across the full sample, there was no relationship between maternal sensitivity scores at age 6 months and BMI z-scores at age 48 months in children who were not exclusively breast-fed at age 6 months ($R^2=.013$). On the other hand, there was a *positive* relationship between maternal sensitivity scores and BMI in
children who were exclusively breastfed at six months of age ($R^2=0.119$). The moderation effect of exclusive breast-feeding on the relationship between maternal sensitivity and BMI was not related to obesity risk, but rather to risk of being at a very low BMI at age 48 months i.e. at the lower extreme of maternal sensitivity, the regression line approached a BMI z-score of -2, which is pathologically low, while at the higher extreme of maternal sensitivity, the regression line was close to zero. This suggests that in children who were exclusively breast-fed at six months who were underweight were able to move towards and with higher maternal sensitivity were able to reach normal weight.

The finding that exclusive breast-feeding through six months of age moderated the association between low maternal sensitivity and higher BMIs z-scores is both novel and of potential clinical importance for the field. It also supports current breast-feeding recommendations by the WHO. This is tempered however by the fact that a low percentage of MAVAN children (11.5 %) were exclusively breastfed at 6 months, and with an imbalance in the numbers of boys (two-thirds) vs. girls (one-third) having this exposure. The 11.5% rate of exclusive breast-feeding at six months is very low compared to the current Canadian average of 26 % (Statistics Canada, 2012). The use of exclusive breastfeeding was particularly low at the Montreal site compared to the Hamilton site, and may reflect cultural or socioeconomic differences between these subpopulations.

While this was controlled for as much as possible in the statistical analyses, the generalizability of the current findings remains in question and will require further study in other samples as a result.
7.3. Study Benefits and Limitations

The MAVAN Cohort:

All data for the current project was provided by the Maternal Adversity Vulnerability and Neurodevelopment project (MAVAN). There are several unique strengths of the MAVAN project that stood out in this regard. In the first place, MAVAN was designed and administered by a highly accomplished multidisciplinary team of researchers across several University sites with expertise in all of the specialized areas necessary for the current project. This varied expertise allows for very detailed and rich phenotyping of the MAVAN children over time. The availability of reliable and validated maternal sensitivity data which requires highly specialized training to be scored is rare in cohort studies of this type and was critical for the current hypothesis testing. The detailed assessments of both eating behaviour and BMIs over time, including instruments such as the CEBQ, and the detailed breast-feeding data used for chapter 6, are also noteworthy in this regard. Performing this extensive phenotyping is resource and time intensive, and thus sample size for the MAVAN project is on the small size for a longitudinal cohort. This can be problematic when studying moderation and mediation effects, and might have led to false conclusions regarding the moderating effects of sex in particular i.e. the relative lack of findings in boys compared to girls in the current studies may reflect a lack of sufficient statistical power. One solution to this trade-off between deep phenotyping versus larger sample size is to attempt replication of findings in other cohorts. Such collaborations are currently being developed, and will allow
for replication testing of the current hypotheses in other samples such as the
generation Rotterdam (GEN-R) study.

The current studies for this dissertation are focussed on the early mother-
infant relationship associated with BMI in conjunction with emotional eating
patterns and breastfeeding.

a. Dataset of cohort for this research

Using secondary data has many advantages, particularly in this case when a
researcher is interested in a population of adverse and vulnerable subjects who
are followed over equivalent time points, and using the same tools to evaluate
the mother-child relationship. Challenges using two sites in different provinces
and two languages provide adjustment and learning for researchers. To enable
reliable data it is important to carefully screen and clean datasets, concerning
outliers, missing data, and aiming to provide normality, all of which will provide
power to analyses when using secondary data.

While the current data suggest that boys (in chapters 4 and 5) will not
show an association between maternal sensitivity and BMI even with a much
larger sample size, similar studies in other cohorts will be needed to assess this
more fully. Our current sample size is much smaller than the large scale studies
(Anderson SE et al, 2012; Wu et al, 2011; Gillman MW et al, 2003, 2006; Hohwa-
L et al, 2014; Harder T et al, 2005), which limits statistical power.
b. Missing data

The current sample of 223 children was based on availability of maternal sensitivity data at 6 months and BMI data at 48 months at the time of completion of study 1. As subsequent studies were extensions of study 1, the same sample of 223 was used as a starting point throughout. However, across the various analyses there was some missing information that led to different sample sizes: breastfeeding was missing for 2% of the sample; the CEBQ scale of Emotional Overeating was missing for 6.3% of the sample; SES-maternal education was missing for 9.4% and maternal BMI was missing for 17% of participants. As mentioned previously, future work on MAVAN will likely use more imputation to address these missing data.

The limitation of the moderating effect on sex in the current study possibly relates to the low percentage of children on exclusive breastfeeding at 6 months in our cohort, which has an imbalance in the numbers of boys (two-thirds) and girls (one-third). Within this dataset of children (n=223), only 11.5 percent of our cohort were using exclusive breastfeeding at 6 months, compared to the current Canadian average of 26 percent (Statistics Canada, 2012). The two research sites were skewed with Hamilton being the primary location where the majority of exclusive breastfeeding at 6 months was used, compared to the Montreal site.

Initially the MAVAN project over-sampled from low SES settings, however this is no longer the practice. (LICO, Statistics Canada, 2005) was near 30% compared to 15% in the general population (Statistics Canada, 2009). However, while education below 10 years was found in only 4% of the mothers of our
sample, this number reaches 12% of adults in the provinces of Québec and Ontario (Statistics Canada, 2011). In sum, SES status was relatively low but education relatively high, relative to Canadian population norms. The missing data is 9.4% in this data set; had there been less missing data it is possible that SES influence might have been stronger.

Missing data for maternal BMI is significant at ~ 17% information. We found in the two sites that mothers who were overweight frequently declined measures of weight at the 48 month clinic when their children were measured. This is a common problem for obesity research in general, and in many cases reflects refusals by women with body image and/or social desirability concerns including many with obesity per se. How this might have influenced the current results is unclear. On a positive note, maternal BMI was a strong predictor of child BMI in all of the analyses, and all of the effects reported occurred with maternal BMI being controlled for.

c. Child Eating Behaviour Questionnaire (CEBQ)

The CEBQ is a tool developed to assess the eating styles of young children, based on parental reports of child behaviours. This is of course a natural limitation when studying young children, and future work using more objective measures of emotional eating once the children are older are needed to help validate these initial findings.
d. **Generalizability**

Our current findings of the large number of mothers with low SES but high educational status may not be generalizable. The high educational status could in theory limit the impact of social adversity on the outcome under consideration.

e. **Limited power**

Our current sample size is much smaller than reported in most prior studies in this area of research (Anderson SE et al, 2012; Wu T et al, 2011; Gillman MW et al, 2003, 2006; Harder T et al, 2005), which limits statistical power. This is most relevant as it relates to negative findings and sex differences for example, whereby the lack of effect in one sex may reflect this low power.

**Treatment implications**

Meta-analyses reported from Europe (Bakermans-Kranenburg MJ et al, 2003; 2005), as well as recent Canadian studies (Moss et al, 2013) suggest that maternal sensitivity and attachment behaviours can be modified through video-based learning; early preventive interactions focusing on maternal sensitivity have been effective in enhancing maternal sensitivity as well as promoting child attachment security. If low maternal sensitivity is in fact causal of early weight gain, such interventions should make an impact on limiting childhood obesity over time. The current findings suggest that girls might benefit disproportionately in this regard.
7.4. Future Directions

Future Research Direction (Short term)

Inspired by the current finding that emotional eating mediates the association between maternal sensitivity and BMI z-scores, and based on the high prevalence of emotional eating in modern society, my plan is to continue with the present focus on the mother-child dyadic relationship, but with a greater focus on emotional regulation. Laboratory based challenge studies that examine eating patterns in response to mild stressors and food related images are one consideration as the MAVAN children reach the adolescent years. I would predict that adolescents who were exposed to low maternal sensitivity as infants would consume more comfort foods in response to mild stress, reflecting a deficit in more adaptive emotional regulation strategies. In many girls, this might take the form of a broader eating disorder such as bulimia nervosa or binge eating disorder. Studying a variety of maternal behaviours relevant to weight regulation, such as eating styles, eating patterns, dieting practices and physical activity are also priorities as it relates to potential modelling of parental behaviours by the children.

The literature has provided clear evidence that maternal weight profiles prior to and during pregnancy are critical moderators of children’s obesity risk over time (Herring SJ and Oken E, 2011; Ludwig DS and Currie J, 2011). Maternal gestational diabetes influences both the developing foetus and the overall health of the pregnant mother and has increased in frequency in recent years (Crume TL et al, 2011; Herring SJ and Oken E, 2011). Examining if and how this aspect
of the pre-natal environment interacts with maternal sensitivity post-natally is an interesting question for future work.

Given the current results related to female gender, studying the unique relationships between mothers and their female children continues to be an important focus for my work, particularly when emotional factors linked to eating behaviour are considered. Studying maternal eating styles and habits that might promote abnormal eating behaviours in girls is of particular interest in this regard (Elfhag K and Linne Y, 2005). Other maternal factors such as stress reactivity, a history of dysfunctional eating patterns or clinical eating disorders, along with the use of alcohol, drugs, and smoking are all significant factors that might influence the risk of pathological weight regulation in the developing foetus and child (Durmus B et al, 2001; Oken E, 2008; Reidel C et al, 2014). As reviewed earlier (e.g. Dubois L et al, 2012), one might expect girls to be more influenced by such factors as it relates to their own eating behaviour and weight regulation.

Given potential protective effects of breastfeeding on obesity risk, further studies on the dyadic relationship pertaining to breastfeeding is another priority e.g. exploring additional factors and reasons that mothers use breastfeeding or turn to substitute artificial feedings. Recent research suggests that sensitive mothering has a vital role in determining the relationship between early breastfeeding occurrence and infant temperament later in life (Jonas W et al, 2015) and reduced duration and decreased exclusive breastfeeding are linked with anxiety but not depression (Adedinsewo DA et al, 2014). Depression has been found to play a key role in determining the relationship between early life
adversity and breastfeeding outcomes, but only for women who are homozygous for a particular gene variant in the oxytocin system and linking with breastfeeding and post-partum depression. As well, these mothers can moderate the adverse effects of early adversity on some measures of breastfeeding (Jonas W et al, 2013).

Future Research Direction (Long Term)

While the detailed phenotyping of the MAVAN sample is a major long term strength, we do not have sufficient data at this time to fully explain the mechanistic basis of our main findings, though this will be an ongoing goal of future work. Adding genetic and epigenetic markers as well as functional MRI studies as the children approach adolescence and beyond have great potential in this regard.

Family functioning is important for many reasons – while this thesis focused on maternal sensitivity, there are many ways by which family functioning can influence self-regulation skills of children associated with eating, and weight management. Further detailed study of familial food choices, eating and activity patterns and attitudes would be of great help. Studying family environments in greater depth might provide greater understanding of eating and high risk over-weight-obesity challenges (Jensen PW et al, 2012), as would the influence of income and education on food habits and the meaning of food.

As alluded to above, assessing whether maternal sensitivity based interventions at 6 months of age can prevent some cases of childhood obesity is
of great public health interest. Based on our findings, we anticipate that girls might have the greatest benefit from these interventions.

On average, working mothers in the United States have only a brief post-partum period at home before returning to work (~4-6 weeks) compared to mothers in Canada who often have a year away from work. Working mothers who want to breastfeed their infants often have to pump their breasts to remove the milk which is then provided in a bottle; while this provides a natural source of breast milk, the infant may not have the same opportunity to choose when to stop suckling and the frequency of offering might not be the same as with time on the breast. Creating a comparative longitudinal study on the links between breastfeeding and weight regulation in Canada vs. the United States would thus be of great interest. A key issue in this regard is whether breast milk in the bottle is equivalent to directly suckled breast milk in terms of overall obesity risk; if time at the breast mitigates the effects of low maternal sensitivity on obesity risk, one might expect less benefit from mother’s milk in the bottle.

7.5. Final Summary

As I reflect once again on the journey that led to this dissertation I am reminded that my clinical experience with families and their children led me on this path many years ago. I now have a much greater understanding of why the first relationship in our lives is so important to our nutritional health. With the help of a generous and accomplished supervisory team I have been privileged to be able to explore how the early mother-child dyadic relationship influences early
obesity risk. My goal back in 2006 was to understand whether attachment or maternal sensitivity was associated with child weight/ BMI – at that time there were no publications available to answer this question. The first publications on this theme were in 2011 and 2012 – using large datasets; our first paper was published in 2014, which nicely replicated and extended the work of Anderson SE et al, 2012 and Wu T et al, 2011) as described above.

The benefits of the MAVAN project, particularly its unique multi-disciplinary team have enabled all of us to learn so much about this area of work and I suspect at the same time learning about ourselves.
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See: http://www.who.int/childgrowth/standards/chart_catalogue/en/


Appendices
Measurement of Attachment Behaviours

The standardized procedure takes place in a small room consisting of two chairs (one for the mother and one for the stranger) along with toys for the child. The room is also equipped with a one way mirror enabling observers to view the procedure. The ‘strange situation’ experiment consists of seven episodes, of about 3 minute intervals, that take place in a consistent order. The experiment is designed to encourage exploratory behaviour but not elicit a sense of fear that might heighten a stress response early on (Ainsworth and Bell, 1970). The seven episodes are arranged in an order that progressively elicits increasing stress to the child. Serial measurement of salivary cortisol is often a component of the ‘strange situation’ in many labs, providing a biological marker of stress reactivity during this experimental procedure.

The seven episodes of the experiment include:

Episode 1: (mother, baby): mother and infant alone in the room;
Episode 2: (mother, baby, stranger): stranger enters room with mother and baby;
Episode 3: (baby, stranger): mother leaves room;
Episode 4: (mother, baby): mother returns to room, stranger leaves;
Episode 5: (baby): mother leaves room – baby in room alone
Episode 6: (baby, stranger): stranger returns to the room;
Episode 7: (mother, baby): mother returns to room, stranger leaves.

Ainsworth was particularly interested in the behaviour of the baby associated with separation from the mother, the presence of a stranger, and also the reunion of baby and mother, when she returned to the experimental room (Ainsworth and Bell, 1970).
Videotaping during the procedure enables systematic coding of the mother-child relationship. Behavioural coding of the ‘strange situation’ enables the classification of attachment styles into 3 distinct stable forms of attachment: the secure style, and two insecure attachment styles: the anxious-avoidant, and the anxious-resistant/ambivalent (Ainsworth MD et al., (1978)/2015). In addition, a fourth relationship pattern has been identified as ‘disorganized/ disoriented’ (Hesse E and Main M, 2000), which lacks a coherent attachment approach. The disorganized attachment is used to identify child behaviour that is inconsistent and unstable; it is identified with a double coding, comprising one of the 3 organized attachment classifications along with the disorganized code (Goldberg S, 1997).

Caregivers respond to the signals of infants indicating the effect of the child’s behaviour on the caregiver (Goldberg S, 2000; Crittenden PM, 1995). Infants that are securely attached learn that when they signal anxiety or discomfort they can count on the caregiver to respond in a predictable comforting way. Infants with an insecure attachment cannot rely on a positive acknowledgement of the caregiver to support them in times of stress and anxiety, so they adopt behaviours that feel protective, in the absence of a valuing or sensitive caregiver (Goldberg S, 2000; Crittenden PM, 1995).

The Maternal Behaviour Q-Sort (MBQS)

Overview, Available Materials and Support

The Maternal Behaviour Q-Sort was developed by David Pederson, Greg Moran and Sandi Bento to describe the quality of mother-infant interaction based largely on Mary Ainsworth's concept of maternal sensitivity. The MBQS has now been used extensively based on home observations and a variety of video-recorded samples of interaction. There are a number of versions, including the standard 90-item card set and a mini-MBQS, 25-item set that involves less time and is well-suited to video-recordings of interaction in a limited context but, of course, provides a less detailed description of the interaction. The instrument has also been used to produce a number of different metrics for analysis, including a global measure of sensitivity describing a mother's interaction relative to a prototypically sensitive interaction, measures derived from q-factor analyses, and rationally defined measures that describe the substance or content of the interaction.

This section of our website contains a number of documents related to the MBQS. We are continually adding to this list. The first document contains the 90-item sort and information relevant to its use. Although this document is described as a manual, we have developed a much more extensive MBQS Manual - Assessing Maternal Sensitivity and the Quality of Mother-Infant Interactions Using The Maternal Behaviour Q-Sort (MBQS) - that includes more detailed background on the MBQS and its use in research as well as recommendations regarding such matters as structuring a home visit, videotaping, and training and maintaining coder reliability. This more complete manual is available by request (mailto:gmoran2@uwo.ca)

Although the MBQS manual is designed to provide the information necessary to apply the instrument without formal instruction, ideally, it is preferable for those new to the MBQS to train with a group that has some experience. We have
occasionally offered brief training sessions here, at Western, and will consider requests to do so again in the future.

Please contact us at anytime should you have any questions regarding the use of the MBQS.

Greg Moran - mailto:gmoran2@uwo.ca
David Pederson – mailto:pederson@uwo.ca
Sandi Bento – mailto:bento@uwo.ca

(October 2009)
# Child Eating Behaviour Questionnaire (CEBQ)

Please read the following statements and tick the boxes most appropriate to your child’s eating behaviour.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>My child loves food</td>
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<td>My child eats more when worried</td>
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<tr>
<td>My child has a big appetite</td>
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<tr>
<td>My child finishes his/her meal quickly</td>
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<tr>
<td>My child is interested in food</td>
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<tr>
<td>My child is always asking for a drink</td>
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<tr>
<td>My child refuses new foods at first</td>
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<tr>
<td>My child eats slowly</td>
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<td>My child eats less when angry</td>
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<tr>
<td>My child enjoys tasting new foods</td>
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<tr>
<td>My child eats less when s/he is tired</td>
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<tr>
<td>My child is always asking for food</td>
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<tr>
<td>My child eats more when annoyed</td>
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<tr>
<td>If allowed to, my child would eat too much</td>
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<tr>
<td>My child eats more when anxious</td>
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<tr>
<td>My child enjoys a wide variety of foods</td>
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<tr>
<td>My child leaves food on his/her plate at the end of a meal</td>
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<tr>
<td>My child takes more than 30 minutes to finish a meal</td>
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</tbody>
</table>

ID:
<table>
<thead>
<tr>
<th>Statement</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Always</th>
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</thead>
<tbody>
<tr>
<td>Given the choice, my child would eat most of the time</td>
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<td>My child looks forward to mealtimes</td>
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<td>My child gets full before his/her meal is finished</td>
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<tr>
<td>My child enjoys eating</td>
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<tr>
<td>My child eats more when she is happy</td>
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<td>My child is difficult to please with meals</td>
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<td>My child eats less when upset</td>
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<tr>
<td>My child gets full up easily</td>
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<tr>
<td>My child eats more when s/he has nothing else to do</td>
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<tr>
<td>Even if my child is full up s/he finds room to eat his/her favourite food</td>
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<tr>
<td>If given the chance, my child would drink continuously throughout the day</td>
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<tr>
<td>My child cannot eat a meal if s/he has had a snack just before</td>
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<tr>
<td>If given the chance, my child would always be having a drink</td>
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<tr>
<td>My child is interested in tasting food s/he hasn’t tasted before</td>
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<tr>
<td>My child decides that s/he doesn’t like a food, even without tasting it</td>
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<tr>
<td>If given the chance, my child would always have food in his/her mouth</td>
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<tr>
<td>My child eats more and more slowly during the course of a meal</td>
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</tbody>
</table>
SCORING OF THE CEBQ

(Never=1, Rarely=2, Sometimes=3, Often=4, Always=5)

Food responsiveness = item mean FR
Emotional over-eating = item mean EOE
Enjoyment of food = item mean EF
Desire to drink = item mean DD
Satiety responsiveness = item mean SR
Slowness in eating = item mean SE
Emotional under-eating = item mean EUE
Food fussiness = item mean FF

*Reversed items


NB: There is an error in the text of this paper concerning the scoring of the CEBQ which is given as 0 - 4. In fact responses were scored 1 - 5 and the means and standard deviations given in the tables reflect this.