Examining the Relationship Between Infant Feeding Practices and Child Hyperactive/Inattentive Behaviours in a Canadian Sample

by

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Abstract

Attention deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder diagnosed in childhood. It is largely accepted that ADHD is a product of gene-environment interactions and method of infant feeding has been proposed as a factor influencing the expression and/or severity of ADHD. The objectives of this study were to determine the relationship between infant feeding (i.e. formula feeding or breast feeding) and subsequent hyperactive/inattentive (H/I) behaviours and ADHD diagnosis and if the relationship between infant feeding and academic performance is moderated by H/I scale score.

This study used data from the 2000/1, 2002/3, 2006/7 and 2008/9 cycles of the National Longitudinal Survey of Children and Youth (NLSCY) (n= 3,895) to follow children longitudinally from the age of 0 to 1 years old to 6 to 7 years old. Infant feeding at 0 to 1 years old, and child H/I score, ADHD diagnosis and academic performance scores at 6 to 7 years old were reported by the biological mother. Multivariable logistic and linear regression were used to determine the relationship between infant feeding and H/I score, ADHD and academic performance adjusting for a range of sociodemographic, birth and home environment factors.

Breastfeeding for more than 12 months was found to be significantly associated with decreased H/I scale scores in the most adjusted model (OR=0.3; 95% CI 0.2-0.8, $p<0.01$). Infant feeding was not associated with ADHD diagnosis and there was no moderating effect of the H/I score on the relationship between breastfeeding and academic performance. A small proportion of mothers breastfeed beyond one year in Canada and this study shows that there might be important child benefits incurred by breastfeeding for longer than 12 months.

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1.0 Introduction

1.1 Attention Deficit/ Hyperactivity Disorder

Attention deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder diagnosed in childhood with a world-wide prevalence of 5.3% in school-aged children.[1] ADHD is known to negatively affect cognitive functioning resulting in (a) poor peer and family relationships,[2,3] (b) learning difficulties,[4,5] and (c) school failure among those affected.[6] ADHD is categorized by a persistent pattern of inattentive or hyperactive-impulsive behaviour that interferes with functioning and development and symptoms of the disorder must be present before 12 years of age.[7]

The direct causes of ADHD are unknown. Genetic etiology is proposed to be the most prominent predicting factor of ADHD, with an estimated 80% of ADHD diagnoses attributable to genetic factors.[8,9] While it is unlikely that environmental factors can independently cause ADHD, several environmental factors are hypothesized contributors to severity of impairment and diagnosis of ADHD such as: exposure to high levels of lead in early childhood, maternal smoking and/or alcohol consumption during pregnancy, preterm birth, brain injury and maternal mental health.[10–18] Results from a study looking at discordant ADHD diagnosis in monozygotic twins confirms the importance of the environmental influence on ADHD diagnosis in addition to genetic predisposition.[19]

The literature has also identified that children who have sub-threshold ADHD-related behavioural symptoms are more similar to their ADHD diagnosed peers than to their healthy peers and are at an increased risk of developing ADHD.[20–22] From a population health perspective, it may be important to identify and study sub-threshold diagnostic behaviour in an effort to understand protective factors that can reduce the risk of clinical level impairment for those experiencing some symptoms. Therefore, this study will look at children with ADHD-related behaviours and diagnosis, as well as those who are diagnosed with ADHD.

Results from the United States indicated that from 1997 to 2008 there was a 33% prevalence increase in ADHD diagnosis.[23] While no longitudinal Canadian ADHD prevalence rates exist, given the similar population demographic and geographical location, it may be reasonable to speculate that the trend in Canada might be similar to the United States. It is unknown whether this increase can be attributed to real changes in the incidence of the diagnosis or to increased awareness of the symptoms of ADHD, and therefore increased rate of diagnosis. Regardless, more attention is being given to ADHD diagnosis and the protective and risk factors associated with its occurrence. This increased attention, accompanied by little concrete evidence for protective or risk factors associated with ADHD, point to the need for more research to evaluate various environmental, biological and genetic predictors of ADHD.

1.2 Infant Feeding Practices as a Possible Predictor of ADHD

Infant feeding practices are related to numerous child cognitive, behavioural and physical health outcomes.[24–29] Areas of behavioural functioning found to be associated with infant feeding practices include social competence, attention, hyperactivity and executive functioning.[30] Breastfeeding initiation and duration have been explored as possible resilience factors associated with ADHD-related behaviours and diagnoses whereby those children who were breastfed as infants are less likely to develop ADHD-related behaviours or to be diagnosed at all.[20,30–37] The mechanisms by which this association occurs will be discussed in the following chapters.

Health Canada and the World Health Organization (WHO) recommend exclusive breastfeeding for the first six months of the infant's life and continued breastfeeding with complementary foods (complementary breastfeeding) until the age of two or for as long as mother and child wish to continue.[38,39] The American Academy of Pediatrics recommends exclusive breastfeeding for six months with continued breastfeeding for up to one year or as mutually desired by the mother and the child.[40] However, many mothers are not able to achieve these recommendations, neither six months of exclusive breastfeeding nor continued breastfeeding beyond 6 months with complementary foods. According to the 2012 Canadian Community Health Survey, 89% of Canadian mothers breastfed or tried to breastfeed their most recent child, while only 26% breastfed exclusively for the first 6 months.[41,42] There are no nationally representative data available on the duration of complementary breastfeeding. While the majority of Canadian mothers are initiating breastfeeding, many are not continuing to breastfeed for the recommended time duration, which could be a contributing factor to possible later behavioural impairment in the child. Furthermore, the reasons why some mothers do not breastfeed for the recommended duration may be a confounding factor in the relationship between infant feeding and ADHD-related behaviours and diagnosis.

Measurement of breastfeeding is complex and its definition can comprise several different components including intensity of feeding (complementary, predominant and exclusive breastfeeding) and mode of feeding (such as expressed milk, at the breast, donor milk etc).[43] The different ways in which breastfeeding can occur, may result in very different experiences for the child, possibly leading to diverse long term outcomes. In the current literature, there is a lack of clear measurement descriptors in studies involving breastfeeding, making comparability across studies and aggregation of findings challenging.[43] In the current study, breastfeeding is defined broadly as the child receiving some breast milk through any mode of feeding.

1.3 ADHD, Breastfeeding and Educational Outcomes

While ADHD is not a learning disability, it is identified in the literature that children with ADHD-related behaviours and diagnosis often have trouble learning and perform poorer on academic tests than the average because of difficulty with focusing on schoolwork.[4,5,44–47] Academic achievement has been identified as one of the most ubiquitous areas of impairment in children with ADHD-related behaviours and diagnosis, therefore, these children often have lower academic performance compared to their peers.[5,47,48] The DSM-V states that along with specific symptoms, impairment must be present in two or more settings.[7] Because most children spend their time either at home or at school, the school environment is a critical place for evaluation of impairment to aid in identifying symptoms of ADHD.

Increased duration of breastfeeding has been linked to increased cognitive performance and IQ scores in children, which can lead to improved academic performance.[49–52] There is evidence that the nutritional components of the breast milk can positively affect measures of intelligence, which can improve performance in school. [49,53] Furthermore, breastfeeding can facilitate the development of a nurturing mother-child bond[54], which may lead to a more intellectually stimulating environment and greater brain development.[55–59] A large body of literature using strong methodological analyses, such as randomized control trials, suggests that the longer the child is breastfed, the greater the benefits on cognitive development and the greater the potential for high academic achievement. [49,50,53,60] However, it is important to note that this relationship is not causal, and there is a smaller body of literature concluding that there is no relationship between breastfeeding and cognitive development.[57,61–63] These studies suggest that breastfeeding may be acting as a proxy for sociodemographic or environmental factors that may be the mechanisms influencing cognitive outcomes.

2.0 Study Objectives

The objectives of this study are to: 1) examine the relationship between breastfeeding initiation and duration and child hyperactive/inattentive behaviour at 6 or 7 years of age, 2) examine the relationship between breastfeeding initiation and duration and parent-reported physician-diagnosed ADHD at 6 or 7 years of age, 3) examine if breastfeeding initiation and duration has a beneficial impact on academic performance among children with both high and low hyperactive/inattentive behaviour at 6 or 7 years of age.

3.0 Review of the Literature

3.1 The Relationship Between Infant Feeding and Hyperactive Behaviours and/or ADHD Diagnosis

There is a wide range of the literature showing the association between breastfeeding and several ADHD-related mental domains such as increased cognitive functioning, executive functioning, behavioural outcomes and IQ scores.[30,49,57,61,64–68] However, there is a limited literature examining the direct relationship between breastfeeding initiation and/or duration and subsequent hyperactive behaviours and ADHD diagnosis and the results from these studies are mixed as to the existence and strength of the relationship.[20,30–37,63,67,69–75]

The literature on the association between breastfeeding and hyperactive behaviours or

ADHD diagnosis has been considered using data from several different countries including Spain[30], Korea[20,70], Poland[31], Iran[33], Israel[32], Turkey[34], Germany[36,75], Saudi Arabia[71], the United Kingdom[67], the Netherlands[69], the Republic of Belarus[73,74] and the United States[35,37,63,72]. The majority of studies showing a significant relationship between breastfeeding and lower scores of hyperactive behaviours or ADHD diagnosis use observational methodologies [20,30–37,63,67,69–72,74,75], accounting for a range of different covariates. The range of covariates included in the current literature showing a positive link between breastfeeding and hyperactive behaviours and ADHD diagnosis is inconsistent, with some studies using descriptive analysis only and accounting for no covariates in the analysis[31,33,37], while another accounted for 18 covariates, including maternal and paternal ADHD diagnosis.[35] Other studies showing a link between breastfeeding and hyperactive behaviours or ADHD diagnosis have used multivariate analyses to control for sociodemographic and some parent and child related covariates such as parental divorce and smoking during pregnancy.[20,30,32] The variance accounted for by including appropriate covariates in the analysis can have a large impact on results and change a positive association to a null association. For example, two studies using the same survey data from Germany (n= 13,318) accounted for a different set of covariates and found breastfeeding to be significantly associated with ADHD in one analysis[36], while not significantly associated in the other.[75] In the significant analyses, covariates included: sex, age, socioeconomic position, maternal gestational diabetes, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, perinatal health problems and atopic eczema. In the non- significant analyses, covariates included sex, age, family income, social status, maternal smoking during pregnancy, exposure to tobacco smoke at home, siblings, atopic eczema, allergic asthma, allergic rhinitis, and paternal history of atopy. It is important to note that there is also a body of literature showing no relationship between breastfeeding and hyperactive behaviours or ADHD diagnosis that have included similar sets of covariates as those used in the studies showing a positive link.[63,67,69,70,72,74,75] While no firm conclusions exist about specific covariates that may or may not have an effect on the relationship between breastfeeding and hyperactive behaviours or ADHD diagnosis, it is clear that this relationship is highly influenced by external factors, so it is important to include a comprehensive list of factors to attempt to isolate the findings.

The majority of the studies on the relationship between breastfeeding and hyperactive behaviours or ADHD diagnosis have used observational data[20,30–37,63,67,69–72,74,75], while a few studies have used more rigorous analyses such as sibling analyses[32,63] and randomized control trials.[73] Observational studies have been criticized for being unable to account for fixed home and environmental effects, which may have a large influence on the mother's decision to breastfeeding and the child's behavioral expressions. To examine the unobserved differences between children who are and are not breastfed, observational sibling analyses or randomized control trials are necessary. Using data from the National Longitudinal survey of Youth (NLSY) in the United States (*n* = 7,319), one study used traditional multiple regression analysis and sibling analysis, controlling for maternal fixed effects, to examine the association between breastfeeding and a range of long term child health outcomes.[63] The authors found that breastfeeding was related to hyperactivity in the multiple linear regression analysis, but the relationship was no longer evident in the sibling comparison. In contrast, a different study used a much smaller sample size (*n* = 159) to conduct sibling comparisons and found that children diagnosed with ADHD had a significantly shorter duration of breastfeeding than the non-ADHD sibling comparison group.[32] Sample size and specific statistical methodology may contribute to the differences in the findings between these two sibling analyses. The NLSY analysis had a much larger sample and used more sophisticated techniques to control for fixed maternal effects, therefore this analysis may be more representative of the true association between breastfeeding and hyperactive behaviours. Unfortunately, sibling analysis is not possible with most data because of the limited number of siblings that are fed discordantly in the sample.

Using a cluster-randomized control trial (RCT), evidence from a large hospital-based breastfeeding promotion intervention in Belarus found that despite the intervention resulting in up to seven-fold higher increases in exclusive and complementary breastfeeding, the parent-reported results on the SDQ for the hyperactivity scale were the same in both groups.[73] This same research group also took an observational approach and measured the actual breastfeeding duration of the mothers who were exposed to the hospital breastfeeding intervention and those who were not.[74] The results from the observational study showed a significant relationship between short duration of breastfeeding and high hyperactivity as measured by the parent SDQ. The authors conclude that the differences between the randomized trail and the observational trial are likely due to residual confounding that can not be accounted for in the observational group, and that the results from the observational study are likely overstating the true association between breastfeeding and hyperactivity.

Taken together, the NLSY sibling analysis and the results of the Belarussian RCT show that it may not be the actual breast milk that impacts child behavioral outcomes but rather the home environment and maternal characteristics that accompany breastfeeding that impact child's behavioural outcomes. Observational studies can still provide important information on the strength of the relationship between infant feeding and hyperactive behaviours or ADHD diagnosis, however, they cannot determine the mechanism by which this association does or does not occur. Sibling analysis and RCTs have this advantage and can more accurately tease out the effect of breast milk from the unobserved effect of the home environment.

There are some limitations of the literature that may contribute to the discrepancy in the findings about the relationship between infant feeding and hyperactive behaviours or ADHD diagnosis. The studies in the current literature use varying measures of assessing breastfeeding duration and exclusive or complementary feeding. Some studies simply use a yes or no assessment of breastfeeding, while others look at both exclusive and complementary breastfeeding in different duration categories. The studies that look more closely at the dose as well as duration of breastfeeding are able to consider the association between breastfeeding and hyperactivity more accurately than the studies that only use a dichotomous breastfeeding variable. There are also varying measures of assessing hyperactive behaviours among the studies; some use actual ADHD diagnosis (from the DSM-IV or V or the ICD-10), while others use parent-reported measures of hyperactivity (using scales such as the Behaviour Problem Index or the Strengths and Difficulties Questionnaire). Studies that use physician diagnosed ADHD as the dependent variable are able to draw stricter conclusions on association between breastfeeding and clinically significant hyperactive/inattentive behaviours, while studies that use parent-reported questionnaires to assess the child's behaviour measure more generic hyperactive behaviours that are subject to the parent's perception of the child behaviour. The process of diagnosing ADHD differs between countries, and depends on the social and cultural context in which the child lives. A worldwide systematic review of the prevalence rate of ADHD showed that studies reporting the rates of ADHD diagnosis differ between continents and are influenced by differences in diagnostic criteria as well as cultural norms.[1] Therefore, it is important to consider the relationship between breastfeeding and diagnosed ADHD in the context in which it exists. The current literature on the relationship between breastfeeding and hyperactive behaviours and ADHD diagnosis uses data from all over the world, therefore examining this association in the Canadian context is warranted, especially due to the differences in breastfeeding culture and breastfeeding acceptance among different countries. A final limitation is that the majority of the studies in this literature review used cross-sectional analysis that rely on retrospective reports of breastfeeding duration and only looked at one child per family. These methods result in possible recall error of breastfeeding duration and inability to observe between-family effects of the home environment on breastfeeding initiation and duration.

The current study will contribute to the literature in several ways. Importantly, this is the first study to examine the relationship between infant feeding and child hyperactive behaviours in a Canadian sample. Breastfeeding duration is highly correlated with several societal factors such as length of maternity leave, social acceptance and amount of support with breastfeeding technique, which may differ in other countries. [76–80] Therefore, findings from other countries may not be generalizable to the Canadian population. This study is also the first to consider if the association between breastfeeding and academic performance is moderated by hyperactive/inattentive behaviours. Furthermore, this study is novel because it will consider the relationship between both parent-reported hyperactive/inattentive behaviours and physician-diagnosed ADHD, which could identify important differences in the risk factors associated with both pre-diagnosis and post-diagnosis ADHD symptoms. Only one previous study has looked at both measures of hyperactivity as well as physician-diagnosed ADHD in relation to infant feeding in the same sample.[20] The results from that study found that breastfeeding was related to decreased prevalence of ADHD, but had no association with the sub-threshold group. Additionally, the current study will determine if there is a dose response relationship between breastfeeding and child ADHD-related behaviours and diagnosis. This analysis is more robust and informative than considering breastfeeding as a dichotomous variable, which has been done in previous literature.[33,36,70,75]

3.2 External Variables that Impact Infant Feeding and Hyperactive Behaviours

There are several external variables identified in the literature that have a significant impact on breastfeeding initiation and duration and/or ADHD-related behaviours and diagnosis. There are large sex differences in the prevalence of ADHD; boys are three to nine times more likely to be diagnosed than girls.[81,82] Therefore, it is critical to account for child sex when considering this relationship. There is no evidence that breastfeeding occurs more frequently or for longer durations for boys than for girls. Mothers with advanced age are more likely to breastfeed their infants and are less likely to have children with ADHD diagnosis than their younger counterparts.[41,83] Maternal education level has been identified as the most prominent predicting factor for breastfeeding initiation and duration, whereby more educated women are more likely to breastfeed.[84–87] Furthermore, children who live in households with higher family income are more likely to be breastfed, as well as have decreased odds of exhibiting ADHD-related behaviours or be diagnosed with ADHD.[22,49,84,86,88,89] Pre-term birth and low birth weight have been linked to negative behavioural outcomes such as attention problems and ADHD diagnosis.[32,90–92] Additionally, pre-term babies are often tube fed at the beginning of life, which hinders mothers from initiating breastfeeding immediately after birth. Single parent status has also been shown to have an effect on breastfeeding initiation and duration and ADHD-related behaviours and diagnosis.[20,32,49,71,85,93] Some studies show that women are more likely to initiate and continue breastfeeding, including exclusive breastfeeding for six months, if they are supported by a partner.[49,85] Furthermore, a study on ADHD in boys indicated that childhood hyperactive/inattentive symptoms are more prevalent in single-parent households [71]; and in other studies, parental divorce was significantly associated with child ADHD diagnosis.[20,32] Evidence from the literature shows that frequent and heavy maternal alcohol consumption during pregnancy increases risk of ADHD diagnosis in offspring.[11,12] There is no specific evidence that mothers who drink alcohol are less likely to breastfeed, however, it could be suggested that mothers who engage in risky prenatal behaviour may have other challenges making it more difficult for them to provide their child optimum health and nutrition post-partum. Smoking during pregnancy has been linked to decreased likelihood of breastfeeding initiation and exclusive breastfeeding for six months.[49,85] Additionally, a large body of literature has found a positive association between maternal smoking during pregnancy and increased odds of ADHD diagnosis.[12–16,93–95] There is a wide range of literature that relates maternal depression to child behaviour problems such as hyperactivity and ADHD, as well as to decreased breastfeeding duration.[17,96–101] While parenting style is not likely to play a role in the etiology of developing ADHD, research shows that it can impact the severity of symptoms.[94,102] Parenting style plays a role in child behaviour regulation and cognitive functioning,[103] and positive parenting has been shown to positively affect behaviour outcomes.[104–106] All twelve of these aforementioned covariates will be accounted for in this study, however, this study cannot control for other important covariates such as: duration of exclusive breastfeeding, child exposure to environmental factors such as exposure to lead or head trauma, mother and child IQ score, and most notably, genetic heritability.

3.3 Mechanism of Action of Infant Feeding on Hyperactive Behaviours

There are two main pathways in which breastfeeding is proposed to have a protective effect on ADHD-related symptoms and diagnosis: (1) through the nutritional components of breast milk and (2) through increased maternal-child attachment. Breast milk contains nutritional components that can contribute to enhanced brain development and behaviour regulation. These include biologically active peptides and long-chain polyunsaturated fatty acids (LCPUFA) such as docosahexaenoic acid (DHA), arachidonic acid (AA) and eicosapentaenoic acid (EPA) that are not always present in formula.[107,108] Some formulas are fortified with LCPUFA, however they may not be as biologically available as the LCPUFA found in breast milk because they are synthetic versions.[107] Several studies have demonstrated the link between fatty acid consumption and cognitive, neurological and behavioural functioning.[107–121] A study of 53 children with high scores on Parent and Teacher Connors' Rating Scales measuring ADHD-related behaviour and 43 healthy controls found that the children with ADHD were more likely to have lower concentrations of key fatty acids in plasma and red blood cell samples.[110] Additionally, the control children had significantly longer breastfeeding duration compared to the children with ADHD. Second, a case control study randomly assigned 83 children age 8 to 13 years old who were diagnosed with ADHD into one of three dietary treatment groups: a LCPUFA group, a fish oil group and a placebo group.[119] After the three-month intervention period, sustained attention and impulsivity were assessed with the Test of Variables of Attention (TOVA). The children in the LCPUFA group and the fish oil group presented significantly higher TOVA scores than at baseline compared to controls who showed very little difference over time. Third, a review article of multiple studies relating poly-unsaturated fatty acid consumption to ADHD symptoms or behaviours concluded "Polyunsaturated fatty acids are of central importance for the development and functioning of the brain and nervous system, especially during childhood development".[111(p.159)] There is also emerging evidence that components of breast milk can contribute to the health of gut microbiome which can affect brain development, behaviour and cognition through the gut-brain axis.[122,123] Breast milk can naturally provide the nutrients required for proper growth and development, which may lead to improved behavioural and neurological functioning later in life.

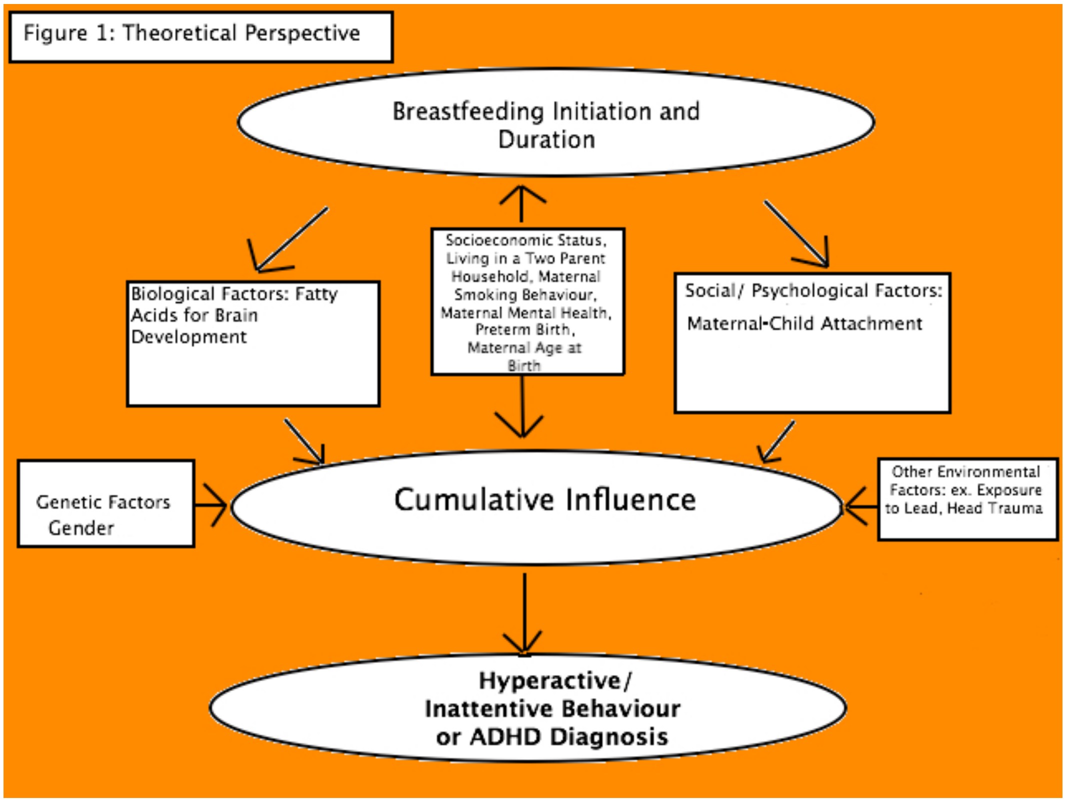
The second proposed protective mechanism is that breastfeeding can facilitate increased maternal-child attachment, which is associated with decreased externalizing disorders including hyperactivity in children.[124] While breastfeeding is neither necessary nor sufficient for strong maternal-child attachment, it is theorized that breastfeeding can facilitate this bond.[125,126] It is also suspected that the strength of the maternal-child attachment would differ between children who were fed breast milk at the breast compared to expressed milk through a bottle. This is due to the different feeding environment that these two groups would experience. Unfortunately, to date, the literature on breastfeeding and maternal-child attachment does not distinguish between different modes of feeding and only refers to a broad definition of breastfeeding that includes all modes of feeding breast milk.

Attachment theory suggests that early parent-child relationships serve as the basis for child self-regulation skills, which are disrupted in children with ADHD, and that infants who do not form secure attachments are at risk for affective and behavioural problems.[127,128] Attachment theory also suggests that infants develop attachments that complement their caregiver's behaviour and level of availability and responsiveness.[129] Breastfeeding mothers may be more responsive to their infants, touch their infants more often, have more skin-to-skin contact and spend more time in mutual gaze than bottle-feeding mothers.[125,130,131] These behaviours are associated with increased maternal oxytocin that is released during the milk letdown reflex. Oxytocin is known to reduce maternal anxiety and increase parasympathetic regulation resulting in decreased maternal stress and possibly improved mother-child interaction and bonding.[125,132] Infants also experience a calming, analgesic effect when breastfeeding and increased oxytocin release leading to reduced heart rate and reduced ability to perceive pain during feeding.[54,133] The skin-to-skin contact that is associated with breastfeeding is proposed to stabilize body temperature and respiration rates[134,135], decrease stress hormone release[136] and aid in self-regulation skills.[137] A study on 42 mother-infant dyads showed that women who chose to breastfeed past six weeks post partum showed more behaviours that suggest optimal maternal-infant attachment.[126] Developing secure maternal-child attachment is possible and likely for women who do not breastfeed, however, breastfeeding can be an important contributor to the facilitation of this bond. The act of breastfeeding may help to promote positive behavioural regulation and decrease childhood hyperactivity.

4.0 Theoretical Perspective

A modified version of the biosocial model of violence first proposed by Raine, Brennan, Farrington and Mednick (1997), and further adapted by Lui (2004) to model externalizing behaviours (including hyperactivity)[138] was used to examine the relationship between breastfeeding and ADHD-related behaviours and diagnosis.

Figure 1: Theoretical Perspective



This model depicts the two main mechanisms by which breastfeeding can have a protective effect on ADHD-related behaviours and diagnosis: a) biological protective factors and b) social protective factors.

Biological protective factors make up the left hand side of the model. These protective factors are the cellular-level components of breast milk that aid in brain development and behaviour regulation. Through this mechanism, brain development and behaviour can be altered by the concentration and type of fatty acids consumed by the infant through the breast milk.[107,108]

The right hand side of the model comprises the social protective factors that link breastfeeding to ADHD-related behaviours and diagnosis. The mechanism by which this occurs is the maternal-infant bond that can be facilitated through breastfeeding. A strong maternal-infant bond can positively impact the child's neurodevelopment and increase mother's mood, leading to improved child behavioural outcomes.[54,125–128] Both the biological factors and the social factors cumulatively influence ADHD-related behaviours or diagnosis.

Other social protective factors that influence mothers' who breastfeed and ADHD-related behaviours and diagnosis separately are shown in the middle of the figure with arrows pointing to both the breastfeeding circle and the cumulative influence circle. These include socioeconomic status (comprising maternal education and household income), living in a two-parent household, maternal smoking during pregnancy, maternal mental health, preterm birth and maternal age at birth. A review of initiation and duration of breastfeeding across Europe, Canada, Australia and the United States discovered that mothers who continue to breastfeed are older, better educated, married and have higher family incomes than women who do not breastfeed their children.[84] Additionally, there is evidence that mothers with advanced age are more likely to have children with ADHD.[139] A study from the United States showed that more children from lower SES backgrounds are diagnosed with ADHD than from higher SES backgrounds.[88] Living with a supportive partner or in a two-parent household is predictive of initiation and increased duration of breastfeeding [49,85] as well as decreased incidence of ADHD-related behaviours and diagnosis.[71] Smoking during pregnancy has been shown to negatively affect mothers' decision to breastfeed [49,85] as well as increase the incidence of ADHD-related behaviours and diagnosis in offspring. [12–16] Additionally, maternal mental health, and specifically maternal depression, has been shown to have significant negative impacts on breastfeeding duration [100,101] and child behaviour.[17,96–99,140] Children who are born premature are more likely to be diagnosed with ADHD and are also less likely to be breastfed because they are often separated from the mother directly after birth, making breastfeeding more complicated. [90–92]

Two other components are also included in the model that contribute to ADHD-related behaviours or diagnosis, but are independent of breastfeeding. ADHD is predominantly predicted through genetic factors; therefore it is important to acknowledge the large affect that genes have on diagnosis. Gender is also considered here due to the large gender differences in ADHD-related behaviours and diagnosis between boys and girls. Other environmental factors such as childhood exposure to lead and head trauma can also influence ADHD-related behaviours or diagnosis but are independent of breastfeeding initiation and duration.

This model shows the complex etiology of ADHD-related behaviours and diagnosis. This study will measure the relationship between breastfeeding and hyperactive/inattentive behaviours and ADHD diagnosis with the understanding that no single factor can cause or prevent these behaviours, but rather it results from the interaction between several factors. This model includes significant genetic and environmental contributors to ADHD-related behaviours and diagnosis and shows the etiological complexity of the disorder.

5.0 Research Questions

1. Is breastfeeding initiation and increased duration of breastfeeding associated with decreases in hyperactive/inattentive behaviours as measured by the Hyperactivity/Inattention (H/I) subscale after adjusting for child sex, maternal age at birth, socioeconomic status, maternal smoking and alcohol consumption during pregnancy, pre-term birth, low birth weight, maternal depression, parent living situation, positive parenting score and ineffective parenting score?

It is hypothesized that breastfeeding initiation and increased duration of breastfeeding will be associated with decreased hyperactive/inattentive behaviour as measured by the H/I subscale.

2. Is breastfeeding initiation and increased duration of breastfeeding associated with less ADHD diagnosis after adjusting for child sex, maternal age at birth, socioeconomic status, maternal smoking and alcohol consumption during pregnancy, pre-term birth, low birth weight, maternal depression, parent living situation, positive parenting score and ineffective parenting score?

It is hypothesized that breastfeeding initiation and increased duration of breastfeeding will be associated with less ADHD diagnosis.

3. Is breastfeeding initiation and increased duration of breastfeeding associated with increased academic performance among children who score high compared to children who score low on the H/I subscale after adjusting for child sex, maternal age at birth, socioeconomic status, maternal smoking and alcohol consumption during pregnancy, pre-term birth, low birth weight, maternal depression, positive parenting score and ineffective parenting score?

It is hypothesized that breastfeeding initiation and increased duration of breastfeeding will be associated with increased academic performance among both high and low H/I score groups, but will have a stronger effect for those in the high hyperactivity/inattention group.

6.0 Methods

6.1 Data

Data were drawn from the National Longitudinal Survey of Children and Youth (NLSCY) administered by Statistics Canada and housed at the Research Data Centre at the University of Manitoba. The NLSCY is unique because it provides opportunity to conduct both longitudinal and cross sectional data analysis. The survey consists of eight cycles that were administered every two years from 1994 to 2008. The purpose of the survey was to collect information about the factors influencing child health and development in cognitive, emotional and physical domains. Most children in the sample were selected from households included in the Statistics Canada Labour Force Survey (LFS), aside from some children age 0 to 1 years old introduced in cycle 3 and some 5 year olds introduced in cycles 3 and 4 who were drawn from Birth Registry data.[141] The LFS is a monthly survey that describes Canada's labour market landscape by focusing on prevalence of employment and unemployment. The Birth Registry data is a census database that includes all registered births in Canada for the previous year. Participants from all 10 provinces were included in the NLSCY; however, the sample excludes those living in the three Northern territories, on First Nations reserves, those who are full time members of the Canadian Armed Forces and inmates.[141]

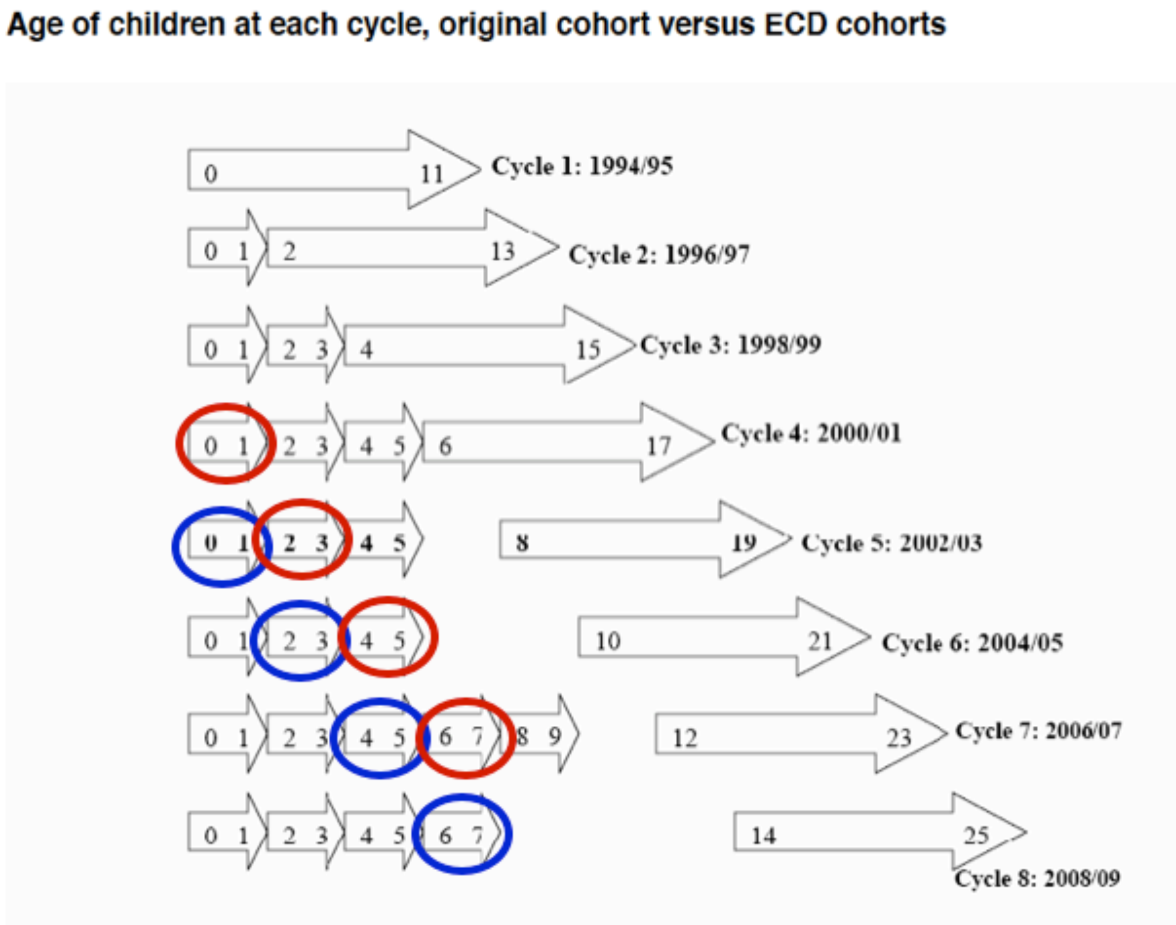
The sampling methods of the NLSCY changed periodically over the 14-year survey lifetime. The first cohort (cycle 1) comprised children age 0 to 11 years old who were followed longitudinally and re-surveyed every two years until the survey ended in 2008. In subsequent two-year intervals following the start of the survey in 1991, a new cohort of children age 0 to 1 years old was added to the survey population and followed until the age of 5, with the exception of cycle 7 and cycle 8, where the children were followed until the age of 9 and 7 years old respectively.[141] The decision to follow these children past 5 years of age was made so that these children could be followed through their transition into school. [142] The cohorts of children age 0 to 1 years old added in cycles 2 through 8 are called the early childhood development (EDC) cohorts and are essential for ensuring there is a representative cross-sectional sample of children from all age groups included in the survey in each cycle. The EDC cohorts are also useful for longitudinal analysis.

Data were collected using computer assisted interviewing (CAI) and paper questionnaires either in person or on the telephone. Information about the child was collected from the person most knowledgeable (PMK) in the household, which was usually the biological mother, but could be the father, a step-parent or a foster parent. For the purposes of this study, the PMK was restricted to only the biological mother to ensure the highest level of accuracy in reporting breastfeeding initiation and duration. The effective age- calculated by subtracting the year of birth from the first year of data collection cycle- was used to determine what questions are asked to the biological mother about the child and ensures the child stays in the cohort to which they were originally assigned, regardless of the time of year data collection occurs for subsequent cycles. For example, for children in cycle 4 who were born in 1998, their effective age would be 2000-1998 = 2. It is possible that a child's actual age- their true age regardless of the time of year data collection occurs- is up to 6 months different than their effective age.

6.2 Population of Interest

This research was conducted by combining two early childhood development (ECD) cohorts consisting of children ages 0 to 1 years old from cycle 4 (2000/1) and cycle 5 (2002/3) and followed these children until they were between the ages of 6 and 7 years old in cycles 7 (2006/7) and 8 (2008/9). This was the largest sample size attainable that would include children with data on all selected variables for the analysis. See sampling diagram from the NLSCY Cycle 8 User Guide.[141]

Figure 2: NLSCY Sampling Diagram



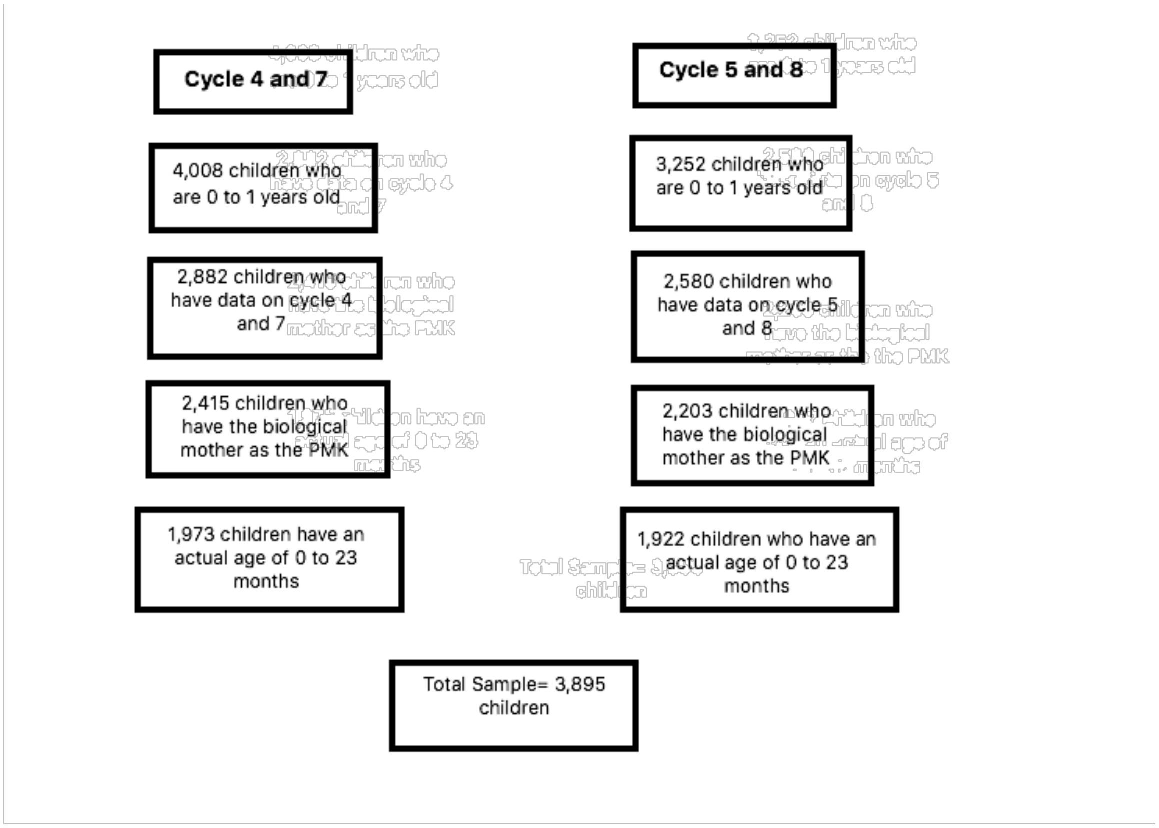
Note: Red circles indicate children in cycle 4 who were followed until cycle 7. Blue circles indicate children in cycle 5 who were followed until cycle 8.

For clarity purposes, herein, data collected in cycle 4 and 5 will be referred to as time one and data collected in cycle 7 and 8 as time two.

Exclusion criteria for this study were as follows: 1) children for whom the PMK was not the biological mother in time one, 2) children who had an actual age greater than 23 months old at time one, and 3) children who did not have data in both time points. These criteria were selected for the following reasons: 1) only children with a biological parent as the PMK were asked the pregnancy and birth questions, 2) biological mothers are the most accurate at reporting the feeding modality of the child, 3) while the pregnancy and birth questions were instructed to be asked of all children with an effective age of 0 to 23 months, a coding error in cycle 5 data resulted in only children with actual age of 0 to 23 months being administered this question; therefore, the sample was limited to children with an actual age of 0 to 23 months in cycle 4 as well, and 4) participation in the survey at both time one and time two was required so that the children could be followed over time.

The majority of children had their biological mother as the PMK; 15.5% of the sample was excluded who did not have the biological mother as the PMK. The survey methodology allowed the PMK to change from cycle to cycle, but the sample was not restricted to children with the biological mother as the PMK at time two because the questions administered at this time point were not as sensitive to the biological mothers' knowledge. Due to the coding error in cycle 5, 723 children from cycles 4 and 5 were excluded from the analysis who had an actual age greater than 23 months but an effective age between 0 and 23 months. The total sample size of the longitudinal cohort followed from cycle 4 to 7 was *n*= 2,882 and the response rate was 89.6%.[141] The total sample size of the longitudinal cohort followed from cycle 5 to 8 was *n*= 2,580 and the response rate was 80.5%. [141] After limiting the sample to only children who had the biological mother as the PMK, had an actual age of 0 to 23 months old, and had data for both time points, the total sample included 1,973 children who were 0 to 1 years old in cycle 4 and 6 to 7 years old in cycle 7, and 1,922 who were 0 to 1 years old in cycle 5 and 6 to 7 years old in cycle 8. This totaled a sample of 3,895 children. See Figure 3 for the sample selection diagram.

Figure 3: Sample Selection for the Current Study



6.3 Independent Variable (Predictor Variable)

The main independent variable in this study was infant feeding initiation and duration which was coded into three variables: one dichotomous and two categorical. The dichotomous variable was a yes/ no variable that measured breastfeeding initiation. The categorical variables consisted of progressively more specific infant feeding durations and aim to uncover possible dose-response associations between breastfeeding and hyperactivity scores and ADHD diagnosis. These variables were derived from three questions about infant feeding: first, the biological mother was asked if her child was ever breastfed; second, she was asked if her child was currently being breastfed; and third, she was asked about duration of breastfeeding if her child had been breastfed but was not currently being breastfed. These questions did not distinguish between exclusive and complementary breastfeeding, therefore intensity of breastfeeding could not be examined. To keep the maximum number of children in the analysis, children who were currently being breastfed were combined into the duration categories with those children who had previously been breastfed but had stopped. It is likely that the children who were currently being breastfed were breastfed for longer than the duration captured in this measurement. This limitation will bias the association between infant feeding and ADHD-related behaviours and diagnosis towards the null hypothesis (no relationship between breastfeeding initiation and duration and H/I scale score or ADHD diagnosis). However, combining currently and previously breastfed children keeps 694 children in the sample, who would otherwise be excluded if only children with full duration of breastfeeding were included in the analysis. Including these children is very important to ensure adequate sample size.

Duration of breastfeeding was measured in the survey in the following categories: less than a week, 1 to 4 weeks, 5 to 2 months, 3 to 6 months, 7 to 9 months, 10 to12 months, 13 to 16 months and more than 16 months. Based on previous literature, a "not established breastfeeding" group was created that combined children who were never breastfed with children who had been breastfed for 4 weeks or less or were currently being breastfed for 4 weeks or less.[59,65,76] See Figure 4 for the derivation of the not established and established breastfeeding groups. Breastfeeding initiation and two infant feeding duration variables were computed. First, a dichotomous variable was computed that consisted of children who did not have established breastfeeding and who did have established breastfeeding. Second, a three-level variable was computed that consisted of no established breastfeeding, breastfeeding for 2 to 12 months and breastfeeding for more than 12 months. Third, a six-level breastfeeding variable was created that consisted of no established breastfeeding, breastfeeding for 2 to 3 months, breastfeeding for 4 to

6 months, breastfeeding for 7 to 9 months, breastfeeding for 10 to 12 months and breastfeeding for more than 12 months. For the three-level variable, the cut off at 12 months was used to test the significance of the American Academy of Pediatrics recommendations that breastfeeding continue for up to 1 year for maximum mother and child benefits.[39] The six-level variable was used to see if there was a dose response relationship between breastfeeding duration and hyperactivity.

Figure 4: Derivation of the Not Established and Established Breastfeeding Groups

Not Established Breastfeeding (*n*=1,211)		Established Breastfeeding (*n*= 2,646)
No Breastfeeding	Breastfeeding for 1 to 4 weeks	Breastfeeding for 5 weeks to more than 12 months
n= 660	*n= 551*	*n*=2,646

Note: Total sample size for infant feeding is slightly smaller than the total sample size in this study due to missing data in the infant feeding variable

6.4 Dependent Variables (Outcome Variables)

There were three outcome variables in this study. The main outcome variable was the child's score on the H/I subscale. This scale is derived from seven behaviour-related questions asked to the PMK when the child is between 6 and 7 years old in time two. The H/I subscale score is used to indicate severe inattention and over-activity representing ADHD symptoms and and earlier version of the scale has been validated as a "highly specific indicator of clinically significant ADHD symptoms".[143(p.45)] This measure has been shown to have internal consistency with a Cronbach's alpha of 0.815 based on cycle 4 data.[144] The H/I subscale produces a score ranging from 0 to 14, with 14 indicating that the child struggled with all seven behaviour components and 0 indicating they did not struggle with any of the components. Each item on the scale is measured with the following response options: 0 = never true, 1= somewhat or sometimes true, 2= often or very true. In the current sample, the mean value on the H/I scale was 4.42 and the standard deviation was 3.12. See Figure 5 for a list of all seven items assessed on the H/I scale.

Figure 5: Items on the Hyperactivity/Inattention Subscale

Question:	Response Option:
Can't sit still or is restless	1) never or not true 2) somewhat or sometimes true 3) often or very true
Has trouble sticking to an activity	1) never or not true 2) somewhat or sometimes true 3) often or very true
Can't concentrate for a long time	1) never or not true 2) somewhat or sometimes true 3) often or very true
Is impulsive, acts without thinking	1) never or not true 2) somewhat or sometimes true 3) often or very true
Difficulty awaiting turns in games/ groups	1) never or not true 2) somewhat or sometimes true 3) often or very true
Is inattentive	1) never or not true 2) somewhat or sometimes true 3) often or very true
Cannot settle on anything for long	1) never or not true 2) somewhat or sometimes true 3) often or very true

There is no established clinically significant threshold to dichotomize the H/I subscale, however, previous literature has dichotomized this variable at 1.5 SD above the mean.[145,146] and at the top 10% of scores.[147–149] In the population used for this analysis, both dichotomization methods result in the same cut off point. The resulting high hyperactivity group consists of children who scored 9 to 14 on the H/I subscale and the average and low hyperactivity group consists of children who scored 0 to 8 on the H/I subscale. For simplicity, these two groups will be called high H/I and low H/I. To ensure complete exploration of the data, the H/I subscale was also examined as a continuous variable using linear regression. Other studies have also used the H/I scale continuously. [150,151] The H/I subscale has a positive skew, with a skewness statistic of 0.688 and a kurtosis statistic of 0.102. These statistics indicate a low level of skewness, however, to normalize the data, a log transformation was applied to this variable. This transformation did not aid in creating normality in the data distribution, therefore untransformed scores were used in the linear regression analysis.

The second outcome variable was ADHD diagnosis. The biological mother was asked "has a health professional diagnosed any of the following long-term conditions for the child" with one of the response options being attention deficit disorder (with or without hyperactivity). PMKs with children with an effective age of 3 to 9 years old in cycle 7 and 3 to 7 years old in cycle 8 were asked this question. This variable was coded into a dichotomous yes/no variable.

The third outcome was academic performance which consists of four different measures including reading, written work, mathematics and overall. The biological mother was asked "Based on your knowledge of his/her school work, including his report cards, how is this child doing in the following areas at school this year:" with response options very well, well, average, poorly, and very poorly. Each variable was dichotomized into a good performance group, consisting of the response options very well, well and average performance, and poor performance group consisting of the response options poor and very poor performance. Four dichotomous variables were created, one for each subject area and for overall.

6.5 Covariates (Independent Variables)

The NLSCY includes data on several variables describing Canada's children and youth that will be included as covariates. Twelve variables were identified from the existing literature to affect infant feeding, child hyperactivity/ inattention or both. All covariates were measured in time one when the child was between 0 and 1 years old.

Child sex was coded as male or female. Maternal age at the child's birth was measured in the following categories: 13-24 years old, 25 to 29 years old, 30 to 34 years old, 35 years old and up. Maternal education was measured as less than secondary, secondary school graduation, beyond high school, and college/ trade or university degree. The total reported household income was measured in the following categories: less than $10,000 to $14,999, $15,000 to $29,999, $20,000 to $29,999, $30,000 to $39,999, $40,000 and over. The highest income bracket assessed for single parents was $40,000 and over. To ensure consistency and accuracy of the classification of the single parent data into the correct income brackets, the household income for the double parent families had to be collapsed to $40,000 and over as well. Premature birth was measured using a dichotomous pre-existing derived variable that coded premature as being born at 258 days or less. Low birth weight was coded into a dichotomous variable of low birth weight (< 2,500g) and normal birth weight (2,500g or more). Children living with one parent were coded as having single parent status. Maternal alcohol consumption was coded into a dichotomous variable of any alcohol consumption during pregnancy or no alcohol consumption during pregnancy. Maternal smoking during pregnancy was also coded into a dichotomous variable of any smoking during pregnancy or no smoking during pregnancy. Maternal depression was coded from a pre-existing derived variable that measures the occurrence and severity of symptoms associated with depression during the previous week. It consists of 12 questions from the Centre for Epidemiologic Studies Depression (CES-D) rating scale, which was shortened from its original 20-item scale by Dr. M. Boyle of McMaster University.[144,152] See Figure 6 for a list of items on the depression scale. In the current sample, the score ranges from 0-34 because no respondents scored 35 or 36. The Cronbach's alpha calculated for all 36 items is 0.820 based on cycle 1 data and has not been calculated since this first cycle.[144,152] High scores indicate the presence of depression symptoms, however there are no clinically significant cut offs established for this scale in the adult population. For the purposes of this study, a dichotomous depression cut off was created that would be sure to include those who had the most severe depression symptoms indicating clinical depression, while also including those who experienced some elevated symptoms, but not necessarily enough to warrant clinical diagnosis. Data from the Canadian Community Health Survey-Mental Health 2012 shows that the prevalence of past 12-month depression is 7.9% among females age 15-44 years old.[153] A published thesis manuscript noted that correspondence with methodologist at Statistics Canada recommended dichotomizing the scale at the top 10% of scores to create a high and low depression group.[154] Based on this recommendation, and the prevalence of female depression in the population from Statistics Canada, this scale was dichotomized with the top 10% of scores indicating high depressive symptoms, and the remaining 90% indicating low depressive symptoms. It is important to note that the cut off used in this study was not meant to represent clinical depression, but rather the subset of the population who presents the most severe symptoms. There are two derived variable measures of parenting for children ages 0 to 23 months of age: 1) positive interaction (created from 5 questions with scores ranging from 0 to 5) and 2) ineffective parenting (created from 2 questions with scores ranging from 0 to 5). High scores indicate the presence of these parenting styles. See Figure 7 and 8 for a list of items on the parenting scales. The positive interaction parenting scale was dichotomized with the bottom 10% of scores indicating low positive interaction and the remaining 90% indicating high positive interaction. The ineffective parenting scale was dichotomized with the top 10% of scores indicating high ineffective parenting and the remaining 90% of scores indicating low ineffective parenting.

Figure 6: Items on the Depression Scale

Question:	Response Option:
I did not feel like eating; my appetite was poor	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I could not shake the blues even with help from my family or friends	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I had trouble keeping my mind on what I was doing	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I felt depressed	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I felt that everything I did was an effort	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I felt hopeful about the future	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
My sleep was restless	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I was happy	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days)

	4) most or all of the time (5-7 days)
I felt lonely	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I enjoyed life	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I had crying spells	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)
I felt that people disliked me	1) Rarely or none of the time (less than 1 day) 2) Some or a little of the time (1-2 days) 3) Occasionally or a moderate amount of time (3-4 days) 4) most or all of the time (5-7 days)

Figure 7: Items on the Positive Parenting Scale

Question: How often do you:	Response Option
Praise this child by saying “ good for you!” or “what a nice thing you did” or “that’s good going!”	1) Never 2) About once a week or less 3) A few times a week 4) 1-2 times a day 5) Many times a day
Talk or play with each other, focusing attention on each other for five minutes or more just for fun	1) Never 2) About once a week or less 3) A few times a week 4) 1-2 times a day 5) Many times a day
Laugh together	1) Never 2) About once a week or less 3) A few times a week 4) 1-2 times a day 5) Many times a day
Do something special with the child that they enjoy	1) Never 2) About once a week or less 3) A few times a week 4) 1-2 times a day 5) Many times a day

Play sports, hobbies or games with this child	1) Never 2) About once a week or less 3) A few times a week 4) 1-2 times a day 5) Many times a day

Figure 8: Items on the Ineffective Parenting Scale

Question: How often do you:	Response Option
Get annoyed with the child for saying or doing something he is not supposed to	1) Never 2) About once a week or less 3) A few times a week 4) 1-2 times a day 5) Many times a day
Tell the child that he is bad or not as good as others	1) Never 2) About once a week or less 3) A few times a week 4) 1-2 times a day 5) Many times a day

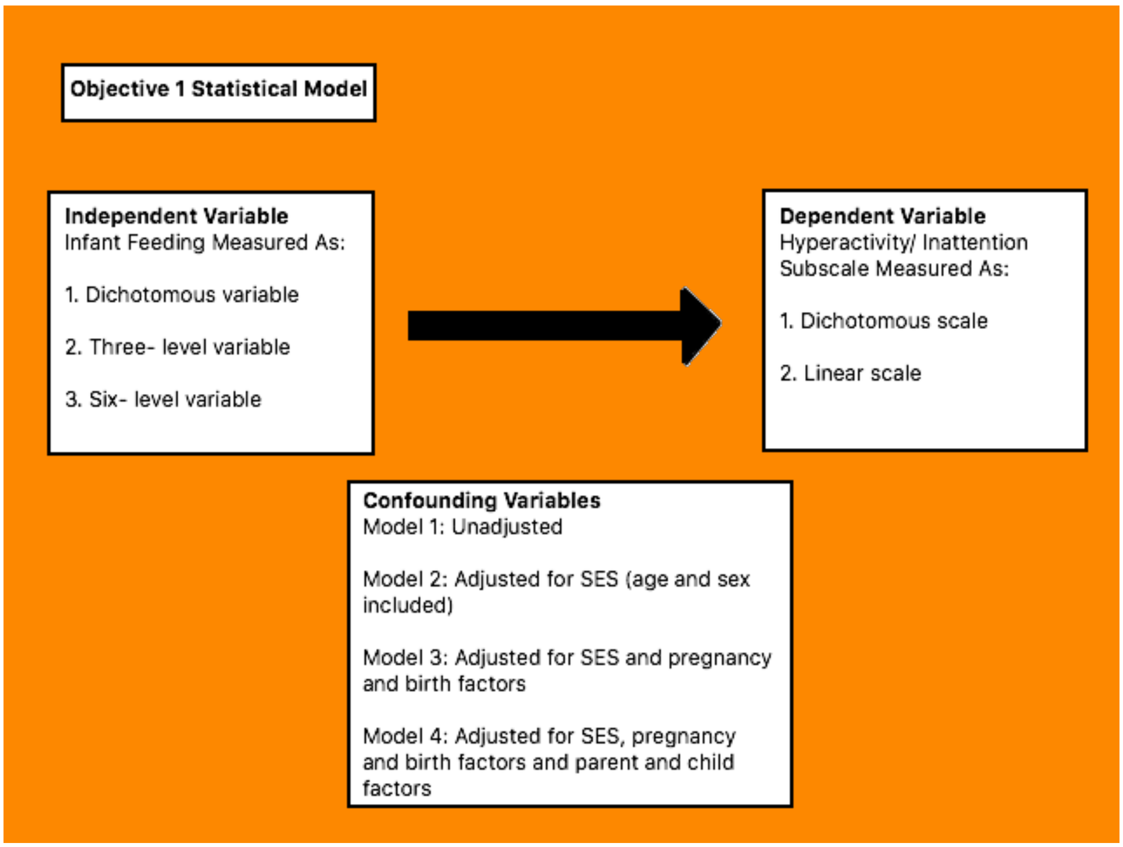
6.6 Statistical Analysis

Analyses were conducted in the Research Data Centre (RDC) on STATA and SPSS.[155,156] Data from cycles 4, 5, 7 and 8 were sorted by person unique identifier using SPSS and then variables from cycle 4 and 7 and cycle 5 and 8 were merged by person unique identifier. All variables were coded in these two individual merged datasets and then sorted by person unique identifier again. Data from cycle 4 and 7 and cycle 5 and 8 were merged by adding cases to create one dataset that had all four cycles combined, which created the final dataset used for this analysis.

First, frequencies were calculated for all variables to provide a description of the population. Second, cross tabs and unadjusted odds ratios were calculated with the dichotomized H/I subscale and all independent variables using logistic regression. This analysis shows the odds of having high hyperactivity for the different covariate categories compared to the reference group. Significance was determined at a p-value of < 0.05, and a 95% confidence interval. Third, the relationship between breastfeeding and the dichotomous H/I subscale was examined using the three different breastfeeding initiation and duration variables; 1) not established breastfeeding and established breastfeeding; 2) not established breastfeeding, breastfeeding for 5 weeks to 12 months and breastfeeding for more than 12 months; and 3) not established breastfeeding, breastfeeding for 2 to 3 months, breastfeeding for 4 to 6 months, breastfeeding for 7 to 9 months, breastfeeding for 10 to 12 months and breastfeeding for more than 12 months. Unadjusted odds ratios as well as adjusted models were computed as follows: 1) Model 1 included no covariates, 2) Model 2 included child sex, maternal age at birth, household income, biological mother education level (labeled as SES (age and sex included)) 3) Model 3 included child sex, maternal age at birth, household income, biological mother education level, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (labeled as SES and pregnancy and birth factors) and 4) Model 4 included child sex, maternal age at birth, household income, biological mother education level, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction and ineffective parenting scores (labeled as SES, pregnancy and birth factors and parent and child factors).

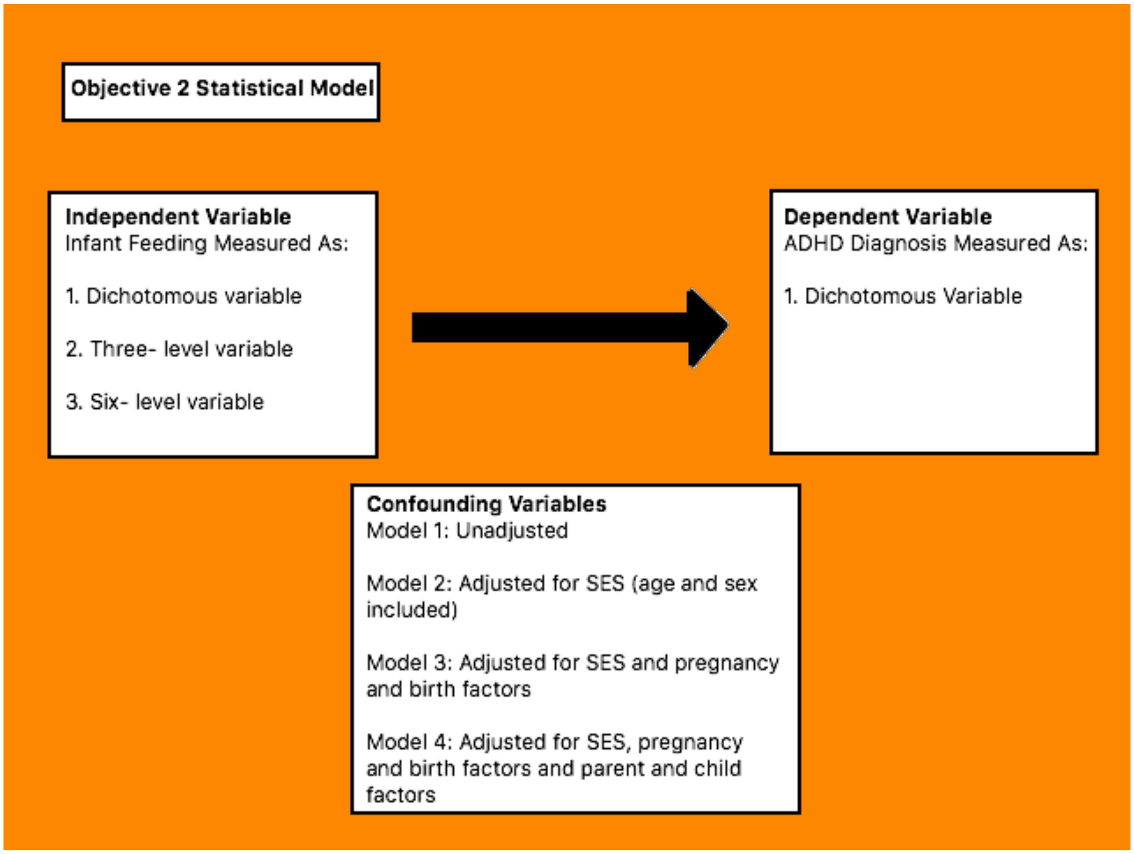
The H/I subscale was also examined as a continuous variable using linear regression. First, mean values of the H/I subscale were calculated for the categories of each variable in this study. Second, regression coefficients for each covariate on the continuous H/I subscale score were calculated using simple linear regression. Third, multiple linear regression was used to determine the relationship between the three breastfeeding initiation and duration variables and the H/I subscale score. Four regression models were calculated that replicate the order in which the covariates were entered in the four models outlined for the logistic regression analysis above. Significance was determined at a p-value of 0.05, and a 95% confidence interval. See Figure 9 for statistical model of objective one.

Figure 9: Statistical Model for Objective One



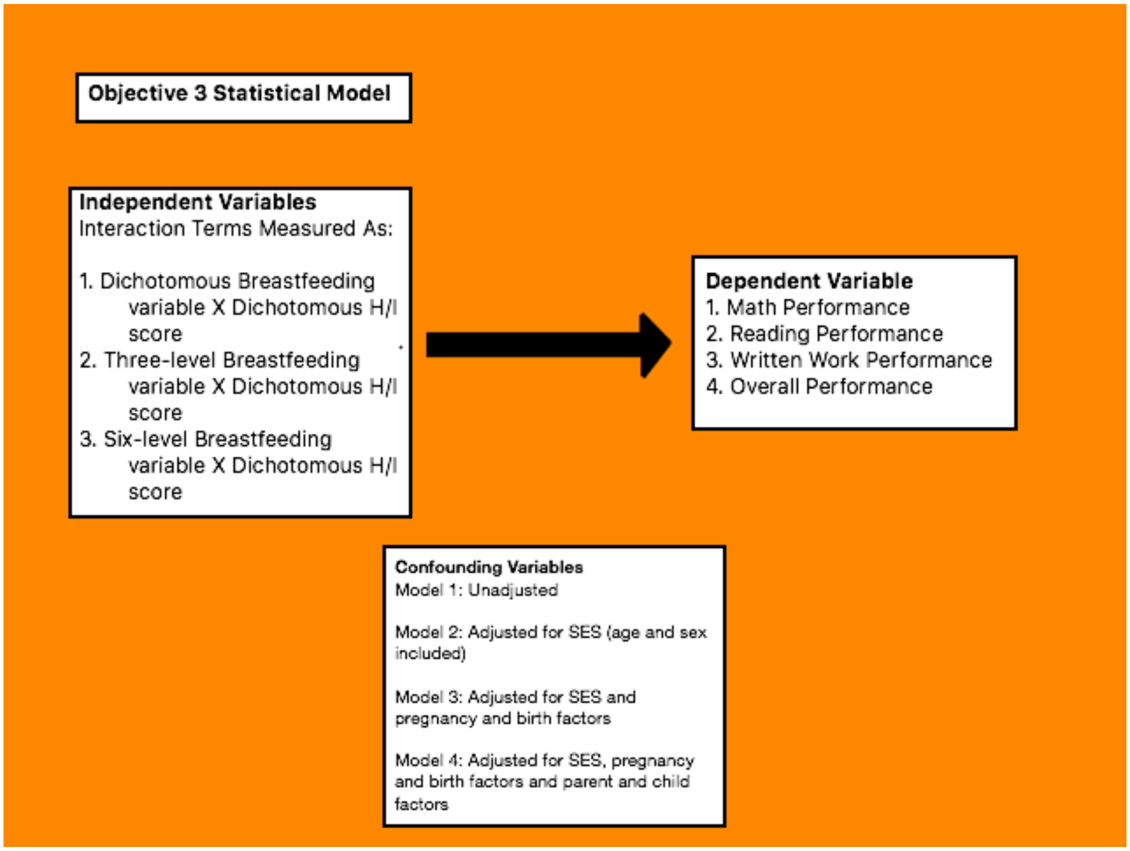
To address the objective number two, logistic regression was used to examine the relationship between infant feeding and child diagnosis of ADHD. Again, this relationship was assessed using all three breastfeeding initiation and duration variables and four logistic regression models: one unadjusted and then three adjusted nested models entering the covariates in the order listed above. Significance was determined at a p-value of < 0.05, and a 95% confidence interval. See Figure 10 for statistical model of objective two.

Figure 10: Statistical Model Objective Two



The third objective of this study was to examine the interaction effect between breastfeeding initiation and duration and the H/I subscale score on all four academic performance measures. Interaction terms using the dichotomous hyperactivity/inattention subscale variable and infant feeding were calculated for all three breastfeeding initiation and duration variables and entered as the independent variable into a model for each academic performance variable along with the main effects. Unadjusted models as well as all three adjusted models were calculated. Significance was determined at a p-value of < 0.05, and a 95% confidence interval. Additionally, logistic regression models between breastfeeding and all four academic performance variables stratified by high and low H/I score were calculated (data not shown). See Figure 11 for statistical model of objective three.

Figure 11: Statistical Model Objective Three



6.7 Weighting and Bootstrapping

The NLSCY is a probability survey. Each participant selected is representative of a much larger group of participants and applying weights to the survey data makes the sample representative of the Canadian general population. Longitudinal, non-funnel bootstrap weights were used on all cases in the sample. Non-funnel weights were assigned to children who were followed longitudinally and who responded in the most recent cycle, but not necessary in all the previous cycles. These weights were used because it is possible that some children who responded to time one and time two, did not respond in the cycles between time one and time two. These children would not be assigned funnel weights, therefore, non-funnel weights were used. Bootstrapping is a statistical technique that involves random sampling with replacement to create a more accurate parameter estimate for the population.[157] The NLSCY supplies 1,000 weights and all were used with the bootstrapping technique in this analysis.

6.8 Missing Data

Missing data were examined for all variables. No variable exceeded 2.2% missing data aside from maternal depression score, which had 6.0% missing data. Response options coded as don't know or refused were coded as missing and response options coded as not stated and valid skip were coded out of the total *n* for the variable to derive the percentage of missing data. Complete case analysis was used in the analysis that excluded children who did not have complete data for all variables in the models. See Figure 12 for percent missing on each variable.

Figure 12: Missing Data Table

Variable	Percent missing
Child Sex	0%
Child Age Time 1	0%
Child Age Time 2	0%
Maternal Age at Birth	0%
Maternal Education	2.0%
Household Income	0%
Parent Living Situation	0%
Preterm Birth	1.1%
Low Birth Weight	1.1%
Smoked During Pregnancy	1.9%
Alcohol During Pregnancy	1.9%
Maternal Depression Score	6.0%
Positive Parenting Score	2.2%
Hostile/ Ineffective Score	1.6%
H/I Scale	1.1%
ADHD Diagnosis	0.1%
Math	0.5%
Reading	0.3%
Written Work	0.9%
Overall	0.2%

Breastfeeding Yes/No	0.6%
Three-level Breastfeeding	0.6%
Six-level Breastfeeding	0.6%

6.9 Assumptions

6.9.1 Logistic Regression

Logistic regression is a statistical test that has fewer restrictions compared to many other parametric tests. Unlike multiple linear regression, there are no assumptions about the distribution of the independent variables included in the analysis. The dependent variable must be dichotomous so as to predict the presence/absence of an event. The text Using Multivariate Statistics by Tabachnick and Fidell [158] outlines some other important assumptions which are addressed below. All assumptions were tested using non-weighted data as these commands do not run with bootstrapping.

Independence: Independence occurs when no data point is linked to any other data point in the analysis. A violation of this assumption would be, for example, if two children from the same family were both interviewed and included in the dataset. Starting in cycle 2, a maximum of one child per household was sampled in the EDC cohorts, except for twins. However, in cycle 5, the rule changed to only include one child per household, including only one twin per household. The cycle 4 returning twins continued to be surveyed until cycle 7, when only one twin was chosen to be included in the sample.[159] The study inclusion criteria states that children must have data for both time one and time two, therefore, if twins from cycle 4 were included in the analysis and only one twin was be resurveyed in cycle 7, only the resurveyed twin would be included in the final analysis. There are no twins or siblings in this sample cohort, therefore, the assumption of independence is verified.

Ratio of Cases to Variables and Adequacy of Expected Frequencies and Power: It is important to ensure there are enough cases in the sample to produce reliable outcome estimates. Including too many variables and not enough cases in the analysis may result in zero cells or groups that are completely independent, which can misrepresent the true relationship between the predictor and the outcome. Tabachnick and Fidell (2001)[158] suggest examining cross tabs between all categorical variables to ensure that all expected frequencies are greater than one and no more than 20% are less than five. To verify this, cross tabs between all independent and dependent variables were examined. There were no zero cells and less than 20% had a count less than five; therefore, this assumption is verified with these data.

Multicollinearity: The presence of mutlicollinear predictors results in unstable parameter estimates and weakens the ability to determine which predictor is having an effect on the outcome.[160] To ensure multicollinearity does not exist, no two variables should have a correlation coefficient larger than 0.8. A value of 1.0 is indicative of complete correlation, meaning that for each value of x, the two variables have the same value for y. All variables were checked for collinearity, and it was predicted that low birth weight and preterm birth might be highly correlated above a value of 0.8. Spearman's correlation coefficient showed that these two variables were in fact the most highly correlated variables in the analysis, however the correlation coefficient was only 0.494. Additionally, the variation inflation factor (VIF) command was computed, which shows how much collinearity between two variables affects the variance of the coefficient (standard error).[160] The rule of thumb is that a VIF value larger than 10 poses a risk of calculating an inflated coefficient for that variable. The highest income category ($40,000 a year or more) had a variance inflation factor above 10; however, this was likely due to so many people being in this category and is highly correlated with another variable that is also common among households with an income of $40,000 a year or more. No other variables has a VIF value larger than 10. Based on these two tests, all variables were left in the analysis and it was decided that multicollinearity was not a significant problem with these data.

Linearity in the Logit: Logistic regression requires a linear relationship between continuous predictors and the logit transformation of the dependent variable.[158] There are no continuous predictors in the current study; therefore this limitation does not apply to this analysis.

Outliers: Extreme outliers can potentially distort the specificity of the estimate of the dependent variable on the independent variables.[158] Outliers can be identified as having a standardized residual value of greater than or less than 3.3. The standardized residual command was run following the regression of the linear H/I scale on breastfeeding and it was determined that a negligible amount were greater than or less than 3.3. Furthermore, a goodness of fit statistic using the ESTAT GOF function produced a non-significant p-value, resulting in failing to reject the null that the model has good fit. From these two tests it was concluded that there were no significant outliers.

6.9.2 Linear Regression

There are several assumptions in linear regression that must be verified to ensure valid and rigorous results. Tabachnick and Fidell (2001)[158] outlined the importance of verifying the following seven assumptions, all of which are addressed below:

Linear Relationship between the Independent Variables and the Dependent Variable: The dependent variable in this analysis is categorical, therefore, this assumption does not apply to these data.

Homoscasdicity: Homoscasdicity ensures that the distribution (variance) of the residuals around the dependent variable are equal for all predictors.[158] To verify this assumption, a scatter plot was used to examine the standardized residuals against the standardized predicted values of the linear H/I subscale and a fit line was applied. The fit line was straight, showing that the variance of the residuals was equal for all data points.

Normality of the Residuals: To gain the most accurate information about the relationship between the independent and dependent variables using linear regression, the residuals of the dependent variable should be normally distributed.[158] To determine the normality of the residuals of the H/I scale, both qnorm and kdensity commands were computed to graphically see the distribution of the dependent variable residuals. The qnorm command produces a quantile - quantile plot (Q-Q plot), which graphs the distribution of the residuals against a normal distribution.[161] This test produced a fairly straight line, but with curves on either end. The kdensity command produces a kernel density plot to show the distribution of the residuals. This plot showed that the residuals did not follow a normal distribution, but a distribution that was skewed to the left. Furthermore, the sktest (skewness test), swilk (Sharpiro-Wilk) and sfrancia (Sharpiro-Francia) tests were run and all produced p-values less than 0.001, which verifies rejecting the null hypothesis that the distribution is normal. The results of these tests, indicate that the distribution of the residuals for the H/I scale are not normally distributed. To address this, the variable was log (base 10) and natural log transformed and retested using the qnorm, kdensity, sktest and swilk commands. Results from these tests revealed that the log transformation did not aid in normalizing the data; therefore the untransformed version of the variable was used in the linear regression analysis. The skewness and kurtosis statistics of the H/I scale were calculated to be 0.688 and 0.102, respectively. A value of zero indicates a normal distribution and values larger than plus or minus two indicate significant deviation from the normal curve.[162] Although transforming the H/I scale did not aid in normalizing the residuals, the skewness and kurtosis statistics showed that the distribution of the values on the H/I scale did not deviate largely from the normal distribution. The inability to meet this assumption does not invalidate the use of the linear H/I scale, but rather slightly weaken the validity of the conclusions from the linear regression analysis.

Ratio of Cases to Independent Variables: As was stated above for logistic regression, it is important to have an adequate number of cases to variables, or an adequate sample size, to ensure reliable results. Tabachnick and Fidell (2001) provide a rule of thumb established by Green (1991) to predict the number of cases needed to test multiple regressions and individual correlations.[158] The equations are as follows: $N >= 50 + 8m$ (m= number of IVs) for testing regressions and $N >= 104 + m$ for testing individual correlations. Applying these equations to these data results in a minimum sample of N > = 50 +8 (13) = 154 for regression analysis and N >= 104 + 13=117 for individual correlations. Furthermore, Tabachnick and Fidell (2001) propose a 40:1 case to independent variable ratio to ensure adequate sample size for stepwise regression. This would result in a minimum sample of 520 cases. In all equations, the sample size used in this study is sufficient to produce reliable results.

Multicollinearity: Multicollinearity does not depend on the statistical tests chosen to relate the independent variable to the dependent variable. Therefore, the absence of multicollineary that was determined for the logistic regression analysis can also be used to conclude that there are no issues of multicollinearity for the linear regression analysis.

Independence: As was established in the logistic regression assumptions above, there are no twins or siblings in the dataset, therefore independence is verified for this sample.

Outliers: Similar to logistic regression, outliers can influence the results of the data by distorting the relationship between the dependent and independent variables. As outlined in the logistic regression assumptions, no significant outliers were found in this data.

6.10 Ethical Considerations

Ethical approval for this project was obtained through the University of Manitoba Research Ethics Board on February 5, 2015 (H2015:051). This project was also submitted and approved through the Social Sciences and Humanities Research Council (SSHRC) for access to the confidential data file of the NLSCY at the Research Data Centre (RDC). Statistics Canada upholds strict data confidentiality standards, such as supressing cells counts under five, and all analyses require vetting by the RDC data analyst. The current analysis did not result in any cell counts under five, however, an initial mistake in the data coding resulted in the misclassification of two participants, therefore, all weighted output was rounded to base five. Rounding did not change any of the results in this analysis.

7.0 Results

7.1 Sample Characteristics

Table 1 provides descriptive statistics of the sample for both the independent and dependent variables. The majority of the sample experienced established breastfeeding (70.8%). The most common duration of breastfeeding was 4 to 6 months, with 23.6% of the sample breastfed for this duration of time. The sample was evenly split between females and males. Slightly more children were between the ages of 0 to 11 months (57.4%) than between the ages of 12 to 23 months (42.6%). In almost a third of the sample, maternal age at birth was between 30 and 34 years of age (31.6%), with over 35 years old at birth being the smallest category (17.4%). Over half the sample had a college/trade or university degree (52.9%) and had a household income of $40,000 dollars per year or more (69.7%). A very small proportion of the sample was born preterm (11.4%), had low birth weight (6.1%), had maternal alcohol consumption during pregnancy (15.3%) or had maternal smoking during pregnancy (18.4%). Similarly, a small proportion of the sample was living with only one parent (9.4%), had a mother with a high depression score (10.7%), had low positive interaction parenting (11.9%) or had high ineffective parenting (6.6%). A larger proportion of the sample scored high on the H/I subscale

(10.5%) compared to the proportion of children who had a parent-reported ADHD diagnosis (2.3%). Scoring poor or very poor was rare in all academic performance categories, and was highest for written work with 6.5% of the sample scoring poor or very poor.

Table 2 shows the descriptive statistics and simple logistic regression for the H/I subscale with each covariate. Boys have significantly higher odds of having a high score on the H/I subscale compared to girls (OR=2.2; 95% CI= 1.6-3.0, $p < 0.001$). As maternal age at birth increases, the odds of the child scoring high on the H/I scale decreases (OR decreasing from 0.6; 95% CI 0.4-0.9, $p < 0.05$ to 0.4; 95% CI 0.3-0.7, $p < 0.001$). Mothers with a college, trade or university degree have a significantly decreased odds of having a child with a high H/I score (OR= 0.5; 95% CI= 0.3-0.8, $p < 0.01$). As household income increases, the odds of the child having a high H/I score decreases (OR decreasing from 0.7; 95% CI 0.3-1.8, to 0.4; 95% CI 0.2-0.7, $p < 0.01$). Neither birth weight nor preterm birth were significantly associated with child H/I score. Living in a single parent household resulted in significantly greater odds of the child having a high H/I score compared to living in a two parent household (OR=1.9; 95% CI 1.2-3.0, $p < 0.01$). Maternal alcohol consumption during pregnancy did not increase the odds of the child having a high H/I score, however, smoking during pregnancy resulted in significantly higher odds of the child having a high H/I score compared to no smoking during pregnancy (OR=2.2; 95% CI 1.6-3.0, $p < 0.001$). Children with mothers who had a high depression score had increased odds of having their child score high on the H/I scale (OR=2.3; 95% CI 1.6-3.3, $p < 0.001$). Children with mothers who had a low positive interaction score had greater odds of having a child with a high score on the H/I scale (OR=1.6; 95% CI 1.0-2.4, $p < 0.05$), while there was no significant association between ineffective parenting and child H/I score.

7.2 Logistic Regression Results of Infant Feeding on Hyperactivity/Inattention Score

Table 3 shows the prevalence and the logistic regression analysis between the dichotomous infant feeding variable (established breastfeeding verses no established breastfeeding) and dichotomous H/I scale score. Compared to children with established breastfeeding, children without established breastfeeding had a higher prevalence of scoring high on the H/I scale (13.3% vs. 9.1%). Only in the unadjusted model, children who had established breastfeeding, compared to children who did not have established breastfeeding, had a significant decrease in the odds of having high H/I score (OR= 0.7; 95% CI 0.5-0.9, $p < 0.01$). In the further adjusted models, the association between established breastfeeding and H/I scale score was no longer significant.

Table 4 shows the prevalence and the relationship between the three-level infant feeding variable and the dichotomous H/I score. Compared to children who were breastfed for more than 12 months, children who did not have established breastfeeding had a higher prevalence of scoring high on the H/I scale (13.3% vs 3.0%). In the unadjusted model, as well as in all adjusted models, children who were breastfed for more than 12 months, compared to children who did not have established breastfeeding, had significantly lower odds of having a high H/I score (OR ranging from 0.2; 95% CI 0.1-0.4, $p < 0.001$ to 0.4; 95% CI 0.2-0.8, $p < 0.01$). Only in the unadjusted model was breastfeeding for 5 weeks to 12 months associated with decreased odds of having a high H/I score (OR 0.7; 95% CI 0.5-0.99, $p < 0.05$).

Table 5 shows the prevalence and relationship between the six-level infant feeding variable and the dichotomous H/I score. Children in the 2 to 3 months of established breastfeeding group had the highest prevalence of having a high H/I score (16%), with the prevalence decreasing and remaining stable for the 4 to 6 month, 7 to 9 month and 10 to12 month groups at 9.3%, 8.3% and 9.2%, respectively. The prevalence of having high H/I score drops to 3.0% in the more than 12 months breastfeeding group. In the unadjusted models, established breastfeeding for 4 to 6 months and 7 to 9 months was significantly associated with decreased odds of having a high H/I score, however, breastfeeding for 2 to 3 months and 10 to 12 months was not significantly associated with decreased odds of high H/I score. None of the adjusted models with breastfeeding durations less than 12 months produced a significant association between infant feeding and child H/I score. Breastfeeding for more than 12 months was significantly associated with a decrease in child H/I score in all adjusted models.

7.3 Logistic Regression Results of Infant Feeding on ADHD Diagnosis

Tables 6 to 8 show the prevalence and relationship between the three infant feeding duration variables and ADHD diagnosis. All six levels of breastfeeding duration had more similar prevalence estimates of ADHD diagnosis than what was observed between the different breastfeeding duration categories and high H/I score (ADHD prevalence ranged between 1.8% and 3.2%). None of the models showed significant associations between breastfeeding and ADHD diagnosis. In Table 8, the six-level breastfeeding analysis, the unadjusted odds ratios range from 0.4 (95% CI 0.1-2.0) to 0.9 (95% CI 0.4-2.0), and in the most adjusted model, the odds ratios range from 0.6 (95% CI 0.1-2.7) to 1.2 (95% CI0.5-3.1). None of these odds ratios reached statistical significance.

7.4 Linear Regression Results of Infant Feeding on Hyperactivity/Inattention Score

In addition to logistic regression, the results of the H/I scale were also run using linear regression. Table 9 shows the mean value and the linear regression analysis of each independent variable on the continuous H/I scale score. Results from the linear regression analysis followed a similar trend as the logistic regression analysis. Compared to females, males have a H/I score that is 1.1 points higher (95% CI 0.8, 1.4; $p < 0.001$). As maternal age increases, H/I scale scores decreases, with a value of 0.5 (95% CI -0.9, -0.1, $p < 0.05$) points lower for 25-29 year olds compared to 13 to 24 year olds to 1.0 (95% CI -1.4, -0.5, $p < 0.001$) points lower for 35 year olds and up compared to 13 to 24 year olds. Mothers with a college/trade or university degree were significantly more likely to have a child with a lower H/I scale score compared to mothers with less than secondary education ($\beta = -1.0$; 95% CI -1.5, -0.5, $p < 0.001$). Children living with a household income of $30,000 to $39,000 and $40,000 or more were more likely to have a lower H/I scale score with β values of 1.0 points (95% CI -1.8, -0.1, $p < 0.05$) and 1.2 points (95% CI -2.0, -0.5, $p < 0.01$) lower compared to children living with a household income of less than $10,000 to $14,999. Both preterm birth and low birth weight were not significant predictors of H/I scale score. Children of mothers who consumed alcohol during their pregnancy had an average H/I score of 0.6 points higher (95% CI 0.1, 1.0, $p < 0.01$) compared to mothers who did not consume alcohol during pregnancy. Children of mothers who smoked during pregnancy had an average H/I score of 1.0 points higher (95% CI 0.6, 1.4, $p < 0.001$) compared to mothers who did not smoke during pregnancy. Living in a one parent household resulted in a significant increase in the H/I scale score by 0.9 points (95% CI 0.3, 1.4, $p < 0.01$). High maternal depression score resulted in an increased H/I scale score of 1.2 points (95% CI 0.7, 1.7, $p < 0.001$). Having a low positive interaction score and a high ineffective parenting score resulted in increases in the H/I scale score by 0.6 points (95% CI 0.1, 1.1, $p < 0.05$) and 0.7 points (95% CI 0.2, 1.3, $p < 0.05$), respectively.

Tables 10 to 12 show the linear regression analysis between the three different infant feeding variables and the continuous H/I scale score. Table 10 shows the results of the dichotomous infant feeding variable. In model one, which does not include any covariates, established breastfeeding is associated with a 0.5 point decrease in the H/I scale score (95% CI -0.9, -0.2, $p < 0.001$). The remainder of the adjusted analyses produced non-significant results. Table 11 shows the regression results of the three-level infant feeding variable and the continuous H/I scale score. Established breastfeeding for 2 to 12 months compared to no established breastfeeding is associated with a 0.4 point decrease (95% CI -0.8, -0.1, $p < 0.01$) in H/I scale score only in model one, which does not adjust for any covariates. Established breastfeeding for more than 12 months was associated with a decreased H/I scale score in all four adjusted models (β=-1.1; 95% CI -1.6, -0.7, $p < 0.001$ for model one and β=-0.6; 95% CI -1.0, -0.1; $p < 0.01$ for model four). Table 12 shows the regression analysis between the six-level infant feeding variable and the continuous H/I scale score. Children who had established breastfeeding for 4 to 6 months had a decreased H/I scale score of 0.6 points (95% CI -1.0, -0.2, $p < 0.01$) lower in model one and 0.4 points (95% CI -0.8, -0.02, $p < 0.05$) lower in model two. Children who had established breastfeeding for 7 to 9 months and 10 to 12 months had a decreased H/I scale score of 0.5 points (95% CI -1.0, -0.1, $p < 0.05$) lower and 0.5 points (95% CI -1.0, -0.02, $p < 0.05$) lower in model one, respectively. Established breastfeeding for more than 12 months was associated with a decreased H/I scale score in all four adjusted models (β=-1.1; 95% CI -1.6, -0.7, $p < 0.001$ for model one and β=-0.6; 95% CI -1.2, -0.1; $p < 0.05$ for model four). These linear regression results mirror the results found from the logistic regression analysis.

7.5 Interaction Term Results of Infant Feeding and Hyperactivity/Inattention Score on Academic Performance

All interaction terms calculated to address objective three were found to be non significant. Unadjusted interaction term results are presented in Table 13. Logistic regression models between the dichotomous breastfeeding variable and all four academic performance variables stratified by high and low H/I score were also found to all be not significant. Ad hoc main effects analysis was conducted to examine the relationship between the dichotomous breastfeeding variable and each measure of academic performance. Breastfeeding for 5 weeks or more was found to be marginally significantly related to a higher odds of having a high math score (OR 1.7; 95% CI 1.0-2.9, p=0.48), but was not related to any other measure of academic performance. After adjusting for covariates, this significant relationship between established breastfeeding and higher math score became non significant (data not shown).

8.0 Discussion

This is the first study to examine the relationship between infant feeding, hyperactivity/inattention score, ADHD diagnosis and academic performance among children using a nationally representative Canadian sample. The main findings from this study are as follows: 1) breastfeeding for more than 12 months was associated with a decreased odds of having a high H/I score, even after adjusting for sociodemographic variables, pregnancy and birth factors as well as parent and child factors; 2) breastfeeding initiation or duration was not associated with decreased odds of having physician-diagnosed ADHD; 3) there was no interaction effect of breastfeeding initiation or duration and H/I score on any measure of academic performance.

8.1 Discussion of Descriptive Results of Infant Feeding on Hyperactivity/Inattention Score

The descriptive results of the current study are overall congruent with the current literature, aside from a few exceptions. In line with the current knowledge base, this study found that boys have an increased odds of having high H/I scores compared to girls.[81,82] Furthermore, as maternal age at birth, maternal education and household income increased, the odds of having a high H/I score decreased. Living with one parent, smoking during pregnancy, a high maternal depression score as well as a low positive interaction parenting score were associated with an increased odds of having a high H/I score. These results are all comparable to results found in the existing literature.[17,22,83,93,106] The evidence surrounding some perinatal risk factors for ADHD diagnosis is contradictory. In the current study, and in one other publication[94], both preterm birth and low birth weight as well as maternal alcohol consumption during pregnancy had no effect on high H/I scores. However, other literature has shown significant associations between these variables and hyperactive behaviours and/or ADHD diagnosis.[11,12,83,90,91] Differing findings on the relationship between these variables and H/I score could be due to different ways of measuring the variables or different study methodologies. For example, the current study combines drinking one time during pregnancy and every day into the same category. The relatively benign effect of drinking one time during pregnancy may be washing out the negative effects of drinking every day because there is likely a much higher proportion of mothers who drink one time during pregnancy compared to every day. One study showed that heavy maternal drinking during pregnancy is associated with ADHD diagnosis in offspring and defined heavy alcohol consumption as drinking daily or going on binges. [12] Additionally, preterm birth has been associated with increased hyperactivity or ADHD diagnosis in some samples[83,90,91], but was not found to have a significant association in this study. This could be due to difference in the definition of preterm birth. The current study defined preterm birth as before 37 weeks, while another study that found a significant association with ADHD considered preterm as birth before 32 weeks. [83]

When the descriptive analyses were conducted using a linear version of the H/I scale, identical results were found for all covariates except for maternal alcohol consumption during pregnancy and ineffective parenting score. In the linear regression analysis, these covariates became significantly associated with increased odds of high H/I scores, while the logistic regression analyses showed no relationship. It is possible that using the linear H/I scale produces a more sensitive analysis because it considers each incremental change in the H/I scale instead of dichotomizing it to a low and high score. Overall the descriptive statistics of the study sample are similar to what has been found in previous literature.

8.2 Main Finding #1: Breastfeeding for More than Twelve Months was Significantly Associated with a Decreased Odds of Having a High Hyperactivity/Inattention Score

Breastfeeding for more than 12 months is the only feeding duration that has a significant association with decreased H/I score, even after adjusting for all covariates. The odds ratio and beta coefficients vary only slightly between the unadjusted and most adjusted models, showing that the addition of these covariates do not account for a large proportion of the variance beyond breastfeeding. These results point to a threshold of more than 12 months of breastfeeding having a significant association with decreased H/I score.

The most recent descriptive measure of breastfeeding duration rates in Canada is from the Canadian Community Health Survey collected in 2011 and 2012. Reports from this survey measure breastfeeding initiation and exclusive breastfeeding up to 6 months post partum (89% of mothers initiated breastfeeding and 26% breastfed exclusively for the first 6 months), but do not report the prevalence of complementary breastfeeding beyond 6 months.[41] The Maternity Experiences Survey collected by Statistics Canada in 2005 and 2006 surveyed 8,542 women and found that at 6 months 54% of mothers were still providing their infants some breast milk (complementary breastfeeding).[163] Data on complementary breast feeding rates beyond 6 months post partum were not reported, however it is assumed that the rate is much lower than this. In the current study, 9.6% of mothers reported breastfeeding past 12 months.

It is possible that the lack of research and data on breastfeeding beyond one year is due to the fact that this population is very small and that the benefits of long term breastfeeding are not well understood or are not well substantiated by the current knowledge base. Additionally, it may be the case that the most significant benefits incurred through long term breastfeeding are constructs that are more difficult to quantify, such as quality of the maternal-child bond, therefore these results may not be as definitive or persuasive as some of the clear immune system benefits that are incurred to the child from even shorter durations of breastfeeding.[164] Focusing on the benefits of long-term breastfeeding is not a current research priority and data on this population is lacking. However, the current study suggests that there could be important benefits of breastfeeding on hyperactive/inattentive behaviour only after 12 months of breastfeeding.

The theoretical basis for the relationship between breastfeeding and H/I score proposes that there are two main pathways by which breastfeeding can effect hyperactive/inattentive behaviours. The first is through the biological components of breast milk that can effect brain development and behavioural regulation and the second is through the maternal-child attachment that can be facilitated by breast feeding and result in improved behavioural self-regulation. The main nutritional components that have been found to reduce hyperactivity or symptoms of

ADHD are polyunsaturated fatty acids such as docosahexaenoic acid (DHA), arachidonic acid (AA) and eicosapentaenoic acid (EPA).[109–112,114,115,118,119] Adequate quantities of these fatty acids for proper development are found in breast milk, and can also be found in infant formula, however, they are synthetic versions which may not be utilized as easily in the infant body.[107] A meta-analysis of 10 randomized control trials (RCT) considering the relationship between fatty acid consumption and ADHD-related behaviours and diagnosis did not include any studies that looked at the effect of fatty acid consumption for durations longer than four months on improved behavioural outcomes.[165] There is no evidence from these RCTs to show that fatty acids only effect behaviour after 12 months of supplementation. It is important to note that none of these randomized control trials compared breastfed to formula fed infants in relation to their fatty acid levels and subsequent behavioural outcomes due to ethical implications. These trials only looked at external fatty acid supplementation when the child was already weaned off breastfeeding, if they were breastfed.

In the current study, the dietary fatty acid content of the children who were not breastfed as well as the fatty acid content of supplementary foods that were given to children who were breastfed for more than 12 months is unknown. Also, the fatty acid composition of the breast milk for the children who were breast fed is unknown. While some infant formulas do contain fatty acids, the inclusion of docosahexaenoic acid (DHA) and arachidonic acid (AA) in infant formula is not regulated in Canada.[166] Both omega 3 and omega 6 are required to be in all formulas, and these essential fatty acids can be converted into DHA and AA given the correct biological conditions.[166,167] However, infants' ability to convert omega 3 and 6 into DHA and AA is still under question and may not be efficient enough to receive the full benefits from these components.[107] In the current study, infants in the non-established breastfeeding group may or may not have received formula that contains DHA and AA and there is a wide margin of variation for the level of consumption of fatty acids among the non-established breast feeders. Given the lack of a dose-response relationship between increased duration of breastfeeding and decreased H/I score and the reduced dose of breast milk that the child would be receiving when they are more than 12 months old, it is not likely that the nutritional components of breast milk are significantly contributing to a decreased H/I score only after 12 months of breastfeeding. This study is unable to determine through what mechanism breastfeeding may effect behaviour, however, it is more likely that the mechanism of action that is influencing the relationship between more than 12 months of breastfeeding and H/I score is the maternal-child attachment that is facilitated through breastfeeding and other maternal characteristics that accompany breastfeeding mothers.

A special bond is created between the mother and child through the act of breastfeeding. Breastfeeding can facilitate positive maternal-child attachment[126], which can serve as the basis for child self-regulation skills.[127,128] These self-regulation skills are often disrupted in children with ADHD. While maternal-child attachment is not exclusive to breastfeeding, the act of breastfeeding can stimulate hormonal, physiological and emotional responses in the mother and the infant that can enhance this mutual bond. It is known that positive maternal- child attachment contributes to healthy infant development [124], however, few studies look specifically at this bond with mothers who breastfed for more than 12 months. A qualitative study involving 82 mothers in the United States who breastfed for more than 12 months showed that the most common reason for long-term breastfeeding was the desire to continue to experience the special mother-infant time that occurs while breastfeeding.[168] Another qualitative study looking at the perceptions of the positive consequences of breastfeeding beyond 12 months interviewed 141 mothers from the United States and Canada to determine their reasons for long term breastfeeding. Almost one third of the mothers reported that "positive emotional effects on the child" was one of the positive consequences of breastfeeding beyond 12 months. Other benefits included "close relationship between mother and child" and "nursing comforts and sooths the child".[169] It is important to note, however, that the these studies did not specify the mode in which breastfeeding beyond 12 months occurs. It is not known if breastfeeding occurred at the breast or if breast milk was expressed and then fed through a bottle. Regardless, these qualitative results show that mothers who breastfeed for longer durations believe that this practice improves the maternal-child bond, which would have developed differently had they not breastfed for as long. It is possible that the mothers in this study who engaged in long-term breastfeeding developed stronger bonds with their children, which helped to improve the child's behavioural and self regulation skills, in turn possibly contributing to lower child scores on the H/I scale.

There are also several maternal characteristics associated with mothers who breastfeed that might influence the expression of child hyperactive behaviours aside from the effect breastfeeding alone. One study considered the relationship between level of maternal sensitivity and breastfeeding duration and found that mothers who score higher on the Sensitivity to Cues subscale of the Nursing Child Assessment Satellite Training Feeding Scale are more likely to breastfeed for longer durations than mothers with low sensitivity scores.[129] The authors suggest maternal sensitivity may be a maternal characteristic that predicts breastfeeding duration[129] and that breastfeeding mothers may also provide a more nurturing and enriching home environment which may contribute to improved executive functioning and cognitive and brain development.[55–59] Maternal sensitivity may be particularly important for this study because the H/I scale is a parent-reported measure of child behaviour. It is possible that mothers who are more sensitive and attentive to their child's needs and more involved in their development will be less likely to report their child's behaviours as problematic. It is also possible that mothers who breastfeed for more than 12 months do not work full time, or at all, and therefore have more time to commit to the relationship with their child, which could be especially important if their child has more challenging behaviour. While these maternal characteristics are not exclusive to mothers who engage in long-term breastfeeding, they are more common among those who breastfeed their children for longer durations.

Historically, the typical duration of breastfeeding was much longer than it exists today, with a mean weaning age between two and five years old.[170] Ancient Greek and Roman societies claimed that breastfeeding should continue until the onset of menses or until the child's complete set of teeth have grown in, between 2 and 3 years of age.[171] After the widespread introduction and promotion of artificial formula in early 1900s, the initiation and duration of breastfeeding decreased significantly.[172] In the 1970s breastfeed began its resurgence and today is seen as the optimal nutrition source for infant development, although formula feeding is still prevalent. [172] Today in Canada, 89% of mothers initiate breastfeeding in hospital[41], however, a much smaller proportion of mothers continue to breastfeed beyond one year. Looking back to historical populations, it is clear that durations of breastfeeding past one year were beneficial to the child.

There are several possible reasons for why, historically, breastfeeding continued for longer durations than commonly practiced today. Breastmilk may have been the only reliable infant food source due to poor sanitation, and may have provided the infant with irreplaceable immune system benefits that ensured health and vitality. It is also possible that ancient societies recognized the importance of the mother-child bond and skin-to-skin contact that is facilitated through breastfeeding. In today's Western society, the physiological benefits of long-term breastfeeding may not be as necessary for infant health and development, however, the possible social and emotional benefits of long-term breastfeeding are still very relevant and can potentially have long-term effects on child behaviour.

The early age of weaning that is "acceptable" or "normal" in today's society is shorter than what is historically supported, and some may argue it is fueled by the long history of pressure imposed by formula companies to forgo breastfeeding entirely or introduce supplementary foods early on.[172] In the most recent Canadian Community Health Survey, the most common reason for stopping breastfeeding before six months post partum was "not enough breast milk".[41] While sufficient milk production may be a valid medical concern for some mothers, it is suggested that this belief is widely overstated and possibly fueled by consumer advertising that mothers can not trust their bodies to fully and properly support the health and development of their children. [173,174] Furthermore, insufficient or improper lactation counselling may result in latching difficulties for the child and subsequent weight loss because the child is not able to access adequate quantities of milk that the mother produces. [175] Additionally, long term breastfeeding has been subjected to impractical societal expectations about the appropriate relationship between the mother and child and the appropriate setting for feeding at the breast. Largely in Western culture, long term breastfeeding, especially long term breastfeeding in public, is not socially supported and receives significant negative attention. A survey of mothers recruited from La Leche League conferences across the United States found that 44% of women stated that social stigma was a negative aspect of breastfeeding past 12 months.[80] Furthermore, maternal employment may largely impact the duration of breastfeeding whereby mothers who return to work one year post partum stop breastfeeding because it is no longer feasible with their daily schedule. Although Western society has reached significant improvements in increasing initiation of breastfeeding, for a variety of reasons as stated above, mothers in our current society still breastfeed for significantly shorter durations than our ancestors, which could deny children the potential benefits of long-term breastfeeding.

In the present study, the prevalence rate of high H/I score was almost four times that of ADHD diagnosis. In another sample that considered the association between breastfeeding and full syndrome ADHD as well as sub-threshold ADHD (similar to those scoring high on the H/I scale in this study), the prevalence of sub-threshold ADHD was approximately double the prevalence of full syndrome.[20] Although the dichotomization of the H/I scale cold be argued to result in too lenient a measure of hyperactive/inattentative behaviour, results from the linear regression analysis, where the H/I score was analyzed as a continuous measure, confirmed the finding that breastfeeding for more than 12 months was associated with decreased H/I scale score. In fact, in the linear unadjusted models, all breastfeeding durations, aside from 2 to 3 months, were significantly related to decreased H/I score, while in the dichotomized, unadjusted models, breastfeeding for 2 to 3 months and 10 to 12 months were not significantly related to decreased H/I score. This is likely due to the fact that the linear model is more sensitive to small changes in the H/I score, and that the dichotomous model simply does not have enough power to detect significant differences in the 10 to 12 month duration category. However, this analysis shows that regardless of the way the H/I scale score is analyzed, longer duration of breastfeeding is still associated with H/I score.

8.3 Main Finding #2: Breastfeeding had No Association with ADHD Diagnosis

The results from this study show that initiation or duration of breastfeeding was not associated with a change in physician-diagnosed, parent-reported ADHD. This finding is not consistent with the first main finding that breastfeeding beyond 12 months is associated with lower H/I scale scores. There are several reasons as to why this might be the case.

First, it is possible that not all children who present symptoms of hyperactive/inattentive behaviours are officially diagnosed with ADHD at age six and seven years old. It is estimated that the prevalence of ADHD in North America is 6% of the child and youth population[1], a higher prevalence than what is seen in this study. This is likely because the current sample only included children age six and seven years old. Many children are diagnosed with ADHD when they begin school because the diagnostic criteria for ADHD states that impairment must be present in at least two settings[7] and poor academic performance is a hallmark symptom of ADHD.[176] At age six, the children in this sample may only be in kindergarten, possibly only for a half day, and therefore, not be old enough for a physician to confidently diagnose the child with ADHD. It is possible that if this sample was followed up until the ages of 10 to 12 years old, more ADHD diagnoses would be present. As a result, if it is true that ADHD is underreported due to the sample being too young to accurately diagnose ADHD, there would be some children who would eventually be diagnosed with ADHD in the 'no ADHD' group, diluting the dichotomy of this group. The H/I scale is a more sensitive measure of behaviours that might point towards ADHD diagnosis but might not be severe enough at age 6 or 7 to warrant diagnosis. It is also possible that the current sample is underpowered and the lack of a significant relationship is the manifestation of a type two error, whereby a relationship exists, but we can not statistically detect it because of low sample power.

Another possible explanation for the differing results between the H/I scale score and ADHD diagnosis results is that the H/I scale is parent-reported while ADHD diagnosis is parent-reported but physician-diagnosed. The H/I scale relies fully on parent perception of the child's behaviour, which may be subjective depending on the parent's tolerance level of adverse behaviours, stress levels and situational factors. The seven behaviour questions on the H/I scale ask about different child behaviours that are "not true" "somewhat or sometimes true" or "often or very true". These thresholds could be interpreted differently for different parents and result in less systematic conclusions about child behaviour compared to more stringent diagnostic criteria that is upheld when officially diagnosing ADHD.

Overall, this study does not support the hypothesis that breastfeeding decreases the odds of being diagnosed with ADHD. It is likely that the age group that was included in this sample was too young to capture the true prevalence rate of ADHD diagnosis in the population and therefore, these results understate the relationship between breastfeeding and ADHD diagnosis.

8.4 Main Finding #3: No Interaction Effect of Breastfeeding Initiation and Hyperactivity/Inattention Score on Any Measure of Academic Performance

The hypothesis that breastfeeding initiation or duration and H/I score have an interaction effect with academic performance was not supported by this data. This interaction effect has not been considered previously in the literature, however, the main effect of breastfeeding initiation or duration and academic performance has been studied widely. The majority of the current evidence shows that breastfeeding improves cognitive outcomes which often result in improved academic performance.[49,50,60,68,69] One randomized control trial in Belarus including over 17,000 newborns randomized 31 maternity hospitals to either receive a hospital breastfeeding promotion campaign called the Baby Friendly Hospital Initiative, or to continue with regular hospital practices.[68] The Baby Friendly Hospital Initiative significantly increased duration of exclusive and complementary breastfeeding in the intervention group. At age 6.5 years, the children whose mothers were in the intervention group had higher intelligence and teacher academic rating scores than the ones who were in the control group. This is the closest to a true randomized control trial that is ethically feasible in the area of infant feeding and provides more rigorous results compared to the more common observational analyses. Additionally, two separate meta-analyses have been conducted on the relationship between breastfeeding and cognitive development and intelligence, and both conclude that there is a direct relationship between increased duration of breastfeeding and improved child cognitive development and intelligence.[52,60] Alternatively, two studies that used sibling analysis to account for within family effects found no difference between breastfed and non breastfed siblings on measures of academic achievement and intelligence.[61,63] The sibling methodology used in these two studies is highly rigorous because it can account for within family effects that might otherwise be contributing to the positive effects of breastfeeding on child outcomes. Therefore, although the majority of the evidence points towards a positive association between breastfeeding and academic performance, it is important to acknowledge the studies that have found no relationship and support the null relationship found in this study.

It is possible that the measures of academic performance used in this study were not specific or detailed enough to see real improvements among those who were breastfed. The academic performance domains included math, written work, reading and overall performance using a parent-reported, five-point categorical scale with the response options, very well, well, average, poor or very poorly. Other studies that have found a relationship between breastfeeding and academic performance have looked at standardized measures of cognitive ability such as the intelligence quotient, the Peabody Picture Vocabulary test and teacher reported academic performance[49,73,177], which might be more accurate than parent reported scales of academic performance. It is also possible that this analyses is under powered, and has a high probability of a type two error. Scoring poorly on the academic performance variables is a rare result and a larger sample size with a larger number of subjects in the poor academic performance groups might reveal different results.

This study found no interaction effect of H/I score on the relationship between breastfeeding initiation and academic performance. The main effects and the interaction term should be considered in a larger sample with more statistical power.

8.5 Strengths

This study has numerous strengths and can address several limitations that exist in the current literature. First, a cross-sectional sample has been used for the majority of studies examining the relationship between infant feeding and ADHD-related behaviours and diagnosis.[20,31–36,70,71,75] This results in the possibility of breastfeeding duration recall error, as these studies asked retrospectively about the length of time the child was breastfed. The current study uses a prospective, longitudinal design and measures breastfeeding when the child is 0 to 23 months of age, limiting the risk of recall bias, as this is within the time period that most mothers breastfeed. Previous research has shown that maternal recall of breastfeeding in the first three years of the infants life is the optimal time to obtain accurate breastfeeding duration data.[178] Second, the current study includes twelve covariates identified from the literature that may affect the relationship between breastfeeding and ADHD-related behaviours or diagnosis. Much of the current literature on this topic does not control for many important covariates, resulting in less rigorous analysis. In this study, the relationship between breastfeeding and ADHD-related behaviours and diagnosis can be isolated to a greater degree than some of the studies that did not control for any or few external covariates. Additionally, this study considered infant feeding using one initiation variable and two duration variables using six different categories of duration; therefore, we can be confident that the relationship between complementary breastfeeding initiation and duration and H/I score and ADHD diagnosis is more fully explored than analyses looking only at breastfeeding initiation. Finally, this study is the first to examine the relationships between breastfeeding and ADHD-related symptoms or diagnosis using a representative Canadian sample.

8.6 Limitations

This study has some important limitations that need to be considered when interpreting the findings. First, the NLSCY did not measure exclusive or complementary breastfeeding nor the mode of breastfeeding; therefore, we do not know the quantity of breast milk or amount of time at the breast that each child experienced. There is literature to suggest that mothers who breastfeed for longer durations also exclusively breastfeed for longer[168], so it is likely that the children who were breastfed for more than 12 months in this study also had longer durations of exclusive breastfeeding compared to their counterparts who were not breastfed for more than 12 months. It is also possible that outcomes might be different for children who were fed breast milk at the breast compared to expressed breast milk through a bottle. Second, the parent-report nature of the H/I scale, the ADHD diagnosis variable and the academic performance measures result in possible reporting bias. Third, this study is unable to measure other external factors that may contribute to ADHD-related behaviours and diagnosis such as familial history of ADHD, maternal and child IQ, and environmental factors such as exposure to lead and head trauma. ADHD is highly genetic, with up to 80% of ADHD diagnosis occurring in children with a family history of ADHD[8,9], therefore this may account for a portion of the variance between breastfeeding and H/I score and ADHD diagnosis. Fourth, because there is only one child from each household is in this study, household fixed effects can not be fully accounted for. The differences in household environment may affect child behaviour and responses to the parent-reported scales. Fifth, the duration of breastfeeding will be underestimated for some children who are currently being breastfed at the time of the interview because breastfeeding duration is only assessed one time for each child. Sixth, the data is over a decade old, however, it is important to note that this study is looking at the relationship between breastfeeding and ADHD-related behaviours and diagnosis, and not at time sensitive trends that may be more subject to change. Due to the nature of the research questions, these data can still be used to produce relevant information on the relationship between breastfeeding and ADHD-related behaviours and diagnosis. Seventh, the outcome variables of ADHD diagnosis and poor academic performance are rare events, therefore, it is possible that the analyses using these variables are underpowered. An underpowered analysis can result in a type two error whereby no significant relationship is detected, when one actually exists. A larger sample size with more children who experience the outcome of interest would be able to more accurately address these research questions. It is also important to point out the possibility that ADHD precludes breastfeeding. It is possible that the reason the mother is unable to breastfeed is because of her child's hyperactive behaviours. In this way, "a shorter duration of breastfeeding in the ADHD group might be the result, rather than the cause, of ADHD". [32 (p4)] This limitation could be addressed by determining why the mother stopped breastfeeding (e.g. child was restless/ did not want to nurse for a long time).

8.7 Future Research

There are several important avenues for future research that deserve exploration. First, both infant feeding and hyperactive/inattentive behaviours are highly influenced by social, familial and cultural effects, which are difficult constructs to measure and control for in analysis. Using methods such as sibling analysis, whereby two siblings from the same household who were fed discordantly are both followed up over time, within family effects can be accounted for. A recent study by Colen and Ramey[63] utilized this design and found no meaningful differences between siblings who were breastfed and those who were not on a range of behavioural, physical health and academic performance outcomes. Another sibling study found similar results for the outcome of child intelligence[61], and a third found that many indicators of physical and emotional health were the same between discordantly fed siblings except for cognitive ability which was significantly different.[179]

Second, measuring duration of exclusive and complementary breastfeeding is important to determine the dose of breast milk and duration of time at the breast that the child experienced. In the current study, a child who is breastfed one time per day at age 6 months is grouped into the same category as the child that is breastfed exclusively at 6 months of age. These two children may have very different outcomes, but these differences would not be detected because they are grouped into the same feeding duration categories. A previous study considered the duration of complementary and exclusive breastfeeding in an ADHD diagnosed group and a non-ADHD group and found significant differences when looking at exclusive breastfeeding as the predictor variable, but found differences that were no longer significant when combining both exclusive and complementary breastfeeding together.[34] This type of washout effect could also be present in the current study as the children who were exclusively breastfed could not be separated out from those that were complementary breastfed. It is advised that further surveys always ask about duration of exclusive and complementary feeding as different duration and exclusivity categories may have different associations with child outcomes.

Third, measuring mode of infant feeding (i.e. child fed breast milk at the breast or breast milk through a bottle) is an important distinction to measure in future studies. Making this distinction could help to isolate the mechanism by which breastfeeding may effect child behaviour. For example, by examining the differences in H/I score between children who are fed breast milk at the breast compared to children who are fed breast milk through a bottle, it is possible to gain insight into if the breast milk itself is contributing to decreased H/I score, or if it is the physical time at the breast and the mother-child bond that is associated with breastfeeding at the breast, that is contributing to decreased H/I score. To date, no studies have considered the mode of feeding breast milk when examining the relationship between infant feeding and child behavioural outcomes.

Fourth, this study supports the potential benefits of long-term breastfeeding, however, little research has been done in this area. More research should be dedicated to considering the benefits of breastfeeding for more than one year on maternal and child outcomes.

9.0 Conclusion

This study uses a large, nationally-representative sample to examine the association between infant feeding and hyperactive-inattentive behaviours and ADHD diagnosis in children age 6 and 7 years old. Furthermore, this study examines the association between breastfeeding and academic performance for those who have high and low H/I scale scores. The results show that breastfeeding for more than twelve months is associated with a decreased odds of having high H/I scores, but no significant relationship exists between infant feeding and ADHD diagnosis or academic performance for children who score high or low on the H/I scale score. The literature on the relationship between breastfeeding and ADHD-related behaviour or diagnosis has produced mixed results, and this study is no exception. It is possible that the models including ADHD and academic performance variables are underpowered and may show significant results if a larger sample size was used for the analysis.

The H/I scale has been shown to be a clinically significant indicator of ADHD diagnosis, and may indicate children at risk for subsequent diagnosis.[143] It is possible that children who are showing hyperactive/inattentive behaviours at age 6 and 7 years old but are not diagnosed with ADHD will go on to be diagnosed at an older age. The current study may be particularly useful for families of children who have a genetic predisposition to ADHD or are exposed to other environmental risk factors and therefore are at higher risk of diagnosis. Mothers who plan to breastfeed before they give birth have a higher likelihood of continuing to breastfeed[79]; therefore, if mothers of children with a family history of ADHD are aware of the association between breastfeeding and hyperactive/inattentive behaviours, they may be more likely to plan, initiate and continue breastfeeding. This could result in a reduction in hyperactive/inattentive behaviours and possible subsequent ADHD diagnosis.

Breastfeeding beyond 12 months is not common in Canada and this study warrants further investigation into the demographic characteristics of mothers who do breastfeed for more than on year, why many mothers stop breastfeeding before one year, and how barriers can be reduced or eliminated so that more mothers can continue with this practice. There is also little research on the prevalence of breastfeeding for longer than 12 months in Canada and the subsequent maternal and child effects of this practice. This study points to the fact that there might be a special relationship between breastfeeding beyond 12 months and child hyperactive/inattentive behaviour and that more attention should be given to the potential benefits of long term breastfeeding.

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Table 1: Descriptive Statistics of the National Longitudinal Survey of Children and Youth (weighted *n*= 901,060)

Cycle 4 and 5 Variables	% (weighted *n*)
Infant Feeding	
No established breastfeeding (no breastfeeding or less than 5 weeks of breastfeeding)	29.2% (259,885)
Established breastfeeding (breastfeeding for more than 5 weeks)	70.8% (630,470)
Duration of Breastfeeding	
No Established breastfeeding	29.2% (259,885)
2-3 months of breastfeeding	9.0% (80,525)
4 to 6 months of breastfeeding	23.6% (210,210)
7 to 9 months of breastfeeding	16.8% (149,725)
10 to 12 months of breastfeeding	11.8% (104,780)
More than 12 months of breastfeeding	9.6% (85,230)
Child Sex	
Female	49.6% (446,950)
Male	50.4% (454,110)
Child Age in Cycle 4 and 5 (age at baseline)	
0-11 months	57.4% (517,580)
12 months to 23 months	42.6% (383,475)
Maternal Age at Birth	
13-24	20.2% (181,825)
25-29	30.8% (277,665)
30-34	31.6% (285,120)
35 and up	17.4% (156,450)

Maternal Education Level*	
Less than secondary	12.3% (106,900)
Secondary school graduation	14.4% (125,585)
Beyond high school	20.4% (177,925)
College/ trade or university degree	52.9% (460,105)
Household Income	
Less than $10,000 to $14,999	3.8% (34,000)
$15,000 to $19,999	4.0% (35,765)
$20,000 to $29,999	10.0% (89,195)
$30,000 to $39,000	12.7% (114,330)
$40,000 or more	69.7% (627,770)
Preterm Birth	
Not preterm (after 37 weeks)	88.6% (786,340)
Preterm (before 37 weeks)	11.4% (100,860)
Low Birth Weight	
Not low birth weight (more than 2,500g)	93.9% (832,830)
Low birth weight (2,500 g or less)	6.1% (53,670)
Maternal Alcohol Consumption During Pregnancy	
Never	84.7% (730,630)
Less than once a month to every day	15.3% (132,250)
Maternal Smoking During Pregnancy	
No	81.6% (704,510)
Yes	18.4% (158,370)
Parent Living Situation	
Two parent	90.6% (816,355)

One parent	9.4% (84,705)
Maternal Depression [a]	
Low score	89.3% (732,625)
High score	10.7% (88,030)
Parenting Scores	
Positive Interaction [b]	
High score	88.1% (775,135)
Low score	11.9% (104,795)
Ineffective Parenting [a]	
Low score	93.4% (825,895)
High score	6.6% (58,780)
Cycle 7 and 8 Variables	
Hyperactive/inattentive Behaviour [c]	
Low	89.5% (794,120)
High	10.5% (92,735)
ADHD Diagnosis	
No	97.7% (879,005)
Yes	2.3% (20,840)
Academic Performance	
Math	
Poor/ very poor	3.1% (25,990)
Average/ well / very well	96.9% (813,070)
Reading	
Poor/ very poor	5.6% (47,320)

Average / well/ very well	94.4% (798,295)
Written Work	
Poor/ very poor	6.5% (49,485)
Average / well/ very well	93.5% (710,585)
Overall Performance	
Poor/ very poor	2.1% (18,325)
Average / well/ very well	97.9% (836,615)

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the variable with the highest *n*. Complete case analysis results in slightly different *n* for each variable.

* In cycle 5, an "other" option was included to the education variable. A small proportion of respondents selected this option. These respondents were coded out of the analysis.

[a] High score is top 10%

[b] Low score is bottom 10%

[c] High score is 1.5SD above the mean

Table 2: Descriptive Statistics and Logistic Regression for the Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth (weighted *n*= 886, 850)

Independent Variables	Dependent Variable		
	Low Child Hyperactivity/Inattention Score % (weighted *n*)	High Child Hyperactivity/Inattention Score % (weighted *n*)	Odds Ratio (95% CI)
Child Sex			
Female	93.1% (410,700)	6.9% (30,630)	1.0
Male	86.1% (383,415)	13.9% (62,105)	2.2 (1.6-3.0)***
Child Age			
0 to11 months old	89.0% (454,225)	11.0% (55,935)	1.0
12 to 23 months old	90.2% (339,895)	9.7% (36,795)	0.9 (0.7-1.1)

Maternal Age at Birth			
13-24	84.2% (150,125)	15.8% (28,165)	1.0
25-29	89.8% (246,450)	10.2% (28,020)	0.6 (0.4-0.9)*
30-34	91.1% (256,960)	8.9% (24,975)	0.5 (0.3- 0.8) **
35 and up	92.4% (140,585)	7.6% (11,570)	0.4 (0.3-0.7)***
Maternal Education Level			
Less than secondary	84.0% (87,825)	16.0% (16,765)	1.0
Secondary school graduation	88.4% (108,360)	11.6% (14,230)	0.7 (0.4-1.2)
Beyond high school	87.4% (151,865)	12.6% (21,955)	0.8 (0.5-1.3)
College/ trade or university degree	91.8% (417,765)	8.2% (37,540)	0.5 (0.3-0.8)**
Household Income			
Less than $10,000 to $14,999	79.5% (26,435)	20.5% (6,830)	1.0
$15,000 to $19,999	84.7% (29,435)	15.3% (5,325)	0.7 (0.3-1.8)
$20,000 to $29,999	87.5% (76,640)	12.5% (10,925)	0.6 (0.3-1.2)
$30,000 to $39,000	89.0 (99,460)	11.0% (12,300)	0.5 (0.2-0.95)*
$40,000 or more	90.7% (562,155)	9.2% (57,355)	0.4 (0.2-0.7)**
Preterm Birth			
After 37 weeks	90.1% (697,740)	9.9% (77,025)	1.0
Before 37 weeks	86.0% (85,095)	14.0% (13,860)	1.5 (0.9-2.4)
Low Birth Weight			
More than 2,500g	89.7% (736,280)	10.3% (84,820)	1.0
2,500 g or less	88.9% (46,180)	11.1% (5,740)	1.1 (0.6-2.1)

Parent Living Situation			
Two parents	90.2% (726,005)	9.8% (78,550)	1.0
One parent	82.8% (68,115)	17.2% (14,185)	1.9 (1.2-3.0)**
Maternal Alcohol Consumption During Pregnancy			
Never	90.2% (649,235)	9.8% (70,310)	1.0
Less than once a month to every day	87.3% (113,645)	12.7% (16,550)	1.3 (0.9-2.0)
Maternal Smoking During Pregnancy			
No	91.3% (633,640)	8.7% (60,360)	1.0
Yes	83.0% (129,240)	17.0% (26,500)	2.2 (1.6-3.0)***
Maternal Depression [a]			
Low score	90.7% (655,155)	9.3% (67,300)	1.0
High score	80.8% (69,495)	19.2% (16,515)	2.3 (1.6-3.3)***
Parenting Scores			
Positive Interaction [b]			
High score	90.1% (688,210)	9.9% (75,795)	1.0
Low score	85.4% (87,795)	14.6% (15,000)	1.6 (1.0-2.4)*
Ineffective Parenting [a]			
Low score	89.8% (729,855)	10.2% (82,790)	1.0
High score	85.6% (49,870)	14.4% (8,385)	1.5 (0.9-2.4)

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the crosstab with the highest *n*. Complete case analysis results in slightly different *n* for each crosstab.

[a] High score is top 10%

[b] Low score is bottom 10%

Table 3: Relationship between Dichotomous Infant Feeding and Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth (weighted *n*= 876, 280)

Independent Variable	Dependent Variable					
	Low Hyperactive/ Inattentive Behaviours	High Hyperactive/ Inattentive Behaviours	Unadjusted OR	AOR 1 (95% CI)	AOR 2 (95% CI)	AOR 3 (95% CI)
No established breastfeeding % (weighted *n*)	86.7% (223,420)	13.3% (34,130)	1.0	1.0	1.0	1.0
Established breastfeeding for 5 weeks or more % (weighted *n*)	90.9% (562,495)	9.1% (56,235)	0.7 (0.5-0.9)**	0.8 (0.6-1.0)	0.8 (0.6-1.2)	0.9 (0.7-1.3)

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the crosstab with the highest *n*. Complete case analysis results in slightly different *n* for each crosstab.
AOR1: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
AOR2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
AOR3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 4: Relationship between Three-Level Infant Feeding and Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth (weighted *n*= 876, 280)

Independent Variable	Dependent Variable					
	Low Hyperactive/ Inattentive Behaviours	High Hyperactive/ Inattentive Behaviours	Unadjusted OR	AOR 1 (95% CI)	AOR 2 (95% CI)	AOR 3 (95% CI)
No established breastfeeding % (weighted *n*)	86.7% (223,420)	13.3% (34,130)	1.0	1.0	1.0	1.0

Five weeks to 12 months of breastfeeding % (weighted *n*)	90.0% (482,740)	10.0% (53,785)	0.7 (0.5-0.99)*	0.8 (0.6-1.1)	0.9 (0.6-1.3)	1.0 (0.7-1.4)
More than 12 months of breastfeeding % (weighted *n*)	97.0% (79,755)	3.0% (2,455)	0.2 (0.1, 0.4)***	0.3 (0.1-0.5)***	0.3 (0.1-0.6)**	0.4 (0.2-0.8)**

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the crosstab with the highest *n*. Complete case analysis results in slightly different *n* for each crosstab.
AOR1: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
AOR2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
AOR3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 5: Relationship between Six-Level Infant Feeding and Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth (weighted *n*= 876, 280)

Independent Variable	Dependent Variable					
	Low Hyperactive/inattentive Behaviours	High Hyperactive/inattentive Behaviours	Unadjusted OR	AOR1 (95% CI)	AOR2 (95% CI)	AOR3 (95% CI)
No established breastfeeding % (weighted *n*)	86.7% (223,420)	13.3% (34,130)	1.0	1.0	1.0	1.0
2-3 months breastfeeding % (weighted *n*)	83.6% (66,955)	16.3% (13,085)	1.3 (0.8- 2.0)	1.3 (0.8-2.1)	1.4 (0.8- 2.3)	1.4 (0.8-2.4)
4-6 months breastfeeding % (weighted *n*)	90.7% (187,440)	9.3% (19,110)	0.7 (0.5-0.98)*	0.8 (0.5-1.1)	0.9 (0.6- 1.3)	0.9 (0.6-1.4)

7-9 months breastfeeding % (weighted *n*)	91.7% (134,875)	8.3% (12,150)	0.6 (0.4-0.9)*	0.7 (0.4- 1.2)	0.7 (0.4-1.2)	0.9 (0.5-1.4)
10-12 months breastfeeding % (weighted *n*)	90.8% (93,470)	9.2 (9,440)	0.7 (0.4- 1.1)	0.8 (0.4-1.3)	0.9 (0.5-1.5)	1.0 (0.6-1.8)
More than 12 months breastfeeding % (weighted *n*)	97.0% (79,755)	3.0% (2,455)	0.2 (0.1-0.4)***	0.3 (0.1-0.5)***	0.3 (0.1-0.6)***	0.3 (0.2-0.8)**

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the crosstab with the highest *n*. Complete case analysis results in slightly different *n* for each crosstab.
AOR1: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
AOR2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
AOR3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 6: Relationship between Dichotomous Infant Feeding and ADHD Diagnosis of the National Longitudinal Survey of Children and Youth (weighted *n*= 889, 270)

Independent Variable	Dependent Variable					
	No ADHD Diagnoses	ADHD Diagnosis	Unadjusted OR	AOR 1 (95% CI)	AOR 2 (95% CI)	AOR 3 (95% CI)
No established breastfeeding % (weighted *n*)	96.8% (251,405)	3.2% (8,375)	1.0	1.0	1.0	1.0
Established breastfeeding (5 weeks or more) % (weighted *n*)	98.1% (617,395)	1.9% (12,095)	0.6 (0.3-1.1)	0.7 (0.4-1.2)	0.7 (0.4-1.3)	0.8 (0.4-1.5)

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the crosstab with the highest *n*. Complete case analysis results in slightly different *n* for each crosstab.

AOR1: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
AOR2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
AOR3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 7: Relationship between Three-Level Infant Feeding and ADHD Diagnosis of the National Longitudinal Survey of Children and Youth (weighted *n*= 889, 270)

Independent Variable	Dependent Variable		Unadjusted OR	AOR1 (95% CI)	AOR2 (95% CI)	AOR3 (95% CI)
	NO ADHD Diagnosis	ADHD Diagnosis				
No established breastfeeding % (weighted *n*)	96.8% (251,405)	3.2% (8375)	1.0	1.0	1.0	1.0
Five weeks to 12 months of breastfeeding % (weighted *n*)	98.1% (534,425)	1.9% (10,435)	0.6 (0.3-1.1)	0.7 (0.4-1.3)	0.7 (0.3-1.3)	0.8 (0.4-1.5)
More than 12 months of breastfeeding % (weighted *n*)	98.0% (82,970)	2.0% (1,660)	0.6 (0.2-1.6)	0.7 (0.2-1.9)	0.7 (0.2-2.0)	0.8 (0.3-2.5)

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the crosstab with the highest *n*. Complete case analysis results in slightly different *n* for each crosstab.
AOR1: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
AOR2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)

AOR3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 8: Relationship between Six-Level Infant Feeding and ADHD Diagnosis of the National Longitudinal Survey of Children and Youth (weighted *n*= 889, 270)

Independent Variable	Dependent Variable		Unadjusted OR	AOR1 (95% CI)	AOR2 (95% CI)	AOR3 (95% CI)
	No ADHD Diagnosis	ADHD Diagnosis				
No established breastfeeding % (weighted *n*)	96.8% (251,405)	3.2% (8,375)	1.0	1.0	1.0	1.0
2-3 months breastfeeding % (weighted *n*)	98.6% (79,365)	1.4% (1,155)	0.4 (0.1-2.0)	0.5 (0.1-2.3)	0.5 (0.1-2.3)	0.6 (0.1-2.7)
4-6 months breastfeeding % (weighted *n*)	98.3% (206,300)	1.7% (3,530)	0.5 (0.2-1.3)	0.6 (0.3-1.5)	0.6 (0.2-1.5)	0.7 (0.3-1.7)
7-9 months breastfeeding % (weighted *n*)	98.2% (146,995)	1.8% (2,730)	0.6 (0.2-1.8)	0.7 (0.2-2.3)	0.7 (0.2-2.5)	0.8 (0.2-3.0)
10-12 months breastfeeding % (weighted *n*)	97.1% (101,760)	2.9% (3,015)	0.9 (0.4-2.0)	1.0 (0.4-2.4)	1.0 (0.4-2.6)	1.2 (0.5-3.1)
More than 12 months breastfeeding % (weighted *n*)	98.0% (82,970)	2.0% (1,660)	0.6 (0.2-1.6)	0.7 (0.2-1.9)	0.7 (0.2-2.0)	0.8 (0.3-2.5)

Note: All weighted *n* were rounded to base 5 for confidentiality. Total unweighted *n*=3,895. Weighted *n* in title reflects the crosstab with the highest *n*. Complete case analysis results in slightly different *n* for each crosstab.
AOR1: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))

AOR2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
AOR3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 9: Descriptive Statistics and Linear Regression for the Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth

Independent Variables	Mean Value of H/I Score	Child Hyperactivity/Inattention Score Regression Coefficient and 95% CI
Child Sex		
Female	3.9	Reference
Male	5.0	1.1 (0.8, 1.4)***
Child Age		
0 to 11 months old	4.5	Reference
12 to 23 months old	4.3	-0.2 (-0.5, 0.6)
Maternal Age at Birth		
13-24	5.0	Reference
25-29	4.5	-0.5 (-0.9, -0.1)*
30-34	4.2	-0.8 (-1.2, -0.4)***
35 and up	4.1	-1.0 (-1.4, -0.5) ***
Maternal Education Level		
Less than secondary	5.2	Reference
Secondary school graduation	4.6	-0.6 (-1.2, 0.1)
Beyond high school	4.6	-0.6 (-1.1, 0.0)
College/ trade or university degree	4.2	-1.0 (-1.5, -0.5)***
Household Income		
Less than $10,000 to $14,999	5.5	Reference

$15,000 to $19,999	5.4	-0.1 (-1.2, 1.1)
$20,000 to $29,999	4.9	-0.6 (-1.5, 0.3)
$30,000 to $39,000	4.5	- 1.0 (-1.8, -0.1) *
$40,000 or more	4.3	-1.2 (-2.0, -0.5)**
Preterm Birth		
Not preterm (after 37 weeks)	4.4	Reference
Preterm (before 37 weeks)	4.8	0.4 (-0.1, 0.9)
Low Birth Weight		
Not low birth weight (more than 2,500g)	4.4	Reference
Low birth weight (2,500 g or less)	4.9	0.5 (-0.1, 1.1)
Maternal Alcohol Consumption During Pregnancy		
Never	4.4	Reference
Less than once a month to every day	4.9	0.6 (0.1, 1.0) **
Maternal Smoking During Pregnancy		
No	4.3	Reference
Yes	5.3	1.0 (0.6, 1.4) ***
Parent Living Situation		
Two parents	4.4	Reference
One parent	5.3	0.9 (0.3, 1.4) **
Maternal Depression [a]		
Low score	4.3	Reference
High score	5.5	1.2 (0.7, 1.7) ***
Parenting Scores		
Positive Interaction [b]		
High score	4.4	Reference

Low score	5.0	0.6 (0.1, 1.1) *
Ineffective Parenting [a]		
Low score	4.4	Reference
High score	5.1	0.7 (0.2, 1.3) *

[a] High score is top 10%
[b] Low score is bottom 10%

Table 10: Relationship between Dichotomous Infant Feeding and Linear Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth

Independent Variable				
	Model 1 Beta Coefficient (95% CI)	Model 2 Beta Coefficient (95% CI)	Model 3 Beta Coefficient (95% CI)	Model 4 Beta Coefficient (95% CI)
No established breastfeeding	1.0	1.0	1.0	1.0
Breastfeeding for 5 weeks or more	-0.5 (-0.9, -0.2)***	-0.3 (-0.6, 0.009)	-0.2 (-0.6, 0.1)	-0.1 (-0.5, 0.2)

Model 1: unadjusted
Model 2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
Model 3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
Model 4: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 11: Relationship between Three-Level Infant Feeding and Linear Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth

Independent Variable				
	Model 1 Beta	Model 2 Beta	Model 3 Beta	Model 4 Beta

	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)
No established breastfeeding	1.0	1.0	1.0	1.0
Breastfeeding for 5 weeks -12 months	-0.4 (-0.8, -0.1)**	-0.2 (-0.6, 0.1)	-0.2 (-0.5, 0.2)	-0.1 (-0.4, 0.3)
Breastfeeding for >12 months	-1.1 (-1.6, -0.7)***	-0.8 (-1.3, -0.4)***	-0.7 (-1.2, -0.2)**	-0.6 (-1.0, -0.1)*

Model 1: unadjusted
Model 2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
Model 3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
Model 4: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 12: Relationship between Six-Level Infant Feeding and Linear Hyperactivity/Inattention Score of the National Longitudinal Survey of Children and Youth

Independent Variable				
	Model 1 Beta Coefficient (95% CI)	Model 2 Beta Coefficient (95% CI)	Model 3 Beta Coefficient (95% CI)	Model 4 Beta Coefficient (95% CI)
No established breastfeeding	1.0	1.0	1.0	1.0
Breastfeeding for 2-3months	0.2 (-0.4, 0.8)	0.2 (-0.4, 0.7)	0.2 (-0.4, 0.8)	0.2 (-0.3, 0.8)
Breastfeeding for 4-6 months	-0.6 (-1.0, -0.2)**	-0.4 (-0.8, -0.02)*	-0.3 (-0.7, 0.1)	-0.2 (-0.6, 0.17)
Breastfeeding for 7-9 months	-0.5 (-1.0, -0.1) *	-0.2 (-0.7, 0.2)	-0.2 (-0.6, 0.2)	-0.04 (-0.5, 0.4)

Breastfeeding for 10-12 months	-0.5 (-1.0, -0.02)*	-0.3 (-0.8, 0.2)	-0.2 (-0.7, 0.3)	-0.04 (-0.5, 0.4)
Breastfeeding for >12 months	-1.1 (-1.6, -0.7)***	-0.8 (-1.3, -0.4)***	-0.7 (-1.2, -0.3)**	-0.6 (-1.2, -0.1)*

Model 1: unadjusted
Model 2: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income (SES (age and sex included))
Model 3: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight and preterm birth (SES and pregnancy and birth factors)
Model 4: adjusted for child sex, child age (at time 1), survey cycle, maternal age at birth, maternal education, household income, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, low birth weight, preterm birth, maternal depression score, parent living situation, positive interaction parenting score, and ineffective parenting score (SES and pregnancy and birth factors and parent and child factors)

Table 13: Interaction Terms Between Dichotomous H/I score and Dichotomous Infant Feeding Variable for Associations with Academic Performance Variables of the National Longitudinal Survey of Children and Youth

Infant Feeding	Math Performance Unadjusted OR (95% CI)	Written Work Performance Unadjusted OR (95% CI)	Reading Performance Unadjusted OR (95% CI)	Overall Performance Unadjusted OR (95% CI)
Not Established Breastfeeding	1.0	1.0	1.0	1.0
Established Breastfeeding	1.4 (0.5- 4.3)	0.9 (0.3-2.3)	0.8 (0.3-1.8)	0.6 (0.1-2.1)

Note: No interaction terms are significant, meaning the relationship between infant feeding and academic performance does not differ for those who score high or low on the H/I scale.