Impacts of the Healthy Families, Healthy Babies (HFHB) Targeted Prenatal Program on Pregnancy, Birth and Early Life Nutritional and Developmental Outcomes in New Brunswick

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Project Number
P0053: Impact of the Healthy Families, Healthy Babies public health program on short-and longer-term outcomes in children and their families in NB

Acknowledgements
We thank our partners from within the Government of New Brunswick (GNB) Department of Health for engaging us to develop research to address their evidence needs; especially Teri Emrich, Aisha Khedheri, Laura Brennan and members of the HFHB program review committee. This work was supported with funding from the ResearchNB NB Wellness Research Fund Partner Grant, on behalf of the GNB Department of Health. This study was also supported by the Maritime SPOR Support Unit (MSSU), which receives financial support from the Canadian Institutes of Health Research (CIHR), the Nova Scotia Department of Health and Wellness, the New Brunswick Department of Health, Research Nova Scotia and ResearchNB. The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. No endorsement by ResearchNB, the GNB Department of Health, the MSSU or the named funding partners is intended or should be inferred.

Project Data
Research analytic outputs were produced using platform data accessed through the New Brunswick Institute for Research, Data and Training, along with Healthy Families, Healthy Babies program data provided by the New Brunswick Department of Health.

How to Cite This Product
Cookson, S. R., Jones, B., & Magalhaes, S. (2025). Impacts of the Healthy Families, Healthy Babies (HFHB) targeted prenatal program on pregnancy, birth and early life nutritional and developmental outcomes in New Brunswick. Fredericton, NB: New Brunswick Institute for Research, Data and Training.

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Executive Summary

The perinatal period is a critical time in life. Experiences and exposures during pregnancy and in the first years after birth are found to have far-reaching implications for early childhood development and health over the life course.

To support healthy pregnancies and childhood development, targeted public health programs are available, with families enrolled prenatally or postnatally and followed throughout pregnancy and the first years of the child's life. Typically, these programs are offered to families having a baby for the first time who are at high risk of poorer outcomes as a strategy to mitigate negative impacts from poverty and early childhood adversity.

Each Canadian province and territory offer a targeted public health perinatal program, with several programs currently undergoing program review. Yet, limited research evidence is available to inform these efforts. Targeted public health perinatal programs are shown to have benefits for program participants and service providers; however, their longer-term impacts have not been properly evaluated among Canadian populations.

In the province of New Brunswick (NB), the **Healthy Families, Healthy Babies (HFHB)** public health program provides targeted services to first-time families at higher risk of poor outcomes, with prenatal home visits provided until birth and postnatal program services from birth to the age of two. Most prenatal visits are provided by Public Health dietitians, and most postnatal visits and services are provided by Public Health nurses. The New Brunswick Institute for Research, Data and Training (NB-IRDT) has been supporting a review of the HFHB program, with a previous study on the early life impacts of the targeted HFHB ***postnatal*** program component[1].

The overall goal of this study is to evaluate the early life impacts of the targeted HFHB *prenatal* program component, with a specific focus on pregnancy, birth and early childhood nutritional and developmental outcomes. Overall, the results of this research will contribute to the ongoing program review of the HFHB program in NB.

A matched retrospective cohort study of all live births in NB, Canada, between April 1, 2012, and March 31, 2020, among individuals parenting for the first-time was developed using population-based administrative data accessible at NB-IRDT. Several linkable administrative data sets were used to define the study cohort, HFHB prenatal program participation, pregnancy, birth and early childhood nutritional and developmental outcomes, as well as a number of confounding variables.

A propensity score matching (PSM) methodology was used to select a matched group of families that did not participate in the targeted HFHB program who were similar to those who participated. Multivariable regression models were used to provide statistically adjusted estimates of the differences in outcomes between groups while accounting for relevant confounding variables.

A birth cohort of 20 832 individuals parenting for the first time was established and followed longitudinally from birth to 18 months; 2000 participated in the HFHB prenatal home visiting program, and 2000 non-participating families were matched to HFHB prenatal program participants.

Highlight of Findings

Overall results do not demonstrate a consistent positive impact of HFHB prenatal program participation on the pregnancy, birth, nutritional and developmental outcomes examined, which are listed below**:**

Pregnancy	Birth	Nutritional	Developmental
-Anemia -Gestational Diabetes -Gestational Hypertension	-Preterm birth -Poor APGAR score -Large for gestational age (GA) -Small for GA	-Breastfeeding initiation and duration -Nutritional risk	-Communication, gross motor skills, fine motor skills, problem solving and personal-social interactions

Analyses suggest that participating in the HFHB prenatal program had a small consistent positive impact on reduced risk of developing gestational hypertension, which was similar when restricting to those under age 25 years.

Several measures of program intensity (enrolled prior to 20 weeks, 7+ HFHB prenatal program visits) were also examined, and results were consistent with the main analyses.

Results obtained are likely underestimations of the true program effects due to:

- Residual confounding, resulting from the inability to PSM well to the HFHB prenatal program participants with the highest propensity scores.

- Selection bias (for nutritional and developmental outcomes specifically), resulting from poor participation in the Healthy Toddler Assessment, accompanied by important differences observed between those who did and didn't according to whether they were in the HFHB prenatal program or not.

This is among the first Canadian studies to evaluate the population-level impact of targeted public health prenatal services on pregnancy, birth and early childhood outcomes. In line with results of our previous study on the postnatal HFHB program[1], the results of this study do not provide evidence for an overall positive impact of the prenatal program component. It will be important to develop a mechanism that enables more frequent conduct of outcome evaluation analyses to continually inform on effectiveness of these programs on key early life outcomes. While this research represents an important contribution to the scientific literature, more research is needed to inform program planning and delivery in Canada.

1. Introduction

1.1 Background

The prenatal period is a critical window of life that is suggested to have far-reaching implications for health and development. In support of the theory of the Developmental Origins of Health and Disease (DOHaD), researchers have documented associations between conditions in pregnancy and health in later life[2], hypothesizing that negative early life exposures lead to poor health and increased risk of disease throughout life[3].

Studies show that prenatal exposure to undernutrition, obesity or gestational diabetes have increased risk for chronic diseases later in life[4]. *In utero* exposure to gestational diabetes, for example, is found to be associated with later development of obesity and glucose intolerance[4,5] as well as increased risk of cardiometabolic and cardiovascular diseases[5,6].

Multiple epidemiological and clinical studies have also reported associations between negative birth outcomes and health later in life. Low birth weight, for example, has been linked to a range of health conditions in later life, including hypertension[7], osteoporosis[8], mental health disorders[9,10], risks of certain cancers[11], obstructive lung disease, asthma[12] and cognitive ability[13].

Given potential impacts on health and development throughout life, it is thus critical to provide adequate prenatal care – both medical care as well as social supports – during and following pregnancy to reduce negative outcomes[14]. Studies demonstrate that receiving prenatal support services is associated with longer duration of breastfeeding[15-17]. Additional benefits of targeted prenatal services observed include better economic self-sufficiency, child and parents' health, child development and positive parenting practices[15,18].

Positive system-level outcomes of targeted prenatal services have also been reported – such as lower service demand associated with poor health and social outcomes, including reductions in emergency department use and Child Protective Services investigations among program participants[19]. This research highlights a variety of important incentives for ensuring adequate supports are in place to meet the needs of families, and especially those who may be at greater risk of these outcomes.

The need for prenatal care is particularly important among families who are young, single and experiencing socioeconomic hardship, as they are less likely to have knowledge of practices to reduce risk of negative outcomes and less likely to have adequate prenatal care[20], further placing them at increased risk for negative outcomes[14]. Canadian women facing greater socioeconomic hardship are less likely to report good or excellent health and are more likely to experience postpartum depression[21]. However, they are also found to be more likely to accept a universally offered home visit from a public health nurse and to continue public health nursing services four weeks postpartum[21]. These results imply these families are both in need of, and receptive to, prenatal support services.

Providing targeted support services during the pre- and postnatal periods is an important public health strategy to help reduce negative impacts associated with poverty and adversity in early life. Typically, perinatal public health programs target younger, single parent families with lower levels of education and poor health behaviours (i.e., smoking, having no prenatal care). Families can be enrolled prenatally or postnatally and are offered visits by public health professionals through pregnancy and early childhood, though the model and specific components of public health programs can vary widely. The greatest overall benefits of participating in public health perinatal programs have been reported in studies with prenatal enrolment, more visits and longer program duration[22], with research suggesting families at the highest risk benefit the most (both functionally and economically) from enrollment in the program[23].

Evaluative research on perinatal home visiting is well established in the United States (US), as federal program funding is conditional on the demonstration of evidence-based practice[18]. Similar evaluative practices are followed in the UK, where cost-benefit analyses of the Family Nurse Partnership (FNP) programme in England have found that, compared with existing services, the FNP is not a cost-effective intervention for mitigating negative birth outcomes[24,25], leading researchers to suggest policy makers may wish to consider other options for investment[25]. However, there is a lack of Canadian-specific research in this area, and there is a need for more population-specific and program-specific evaluations to support evidence-informed delivery of public health perinatal programs in Canada.

Every Canadian province offers a perinatal home visiting program, although there are wide variations in how the programs are delivered and the qualifications required of staff who provide home visits. Several provinces are currently undergoing program reviews, with evaluative research being conducted in British Columbia (BC) and Ontario (ON) to inform on the provision of the Nurse-Family Partnership (NFP) program that was adapted for the Canadian context[26]. More Canadian research on different delivery models is needed to inform decision making across Canada.

This is the case for the province of New Brunswick (NB), which recognized the need for a program review to inform delivery of the provincial Healthy Families, Healthy Babies (HFHB) program. Decision-makers in NB required evidence on impacts of HFHB program participation on intended program outcomes, with the findings of the research presented in this report directly supporting the evidence needs of our partners in Public Health.

The HFHB program (described in further detail below in section 1.2) provides targeted home visiting services delivered by both public health nurses and dietitians; and families can be enrolled either prenatally or postnatally. This is a different model than the NFP, which limits enrolment to the prenatal period and provides home visiting services by public health nurses only, with no additional services from other types of public health professionals. While the NFP has a long history of evidence-based practice in the US, it has met with mixed success in the UK, where the program has produced few observable benefits in birth outcomes[24,25,27] (and at great cost) but is shown to impact school readiness in the longer term[28,29]. It is unlikely that the NFP will be adopted in every jurisdiction in Canada due to the intensity of the programming and resources needed for program delivery.

In 2023, the NB Institute for Research, Data and Training (NB-IRDT) released a study[1] examining the impacts of HFHB postnatal home visiting in NB. The HFHB postnatal program was found to have a positive effect on breastfeeding duration but not on early childhood development[1]. The evidence derived from this previous work was specific to the postnatal component of HFHB and did not consider prenatal participation in the analysis. The current study provides valuable complementary evidence on the impact of the targeted HFHB prenatal program. Our research utilizes a record linkage methodological approach to derive real-world evidence on the long-term program impacts – a methodological approach that is becoming increasingly more common in this context[30-32].

1.2 Program Overview: Healthy Families, Healthy Babies

Healthy Families, Healthy Babies (HFHB) is a public health program that provides families with targeted prenatal and postnatal services from birth to age 2 years. The HFHB targeted components are intended to provide supportive services to families with higher risk for poor outcomes. The program is delivered through the two Regional Health Authorities in NB and is funded by the Government of New Brunswick's Department of Health.

The anticipated program outcomes of targeted services are enhanced fetal/child health and development, enhanced parental health, increased commitment to healthy lifestyles by families and use of available community and social supports, with the goals of the prenatal services focused on fostering a healthy pregnancy.

For the prenatal program, families can self-refer, or they can be referred by a professional or a third party. Eligibility for the prenatal program is based on young age, low education, smoking status and lack of access to prenatal care. This research study examines the targeted prenatal component of the HFHB program. Our previous research focused on the postnatal portion[1].

1.3 Research Questions

The overall goal of this research study is to evaluate the early life impacts of participation in the targeted HFHB prenatal program on stakeholder-selected health and developmental outcomes.

This is achieved by answering the following research questions.

Are participants in the targeted HFHB prenatal program:

- **Less likely than those who did not participate** (i) to develop gestational hypertension, (ii) gestational diabetes or (iii) anemia during pregnancy?
- **Less likely than those who did not participate** (iv) to have a preterm birth, a baby with a birth weight that is (v) large or (vi) small for gestational age, or (vii) with a poor APGAR score?

- **More likely than those who did not participate** (viii) to initiate breastfeeding, (ix) to have longer duration of breastfeeding and (x) to sustain breastfeeding to the age of 18 months?

- **Less likely than those who did not participate** (xi) to have the child be identified as having a high nutritional risk at 18 months of age?

- **Less likely than those who did not participate** (xii) to have the baby be identified as having a developmental concern at 18 months of age?

2. Methods

2.1 Study Design

A matched retrospective cohort study of all live births in New Brunswick (NB) between April 1, 2012, and March 31, 2020, among those parenting for the first time, was developed using population-based administrative data. A baseline of 2012 was selected as the HFHB program eligibility criteria were changed in 2011, restricting enrolment to first-time parents only. A cohort end of 2020 was selected as those born after March 2020 would be born after the start of the COVID-19 pandemic in Canada.

Population-based administrative data were accessed at the NB Institute for Research, Data and Training (NB-IRDT). NB-IRDT is a research institute at the University of New Brunswick and is defined in legislation to have authority to receive, host and link data from government, private sector and not-for-profit organizations in NB. NB-IRDT serves as a data custodian for over 100 linkable data sets which are made accessible to researchers through a rigorous application process.

The ability to link deidentified personal information across data sets on the NB-IRDT secure platform allows the conduct of comprehensive, population-based analyses using large samples with matched control groups. Linked administrative data sets were used to define a study cohort of all first-time births in the province, to identify HFHB prenatal program participants and a sample of matched non-participant controls as well as to derive pregnancy, birth and early childhood nutritional and developmental outcomes along with a large number of potential confounding variables.

The Department of Health's Public Health Priority Assessment (PHPA; 2012-2020) data were used to identify all births in NB. The PHPA is a newborn screening program that is a universal component of the HFHB program, that is used to determine postnatal program eligibility among those not enrolled in the program prenatally. The PHPA is performed by a public health nurse in hospital following a baby's birth, or over the phone for those who leave the hospital prior to completing the PHPA or who have home births. The PHPA has a nearly 100% completion rate.

The PHPA birth cohort was further restricted to those parenting for the first time using the Government of New Brunswick Department of Health Discharge Abstract Data (DAD), Vital Statistics and Citizen Data.

The DAD contains all records for hospital discharges for individuals with an active NB Medicare status. All births in NB (in hospital or in home) are recorded in the DAD, as well as basic demographics, diagnoses/conditions contributing to the length of hospitalization stay, any interventions performed during the hospitalization and discharge disposition (e.g., sent home, died in hospital, etc.). As such, DAD records for admission to hospital for delivery were used to identify their baby, or babies when multiple births occurred. Any previous births (e.g., alive, still births) between 1995-2012 were identified in the DAD. If a previous birth resulted in parenting for less than six months due to death of the baby, the individual was retained in the cohort. Death of a baby was identified using the Vital Statistics death data.

As gender data is not available in PHPA, nor DAD, herein any reference to parent specifically refers to the parent that had a DAD record for the delivery of their baby. Data on the other parent or guardian(s) of babies in the cohort are not available through administrative data in NB and thus could not be reported on or included in the analysis of this study.

A household identifier in the Department of Health's Citizen Data (CD) was also used to identify older children (e.g., those born before 1995 or not born in NB). The CD holds all records for operations related to the provincial health care program (i.e., NB Medicare) between 1971 and 2020, as well as basic demographics (i.e., date of birth, date of death) and residential address information (i.e., effective and termination dates and corresponding six-digit postal codes, household identifiers). This approach may erroneously exclude individuals who are themselves having a baby for the first-time but may have older children in their household (e.g., stepchild).

The final study cohort included individuals parenting for the first time who were categorized according to whether they participated in the HFHB prenatal program, whether they participated in the HFHB postnatal program only (but not in the prenatal program) or whether they did not participate in the HFHB targeted programs (prenatal nor postnatal). A matched design was used to identify a comparable group of non-participants based on demographic, socioeconomic and health-related characteristics. The cohort was then linked to outcome data to define pregnancy and birth outcomes, breastfeeding initiation and duration, nutritional risk and child development at 18 months of age.

2.2 Study Variables

2.2.1 Exposure Variables

The main exposure variable was defined using HFHB program data provided by Public Health NB. These data were used to identify the exposed population who participated in the HFHB prenatal and postnatal targeted programs. Prior to our research, HFHB program data were not previously used for research purposes and required substantial time to clean to enable linking to other administrative data sets. The main analysis in this report focuses on comparing participants in the prenatal component of the targeted HFHB program, regardless of whether they participated in the postnatal program or not. HFHB program participants who participated in the postnatal program only were included in the cohort but not reported on from the analysis. The HFHB postnatal program is the focus of our previous research[1]. The unexposed, non-participant population were those in the study cohort who were not identified in the HFHB targeted prenatal or postnatal program data.

Program exposure was also defined using several program intensity variables, including the number of HFHB prenatal program visits, the trimester of enrolment in the HFHB prenatal program and the duration of time in the HFHB prenatal program. These variations of program exposure were examined in sensitivity analyses to understand differential impacts of program intensity on selected outcomes.

2.2.2 Outcome Variables

Twelve outcomes were examined. Seven outcomes were defined using data collected during pregnancy and at birth, and five were longer-term outcomes defined using data collected at age 18 months. The outcomes were selected in consultation with a large group of program stakeholders from government and both Regional Health Authorities.

The three pregnancy outcomes were gestational diabetes, gestational hypertension or anemia during pregnancy, and the four birth outcomes were preterm birth, large and small for gestational age as well as poor APGAR score. The Horizon Perinatal Data and Vitalité Perinatal Data (PerinatalNB) were used; however, these data only start in 2016. Prior to 2016, pregnancy and birth outcomes were derived from DAD, Canadian Chronic Disease Surveillance System (CCDSS) and PHPA data. Outcome data from PerinatalNB were compared to DAD-derived outcomes for overlapping periods and were found to be concordant.

There are several other outcomes included in PerinatalNB data that cannot be derived using other administrative data sets that are available prior to 2016. While these outcomes were selected by the program stakeholders as relevant to program impact, the timing of data collection during pregnancy, relative to enrolment in HFHB, cannot be determined. Therefore, these outcomes are only presented descriptively. These include specific health behaviours during pregnancy including tobacco, alcohol and substance use, intake of folic acid and weight gain.

The 18-month Healthy Toddler Assessment (HTA) is another of the universal components of the HFHB program. HTA data were used to define nutritional and developmental outcomes. The HTA is a voluntary assessment preformed by a public health nurse when the baby is between the age of 18 to 24 months and is available to all toddlers in NB. The HTA is used to assess a wide range of health and developmental areas of potential concern including accidents/injuries, vision, hearing, oral health, nutrition, parents' mental health, growth, immunizations and use of community or health services, as well as validated scales assessing nutrition and development. From the HTA data, four nutritional outcomes and one developmental outcome were defined. To avoid any impacts from the COVID-19 pandemic, only HTA data collected prior to April 1, 2020, were included in the study.

Parents completing the HTA were asked if the child was ever breastfed or fed breast milk, and this question was used to define an outcome on whether they initiated breastfeeding (yes/no). If they responded yes, they were asked a series of questions about breastfeeding behaviours. Two of these questions were used to define outcomes for duration of breastfeeding: (i) currently breastfed (yes/no at 18 months) and (ii) duration breastfeeding (in months). If they were no longer breastfeeding, they were asked to report the age the child was when he/she completely stopped being breastfed, which was used to calculate duration of breastfeeding. Those children who were currently breastfeeding were assigned a duration of breastfeeding corresponding to the child's age at the HTA. Those children who were never fed breast milk were assigned a breastfeeding duration of zero.

A breastfeeding initiation variable from PerinatalNB data was examined in sensitivity analyses due to low completion rates of the HTA, and potential for selection bias determined from descriptive analyses. While the PerinatalNB variable had minimal missingness, the data collection only began part way through the cohort period (in 2016), and thus this analysis had a similar proportion of the total cohort represented (i.e., similar statistical power) but was anticipated to be less prone to selection biases due to low completion of the HTA. The PerinatalNB breastfeeding initiation variable is collected at birth and specifies whether they initiated breastfeeding (yes/no). A combined breastfeeding variable, using both PerinatalNB and HTA data, was also derived to obtain the most complete breastfeeding variable, taking a yes if reported.

Nutritional risk at 18 months was assessed using the Nutrition Screening Tool for Every Preschooler (NutriSTEP®) score as part of the HTA. NutriSTEP® is a set of questionnaires used to assess toddlers' (18-35 months) nutritional risks[33]. NutriSTEP® questionnaires ask 17 questions about a child's typical food choices, eating behaviour, physical activity and growth, with a score for potential nutrition-related problems calculated based on responses. Total scores were divided into three categories corresponding to (i) low risk, (ii) moderate risk and (iii) high risk. The main outcome variable for nutritional risk was defined as high nutritional risk, though the outcome of moderate nutritional risk was also examined in sensitivity analyses.

Child development at 18 months was assessed using the Ages & Stages Questionnaire (ASQ). The ASQ includes a series of questions designed to capture information about five developmental domains: communication, gross motor skills, fine motor skills, problem solving and personal-social interactions. The ASQ domains each have a total score, with lower scores representing poorer development. The total scores are categorized into three levels using established cut-offs representing (i) appropriate development, (ii) potential developmental concern or (ii) developmental concern identified. The main outcome variable was defined as children who were identified as having a developmental concern identified in one or more of the ASQ developmental domains. In addition, a secondary developmental outcome variable defining if the child had a potential developmental concern identified was also examined.

2.2.3 Confounding Variables

Given the HFHB prenatal program targets a high-risk population, comparing outcomes among program participants to those of all first-born children would not provide a valid estimate of the impact of program participation. To account for differences between comparison groups, several confounding variables were derived and used to identify a comparable group of families that did not participate in the HFHB targeted prenatal program. Confounding variables included time and location of birth, demographic and socioeconomic characteristics, health history and health care use during pregnancy.

Timing/location of birth variables include calendar year of birth, season of birth and health region of birth. Demographic variables include age, marital status (single, married or other) and immigration status. Socioeconomic variables included one individual-level variable: use of the Department of Social Development's social assistance income program. The remainder were neighbourhood-level variables for material deprivation. This included variables representing increasing levels of situational vulnerability, residential instability, economic dependency and ethnocultural composition, which were measured using the Statistics Canada Canadian Index for Material Deprivation (CIMD). An additional Census neighbourhood-level variable for median income quintile was included.

The PHPA newborn screening data are used to determine postnatal program eligibility, but no universal screening data are available prenatally in NB. As PHPA data are available for the entire population, they were used in identifying matched controls. The PHPA is comprised of a series of questions that sum to three sub-scores (congenital factors, family (social) interaction factors and development factors) and a total score, all of which are used to identify high-risk families in need of referral to postnatal support services. The PHPA family interaction factors score was identified as an important confounding variable for this analysis. The PHPA family interaction factors score at time of birth was used as a proxy for a family interaction factor score during pregnancy. The family interaction factors score captures risks related to younger age, lower education, need for mental health and financial and social support.

Health history variables included pre-pregnancy type 1 or type 2 diabetes, hypertension, asthma and mental illness generally, as well as variables specific to mood and/or anxiety disorders and schizophrenia.

Health care utilization during the prenatal period was also described. This was captured using several variables including the number of prenatal visits during each trimester, if a walk-in clinic was used or any hospitalizations were required.

2.3 Statistical Analyses

2.3.1 Propensity Score Analyses

A propensity score matching methodology was used to identify a comparable group among all cohort members that did not participate in the HFHB prenatal program. The confounding variables described in the previous section were included in a logistic regression model to predict the propensity to participate in the HFHB prenatal program (propensity model). The coefficients from the propensity model were used to calculate a propensity score for each cohort member. Descriptive methods were used to compare propensity scores, including summary statistics and histograms. These demonstrated minimal overlap for HFHB prenatal participants with very high propensity scores. Among first time families there were few potential matches among the non-participant sample with high propensity scores, implying the HFHB program successfully targeted the highest risk families for enrolment in the program.

Only one non-participant match was selected per HFHB prenatal program participant to reduce impacts from poor matching (i.e., residual confounding). A nearest neighbour matching approach was used to select one non-participant who had the most similar propensity score to a HFHB prenatal program participant. Summary statistics of the confounding variables were compared between HFHB prenatal program participants and matched non-participants, and any variables that were still imbalanced were included as covariates in multivariable regression models. This approach aimed to reduce impact of confounding on the final study estimates. However, we acknowledge that residual confounding remains given the unique population targeted for the HFHB prenatal program and thus must be considered in interpretation of the study results.

2.3.2 Regression Model Analyses

Multivariable logistic regression models were used to statistically compare outcomes of those who participated in the HFHB prenatal program to those that did not participate in the targeted HFHB program, while adjusting for confounding.

Sensitivity analyses were conducted to examine the impact of further adjustments for PHPA development and congenital scores, pregnancy health behaviours (pre-and during pregnancy tobacco, alcohol and substance use) as well as for pregnancy outcomes (gestational hypertension, diabetes and anemia) in the birth and early childhood outcomes. The results of these sensitivity analyses exploring further adjustment were consistent with the main findings and are not presented in the report. A subgroup analysis was performed considering only those under age 25 years at the time of childbirth to explore potential bias on results due to imbalances in distribution of age between comparison groups. In addition, we explored use of a continuous age variable, using non-linear representations (i.e., polynomials), but results were also consistent with the main analyses.

As a cohort study design was used, the logistic regression coefficients can be used to estimate risk on the outcome associated with participation, with less risk indicating better outcomes among program participants. Outcome percentages presented in the Results section are adjusted and were derived from logistic regression model estimates within Stata using adjrr commands. Both the adjusted risk difference and adjusted risk ratio estimates, and their corresponding 95% confidence intervals (CIs), are displayed throughout the Appendix tables. Risk differences are presented throughout the Results section as this measure provides a sense of how many more (or less) outcomes there are among the HFHB prenatal program participants as compared to the matched non-participants. For example, if the outcome prevalence is 10% in HFHB prenatal program participants and 5% in matched non-participants, the risk difference would indicate the outcome is 5% more common in participants. Meanwhile, the risk ratio would suggest the risk in participants is twice as high as in matched non-participants. While these estimates are related, they have different interpretations.

3. Results

3.1 Study Participants

Over the eight-year study period (2012-2020), there were 20 832 families that met the criteria for inclusion in the cohort study (i.e., parenting for the first time, singleton birth). Of these, there were 2011 HFHB prenatal program participants identified; though, 11 were missing area-level data, and so the final sample of HFHB prenatal program participants in the regression analyses is 2000. There were 3015 HFHB postnatal-only program participants who were not reported in the current analyses as postnatal program participation was the focus of our previous report[1]. The remaining 15 716 families were defined as non-participants. A propensity score (PS) matching procedure was implemented to identify 2000 non-participants individually matched to a HFHB prenatal program participant with the most similar PS value.

Table 1 details baseline characteristics for the study cohort (n=20 832), as well as for the relevant subgroups: total cohort, HFHB prenatal program participants, all non-participants and PS-matched non-participant sample. Comparisons between HFHB prenatal program participants and matched non-participants are the focus of the analysis; however, estimates for all non-participants are provided in Table 1 as a reference. As expected, the non-participants, overall, were older, have higher socioeconomic status and have better health and pregnancy-related behaviours than HFHB prenatal program participants. Matched non-participants were more similar, though differences between groups remained after matching.

HFHB prenatal program participants were younger on average (age 20.5 (4.0)) than matched non-participants (22.9 (4.0)). The percentage of HFHB prenatal program participants who were between the ages of 13 and 19 years was 49.1%, which was more than double than in matched non-participants (22.5%). The higher rate of teenage participants in the HFHB prenatal program reflects the automatic eligibility of expectant teenagers to the program. Matched non-participants were most likely to be in the age category 20-29 years (72.9%), but based on the average distribution, mostly likely to be in their early 20s. There were similar proportions in the 30 and above age category (<5%). Due to this discrepancy in age distribution between groups, sensitivity analyses were conducted restricting to those under age 25 years only.

The PHPA family interaction factors score was one of the confounding variables with the biggest imbalance between groups after matching. Only 4.0% of HFHB prenatal program participants had a PHPA family interaction factors score of 0 (best score), while 61.9% had a score of 10 or above. PHPA family interaction factors scores were more favourable in the matched non-participants (13.5% with a score of 0, and 36.1% with a score of 10 or above) than among the HFHB prenatal program participants.

A similar percentage of HFHB prenatal program participants were on SD income assistance at some point before the baby's birth (72.0%) as the matched non-participants (64.1%). Additionally, the percentage of immigrants in the participant sample (3.2%) was similar to the percentage in the matched sample (3.6%).

For the neighbourhood-level variables, HFHB prenatal program participants were overall more likely to live in areas with higher unemployment, lower median household income, higher residential instability, higher economic dependency and higher situational vulnerability than matched non-participants, but any differences between groups were minimal.

HFHB prenatal program participants were also similar to matched non-participants with respect to health conditions. The most prevalent health condition was mental illness, representing nearly two-thirds of HFHB prenatal program participants and matched non-participants. HFHB prenatal program participants were as likely to have asthma before pregnancy (17.6%) as matched non-participants (16.4%). Diabetes or hypertension before pregnancy was rare. HFHB prenatal program participants (0.8%) had similar rates of pre-pregnancy hypertension (1.1% in matched non-participants) and diabetes (1.2% vs. 1.7%) as matched non-participants.

PerinatalNB includes variables describing pregnancy-related behaviours may have impacted outcomes and been influenced by HFHB prenatal program participation. However, these data were only available for half of the cohort periods and for most we were unable to determine temporality due to limitations in dates when data were collected during pregnancy. Thus, these variables are described as baseline characteristics only (for the latter half of the cohort), not evaluated as program outcomes and examined for confounding in sensitivity analyses.

Both groups had similar levels of folic acid intake and recommended weight gain during pregnancy. However, HFHB prenatal program participants were more likely than matched non-participants to report smoking before pregnancy (54.9% and 42.1%) and to remain smoking during pregnancy (37.0% and 28.4%) and at delivery (28.2% and 21.6%). Given temporality of smoking behaviours throughout pregnancy could be established, the smoking at delivery outcome was examined in sensitivity analysis while controlling for smoking before pregnancy, which did not provide evidence of a positive impact of program participation. HFHB prenatal program participants were also more likely than matched non-participants to report using substances during pregnancy (26.7% and 19.1%). Rates of drinking before and during pregnancy were similar between the two groups.

Health care utilization during pregnancy was, overall, similar between the groups. The number of physician visits during each trimester was similar in both groups, with an increasing number of visits in each trimester. Hospitalizations were also similar between groups (10.2% of HFHB prenatal program participants and 8.3% of matched non-participants), as were the proportion who used a walk-in clinic (~18%).

3.2 Pregnancy Outcomes

Study results demonstrated a small positive impact of HFHB prenatal program participation on gestational hypertension but no consistent positive impact on gestational diabetes or anemia during pregnancy (Table 2). For gestational hypertension, prenatal participants (3.5%) had a 1.3% lower rate compared to matched non-participants (4.8%), with the lower 95% confidence interval suggesting the difference between groups could range from 2.6% less gestational hypertension among HFHB prenatal program participants, and the upper interval suggesting an equal rate in both groups. For gestational diabetes, prenatal participants (5.8%) had a similar outcome rate compared to matched non-participants (4.9%; risk difference: 0.9% (-0.6% to 2.5%)). The same was found for anemia during pregnancy, as HFHB prenatal program participants (2.2%) had a similar rate compared to matched non-participants (2.4%; risk difference: -0.2% (-1.1% to 0.8%)). Results were similar when analyses were restricted to those under 25 years of age.

3.3 Birth Outcomes

Study results did not suggest a consistent positive impact of HFHB prenatal program participation on any birth outcomes examined, including preterm birth, large or small for gestational age and poor APGAR score (Table 2). Overall, these negative birth outcomes appear, on average, more common among HFHB prenatal program participants. However, confidence intervals suggest outcomes were statistically similar to those of the matched non-participants. Results were also similar when analyses were conducted among those under age 25 years only.

While most HFHB prenatal program participants had a normal size baby (82.4%), they were found to be 1.8% less likely to have a large for gestational age (GA) baby (9.4% and 11.2%) but also 1.3% more likely to have a small for GA baby (8.2% and 6.9%) than matched non-participants. Regression results suggest that HFHB prenatal program participants had similar rates of large or small size for GA, based on the range of the confidence intervals.

HFHB prenatal program participants (7.1%) had a higher rate of preterm birth compared to the matched sample (5.8%), though confidence intervals suggest that statistically the groups were similar (95%CI: -0.4% to +2.8%). The likelihood of a poor APGAR score was more similar between groups (HFHB prenatal program participants: 4.8%; matched non-participants: 4.1%; risk difference: 0.7% 95%CI: -0.7% to +2.0%).

3.4 Completion Rates for 18-month Outcomes

When the study cohort was linked to outcome data from the 18-month Healthy Toddler Assessment (HTA), sample sizes decreased substantially due to low completion rates and inability to use HTA data for babies born later in the cohort (to avoid potential impacts of the COVID-19 pandemic). The completion rate for the HTA was 54.9% (n = 11 428) among the entire cohort, with HFHB prenatal program participants (52.5%, n = 1055) having higher completion rates than the matched sample (39.4%, n = 788). Tables 3 and 4 detail baseline characteristics and pregnancy/birth outcomes comparing the samples who completed, and did not complete, the HTA in both the sample of HFHB prenatal program participants and matched non-participants.

Those who completed the HTA were, generally, similar to those who did not complete the HTA with respect to many of the demographic, socioeconomic, health and health care-related characteristics compared. However, several notable differences were observed that are important to consider in interpreting the main study results. The biggest differences observed were for the PHPA family interaction factors score at birth and reported health behaviours during pregnancy.

Those who did not complete the HTA were more likely to have a worse PHPA family interaction factors score. Among the HFHB prenatal program participants, 64.5% of those who did not complete the HTA had a score of 10 or more, compared to 59.5% of those who did complete the HTA. The difference was more pronounced among the matched non-participants, with 41.5% of those who did not complete the HTA having PHPA family interaction factors score of 10 or more, compared to 27.7% of those who did complete the HTA.

Another notable difference related to completion of the HTA was the use of substances and tobacco during pregnancy, though differences were less pronounced than for the PHPA family interaction factors scores. A higher percentage of HFHB prenatal program participants (33.6%) and matched non-participants (21.9%) who did not complete the HTA reported use of substances during pregnancy, as compared to those who completed the HTA (20.8% of program participants and 14.0% of matched non-participants). Smoking during pregnancy was also found to be more common among those with missing 18-month assessment data among both HFHB prenatal participants (41.1% vs. 33.3%) and matched non-participants (29.0% vs. 27.4%).

There are important differences in the population who completed the HTA compared to those who did not complete the HTA which impact interpretation of the outcome analysis at 18 months of age. These results indicate that those who are missing 18-month outcome data may be the children who are more likely to have poorer outcomes compared to those who were included in the 18-month outcome analysis. In addition, with differences being more pronounced among matched non-participants, this suggests that more children with poorer outcomes may be missing from the matched sample in the outcomes analyses. The proceeding results on nutritional and developmental outcomes should be interpreted in the context of these findings.

3.5 Early Life Childhood Nutrition

3.5.1 Breastfeeding Initiation and Duration

There were 50.7% of HFHB prenatal program participants and 38.1% of matched non-participants with valid breastfeeding initiation data at the 18-month Healthy Toddler Assessment (HTA). Additionally, there were 37.7% of HFHB prenatal program participants and 40.0% of matched non-participants with valid breastfeeding initiation data in the PerinatalNB data (data only available after 2016). When these are combined, there are 69.7% of HFHB prenatal program participants and 64.2% of matched non-participants with valid breastfeeding initiation data.

Results demonstrate that HFHB prenatal program participation did not have a consistent positive impact on initiation nor on duration of breastfeeding, though a higher proportion of participants were found to be more likely to remain breastfeeding at the 18-month assessment (Table 2).

When examining whether breastfeeding was initiated at birth, using the HTA data, HFHB prenatal program participants (73.2%) were found to be 4.8% more likely than matched non-participants (68.4%), with confidence intervals consistently suggesting an increase in likelihood of initiation (ranging from 0.6% to 9.1% more likely). However, given evidence for selection bias in HTA data, results derived from PerinatalNB data are anticipated to be less biased. Based on this initiation variable, HFHB prenatal program participants (75.9%) were found to be as likely as matched non-participants (75.8%; 95% CI: -4.0% to 4.3%). For the combined breastfeeding variable (HTA or PerinatalNB), HFHB prenatal program participants (76.7%) were found to be 3.0% more likely than matched non-participants (73.7%) to initiate breastfeeding, with confidence intervals suggesting increased likelihood, though the result was not statistically significant (ranging from -0.2% to 6.2%). The strength of the latter results being primarily driven by results from HTA only analyses.

Duration of breastfeeding (continuous, in months) was also found to be similar between groups. When examining breastfeeding duration in categories (≤1 month (including those who did not initiate), >1-6 months, >6-12 months, >12 months), breastfeeding for one month or less was most common, representing over half of HFHB prenatal program participants (58.9%) and matched non-participants (55.7%). The HFHB prenatal program participants had lower percentages for >6-12 months and for >12 months, however this may be due to lower initiation rates.

While there was a similar rate of remaining breastfeeding for longer than 12 months (10.1% vs. 10.6%), when examining whether individuals remained breastfeeding at the time of the HTA (~18 months of age), prenatal participants had a 2.2% higher rate (8.4%) as compared to the matched non-participants (6.2%). The confidence interval for this estimate ranged from -0.5% less likely to 4.9% more likely and thus was more consistent with increased likelihood, but not statistically significant.

In sensitivity analyses that were restricted to those under age 25 years only, the impacts on breastfeeding initiation and duration were stronger in magnitude and statistically significant for the HTA variables, but not for the initiation variables from PerinatalNB data. Based on HTA data, HFHB prenatal participants were 8.4% more likely to initiate breastfeeding (95% CI: 3.2 to 13.7), to have a longer duration of breastfeeding and 3.8% more likely to remain breastfeeding at 18 months (95% CI: 1.1 to 6.4).

3.5.2 Nutritional Risk

There were 49.9% HFHB prenatal program participants and 38.9% matched non-participants that had complete NutriSTEP questionnaire data available to estimate a level of nutritional risk (low, moderate, high).

Most children had scores indicating low nutritional risk, with high and moderate nutritional risk being very rare. HFHB prenatal program participants had a similar percentage of children with high nutritional risk (2.0%) as the matched non-participants (2.1%). While HFHB prenatal program participants were found to have a higher percentage of moderate nutritional risk, (12.0% and 10.0%), confidence intervals suggest the groups were statistically similar (-1.1% to 5.1%).

3.6 Early Life Childhood Development

There were 51.5% of HFHB prenatal program participants and 38.8% of matched non-participants with valid Ages & Stages Questionnaire (ASQ) data at the HTA.

Results did not provide evidence of a consistent positive impact of HFHB prenatal program participation on child development at 18 months (Table 2). Most children had scores indicating appropriate development in all five developmental domains. A similar percentage of children of HFHB prenatal program participants were found to have a developmental concern identified (10.5%) as compared to matched non-participants (10.4%; 95% confidence interval: -2.9% to 3.1%). While the children of HFHB prenatal program participants were found to have a 3.9% increased risk of having a potential developmental concern identified (32.7%) as compared to matched non-participants (28.9%), the confidence intervals were inconclusive (-0.7% to 8.4%).

3.7 Program Intensity Analyses

The preceding analyses focused on evaluating the effectiveness of the HFHB prenatal program (real-world impact). Thus, the sample includes a mix of HFHB prenatal program participants with varying degrees of program exposure. Tables 5 to 8 detail results of several descriptive and inferential analyses that were undertaken to better understand the impact of HFHB prenatal program intensity on selected outcomes.

Table 5 describes the frequency of HFHB prenatal visits and timing of enrolment. There were 23.8% who were defined as HFHB prenatal program participants, as they were enrolled in the program, but who did not have any HFHB prenatal program visits. Most HFHB prenatal program participants had more than 6 visits (median number of visits), with 15 being the highest number of visits during the prenatal period. Most HFHB prenatal program participants were enrolled in their first (41.8%) and second (46.6%) trimesters, with over two-thirds (68.8%) being enrolled prior to 20 weeks. Those who were enrolled in the HFHB prenatal program earlier in pregnancy were most likely to have 6 or more HFHB prenatal visits, whereas those enrolled later were most likely to have 1-5 HFHB prenatal program visits.

Table 6 compares baseline characteristics for the HFHB prenatal program participants (i) who enrolled and had one or more HFHB prenatal visits, and those (ii) who enrolled but did not have any HFHB prenatal visits. The baseline characteristics for the total cohort and match non-participants that were presented in Table 1 are included again in Table 6 for reference.

While there were differences between the two HFHB prenatal program participant groups, overall, they were relatively similar. Those that had any visits were found to have a higher PHPA family interaction factors score (63.6% vs. 56.5%), be recipients of social assistance (73.7% vs. 66.5%) and to be living in areas with greater socioeconomic vulnerability.

Health-related characteristics were similar between groups. While both groups had the same rate of smoking tobacco before pregnancy (55.0%), those who had HFHB prenatal program visits were less likely to be smoking at delivery (26.3% vs. 33.2%).

Table 7 shows comparisons for the study outcomes between HFHB prenatal program participants (i) who enrolled and had one or more HFHB prenatal visits and those (ii) who enrolled but did not have any HFHB prenatal visits. Those who had HFHB prenatal program visits did not appear, on average, to have better outcomes than those who did not have any HFHB prenatal program visits.

Table 8 presents effect estimates that were derived from adjusted regression models. These models were developed to examine differential impacts of program intensity. Specifically, three populations were examined: (i) those who had one or more HFHB prenatal visits, (ii) those who had 7 or more HFHB prenatal visits and (iii) those who enrolled early in pregnancy (prior to 20 weeks). While 6 was the median number of HFHB prenatal visits, the cut-off of 7 was used for the group to align with methods of previous research reporting on impacts of prenatal program intensity.

Overall, the results presented in Table 8 were similar to those of the main analysis presented in Table 2 (also presented in Table 8 as reference). While average adjusted risk ratios differed, their confidence intervals overlapped substantially, suggesting similar impacts regardless of whether participants had more prenatal program visits or were enrolled earlier in pregnancy.

4. Discussion

4.1 Summary of Findings

A cohort of 20 832 first-born children was established and followed longitudinally through pregnancy to 18 months after birth using population-based linked administrative data. This study design was used to evaluate impacts of participation in the Healthy Families, Healthy Babies (HFHB) targeted prenatal program in the Canadian province of New Brunswick (NB). The cohort included 2011 families that participated in the targeted HFHB program prenatally.

As the HFHB targeted services have very specific eligibility criteria (i.e., highest risk families parenting for the first time), it was critical to identify similar groups of families that did not participate in the HFHB targeted program at all. This was done using a specialized statistical methodology (propensity score matching) that combined relevant demographic, socioeconomic and health data to select non-participants who were most similar to HFHB prenatal program participants based on these characteristics. The goal was to select multiple matched non-participants for each prenatal participant, but as prenatal participants represented a very high-risk population that had different characteristics from all non-participants, only one non-participant match was chosen for each prenatal participant to reduce the impact of residual confounding from poor matching.

While the inability to find good matches is limiting from a methodological perspective, this finding provides credence of the program reach, as the highest-risk families were those that were enrolled. This meant that there were not many non-participants with high propensity scores, which limited the ability to closely match the HFHB prenatal program participants with highest risk. Residual confounding was expected, and further statistical adjustments were made in final regression models for imbalanced variables included in the propensity score model. Based on these findings, we would expect that outcomes in program participants may appear worse than matched non-participants due to residual differences in population characteristics; not because the program leads to poorer outcomes.

Further to this, for outcomes derived on the 18-month assessment, we identified the potential for the influence of selection bias on the final results due to the very low completion rates for the Healthy Toddler Assessment (HTA), and notable difference between groups. Those who completed the HTA were different with respect to several confounding variables, which suggests that outcomes of those missing from the 18-month analysis may be worse than outcomes of those who were included in the analysis. Those who were missing were more likely to engage in negative health behaviours during pregnancy (use of tobacco and/or substances) and were also more likely to have a family interaction factor score indicative of a poor family environment. This was more pronounced among the matched non-participants, who were also much less likely to complete the HTA, suggesting that those at greatest risk are less likely to participate in the HTA. Based on this imbalance in comparison groups, we anticipate differences in outcomes to be greater in magnitude, suggesting reported impacts of participation in the HFHB prenatal program to be underestimates of the true effects. The results of this study need to be interpreted with these caveats in mind.

Overall, results to do not provide evidence for a consistent positive impact of prenatal program participation on selected outcomes.

While a small positive impact was identified for gestational hypertension, no impact was found for the other pregnancy outcomes (e.g., gestational diabetes nor anemia). The rates of birth outcomes were also found to be similar when comparing HFHB prenatal program participants and matched non-participants. Several sensitivity analyses were performed which showed results that were consistent with those of the main analyses.

The greatest positive impact of the ***postnatal*** HFHB program was on breastfeeding behaviours[1], however these positive impacts were not found when examining the ***prenatal*** program participation specifically. As both nutritional support and information on breastfeeding are focused on in the HFHB prenatal program, positive impacts of participating were anticipated, yet no positive impacts were found for breastfeeding initiation. While a rare outcome, and likely underpowered, a positive impact on nutritional risk was not identified.

Similarly, no positive impact was found for child development at 18 months. Participants were found to be as likely as matched non-participants to have developmental concerns identified at 18 months in communication, problem solving, personal-social interactions and physical development (gross motor and fine motor skills).

4.2 Discussion of Findings

This is among the first population-based Canadian research studies to evaluate the impact of targeted public health prenatal services on pregnancy, birth and early childhood nutritional and developmental outcomes. In addition, this is among the few studies to inform on the outcomes into early life, along with the previous study on the targeted HFHB postnatal program[1]. This work helps to fill a gap in the scientific literature among the Canadian landscape.

While targeted prenatal services are offered in every province and territory across Canada, research on program impacts is scarce. There are, however, several provincial programs undergoing program review, with evaluations being conducted in British Columbia (BC) and Ontario (ON) to inform on the provision of the Nurse-Family Partnership (NFP) program that has been adapted for the Canadian context[34,35].

The recently completed BC Healthy Connections Project (BCHCP) provides valuable Canadian-specific evidence on the impact of targeted public health prenatal services on several parental, child and family outcomes[36]. Participation in the NFP was found to be associated with improved child language and mental health (in the form of problem-behaviour scores), though there was no reduction in the incidence of childhood injuries or subsequent pregnancies by the mother. The BCHCP did not examine the same outcomes as were examined in this study. A combined development outcome was examined in this study, though analysis on specific sub-scales of the ASQ, such as communication, can be a focus of future analysis to assess consistency with BCHCP results. Child mental health, injuries and subsequent pregnancies by the mother, examined in BCHCP, can also be examined using linked NB-IRDT data in future research.

While the results of the BCHCP help fill the gap in Canadian literature, it is important to note that more research is needed to inform efforts across provinces. Enrolment in the BCHCP is limited to intensive and specialized services delivered by a public health nurse only. Therefore, more research is needed to better understand the impacts of different models of targeted public health prenatal services among Canadian families.

According to a study on prenatal care conducted in Alberta[37], the types of prenatal advice women receive (i.e., relating to nutrition, weight management and substance abuse) depend on the care provider(s) they see during pregnancy. As different prenatal programs utilize different care providers to deliver targeted prenatal care (in the NFP program, for instance, only public health nurses provide services), the results of our outcome evaluation and those of this study in Alberta[37] suggest the importance of public health dietitians' involvement in providing targeted prenatal services.

Given the associations of exposure to gestational diabetes *in utero* and increased risk for chronic diseases later in life[4-6], as well as associations between prenatal anemia and diminished cognitive and motor skills performance during early childhood development[38,39], increasing the focus of programming on practices to reduce these outcomes is valuable.

While the Canadian literature on prenatal care programs and pregnancy outcomes is scarce, some Canadian research has been conducted in the area of birth outcomes, particularly birth weight and size for gestational age – both of which are suggested to have important implications for determining future health outcomes[7-13,40,41].

A Canadian study, which looked at a prenatal program for low-income women in Newfoundland and Labrador[42], showed that women who enrolled in the program early had fewer births with low birth weight compared to those who enrolled late; and among those who had many other factors that lead to increased risk of low birth weight, those who enrolled early had rates that were about the same as the province as a whole. While we did not directly compare those who enrolled early to those who enrolled later, we did not observe a difference in outcomes for those enrolled prior to 20 weeks relative to the entire sample.

Multiple studies have been conducted on the long-term health benefits of breastfeeding, with results suggesting that breastfeeding is associated with decreased incidence of infectious diseases in infancy and related health care utilization, reduced risk of Sudden Infant Death Syndrome (SIDS), preventative health impacts due to lactation and cost-savings associated with purchasing infant formula[43-45]. As such, duration of breastfeeding has been a key outcome of interest among research studies on perinatal programs and services[15-17], including our previous work on the postnatal program[1]. Though, research on breastfeeding outcomes among targeted perinatal programs has produced inconsistent results, with some studies demonstrating benefits to breastfeeding behaviours while others do not identify an impact of program participation[15,46,47].

In our previous work, it was found that HFHB postnatal program participants were more likely to breastfeed for longer duration and to be breastfeeding at 18 months than matched non-participants[1]. HFHB postnatal participants appeared to be more likely to initiate breastfeeding, but the result was not statistically significant. In comparison, the current study finds that while HFHB prenatal program participants were more likely than matched non-participants to be breastfeeding at 18 months, this result was not statistically significant.

The HFHB postnatal participants previously examined[1] included a mix of prenatal/postnatal and postnatal-only HFHB participants; thus, the results of the current study do not support the hypothesis that HFHB prenatal program participants are more likely to initiate breastfeeding, a results which was not anticipated given a focus of the prenatal programming is on breastfeeding education.

While the impact of the HFHB prenatal program on breastfeeding initiation is not statistically significant in the current study, the previous research on the HFHB postnatal program[1] suggests that participation in postnatal programs is important for sustaining breastfeeding in the longer term. This aligns with the results of a quantitative analysis conducted in the US, which identified that breastfeeding duration increased with a higher number of interactions during which breastfeeding was discussed, highlighting the importance of prenatal enrolment and duration of postnatal visiting on positive breastfeeding behaviours[48].

Nutritional risk during the first few years of life is also an important contributor to child health and can have a negative effect on developmental outcomes. Previous studies indicate that a higher nutritional risk (according to the Nutrition Screening Tool for Every Preschooler (NutriSTEP®) score, which is used in the current study) is associated with more vulnerability in development during kindergarten[49] and with an increase in concentrations of serum leptum: a hormone involved in the regulation of food intake and a biomarker of cardiometabolic risk[50].

We did not observe program impact on child nutritional risk at age 18 months, which could indicate that the benefits of receiving dietitian services during the prenatal period did not continue in the longer term postnatally. Whereas HFHB prenatal program participants had worse nutritional outcomes than the average first-time family, they were equally likely as families who were similar (but not participating) to have high or moderate nutritional risk.

These results were not necessarily surprising, given the likelihood that families at risk of adverse pregnancy outcomes may also be at risk of experiencing household food insecurity. However, there is a scarcity of literature against which to compare these findings. Along with a lack of Canadian research on the longer-term nutritional outcomes of targeted public health prenatal services, existing studies from Australia and the US tend to focus on nutritional outcomes of postnatal home visiting programs[51-54], many of which target families with preschool-age children[53,54]. While these studies find positive associations between participating in nutrition-focused programs and reduced childhood obesity[22], they do not offer insights into outcomes of targeted public health prenatal services.

It is well established that early childhood development is a fundamental social determinant of health, with development during the first years of life serving as a critical window for longer-term outcomes, including academic achievement and employment[55]. While not a direct outcome of the HFHB prenatal program, a positive impact on child development was anticipated given the services are oriented on fostering healthy development and referral to specialized services.

However, due to the high-risk population targeted for enrolment in the HFHB prenatal program, more focused and integrated services may be required to meaningfully impact child development.

Similar to nutritional outcomes, we observed similar levels of developmental concerns in early childhood among HFHB prenatal program participants as similar families who did not participate. These findings mirror those of our previous report[1]. In the separate studies on the postnatal and prenatal components of the HFHB program, participants of each were as likely as matched non-participants to have a developmental concern identified at 18 months.

These findings differ from those of the BCHCP, which shows that prenatal participants of the NFP home visiting program had significantly higher language scores and significantly lower problem-behaviour scores than comparison groups. Though, as the BCHCP used a randomized control trial (RCT) study design, confounding bias had a lesser impact on final results. However, generally, results are not consistent across the limited literature examining longer-term outcomes and impacts of targeted public health services on chid development. For instance, an earlier US study on the long-term outcomes of the NFP (formerly the Nurse Home Visitation Program, which offered visits prenatally until two years) finds few effects on child development, though noting other significant benefits for eligible families[56]. Nearly ten years later, a follow-up study by the same researchers finds better developmental outcomes in children at ages four, six and nine[23]. Thus, longer term follow-up, into primary school and beyond, may be necessary to see difference in child development.

One US systematic review finds that while participants across perinatal programs experienced significant benefits in relation to cognition and problem behaviours, benefits were less consistent regarding language skills[22]. Likewise, a UK study that evaluated the impact of the Family Nurse Partnership (which also offered visits prenatally until two years) using a combination of parentally reported data and administrative data finds a significant impact on school readiness[28,29].

Meanwhile, a recent Brazilian population-based birth cohort study finds no impact of home visiting on childhood development at age four years, overall, except when restricting to those who were enrolled during pregnancy[57]. Notably, there is limited research on the impacts of the timing of program enrolment, which was examined in our current work in combination with our previous work on postnatal program enrolment[1]. There is also limited research on program duration and intensity. We did not find a differential impact of prenatal program intensity on any outcomes.

4.3 Study Strengths and Limitations

There are several strengths and limitations of this research study. The strengths of the study include the use of population-based data, large sample sizes, propensity score matching, consideration of multiple outcomes and a long-term follow-up. The main limitations of this research are the reliance on messy data not created for research purposes, lack of individual-level data on key confounding variables, inability to identify non-participant matches for highest-risk participants and missing outcome data for those attending 18-month assessments.

4.3.1 Strengths

This study used population-based administrative data that enabled sampling from the entire population of NB. The availability of population-based administrative data, made accessible for research purposes through provincial data centres such as NB-IRDT, enables researchers to examine health impacts in population-based samples, as the sampling frame includes all residents of the province.

Data collected as part of the universal newborn screening component of the HFHB postnatal program was used to sample cohort members in this study. As health care in NB is publicly funded and all residents are eligible for a provincial health care card from birth, this study included all first-time births in the province between April 1, 2012, and March 31, 2020. No equivalent of the universal newborn screening data is available during pregnancy; thus, we used these newborn screening data as proxies for prenatal populations.

The use of population-based data sources also inherently provides access to large sample sizes. This is an advantage over RCTs. As RCTs necessitate prospective follow-up, the number of research participants that can be enrolled in a study is limited by many factors. The BCHCP used an RCT design and aimed to enroll over 1000 participants but stopped enrolment at 739, half of which were randomized to the usual care group. In this study, there were 2000 HFHB prenatal participants who were compared to 2000 higher-risk families that received usual care (i.e., non-participants). This is a substantial increase in sample size over previous research in this area.

The use of propensity score methodology is another important strength of this research study. Confounding bias relates to the mixing or confusion of effects. When comparison groups have different characteristics, the results obtained may be due to group differences. For this reason, propensity score methodology was used to identify a comparable group of non-participants. The use of methodological approaches to estimate program impacts have become more common in the literature in this area of research[57,58].

The ability to link data from different government departments longitudinally allows for long-term follow-up, enabling the evaluation of outcomes that would be more difficult to examine prospectively. This is a key reason that research in this area has typically focused on evaluating short-term outcomes, given the resources needed to maintain contact with families over long durations of time. In this study, families were followed longitudinally in administrative data from pregnancy up to the age of 18 months. The ability to link primary study data and administrative data will also enable research studies, such as the BCHCP, to continue following families prospectively, even after the RCT ends. However, this will require consent to link and time to pass as children age.

The impact on longer-term outcomes is an important knowledge gap in the research literature. More research in this area is expected with the establishment of administrative data centres. Recent research from Australia, England and Brazil provides evidence on program impacts beyond the ages examined in this study[28,57,59]. One US study that evaluated the long-term impact of the NFP demonstrated positive impacts on cognitive and behavioural outcomes at age 18 years[60]. Data from the NB Department of Education and Early Childhood Development and public colleges and universities in NB are available at NB-IRDT to enable longer-term follow-up as children age into primary school, high school and beyond.

4.3.2 Limitations

The main limitation of this research study is the reliance on data not created for research purposes. The HFHB program data are stored in an older system that is used by Public Health staff for the purposes of delivering the HFHB program, but it was never designed to be used for research purposes. The data were difficult to pull from the system, to prepare for data linkage and to use, as they were composed of many related tables. In many cases, there were errors in either the participant or baby identifiers, which required correction to enable record linkage with other data sets.

Once data were linkable, missing information in the HFHB Public Health Priority Assessment (PHPA) data was another limitation of this research study. The individual PHPA items were planned to be used in deriving propensity scores, but as a result of missing data, only summary scores were complete and could be used. The individual items contain a lot of information about families and would have been informative to use in identifying a comparable group of non-participant families. More complete data also would have improved the matching of participants to non-participants in this study. Missing, incomplete or inconsistent data are key limitations of using data that were not previously collected for research purposes. Enhancing data capture systems to ensure completeness and facilitate retrieval is needed to increase the rigour of research using administrative data.

In addition, administrative data often also lack key information about individual-level socioeconomic information, such as poverty. Poverty is a major social determinant of health and is highly correlated with eligibility for HFHB targeted services. Poverty was measured using variables for income assistance from the NB Department of Social Development, as well as Statistics Canada Census measures of median area-level income and measures of deprivation. However, there is a wide range of high-risk families that are not on social assistance; and area-level measures can be poor proxies for individual level information. Therefore, measurement of poverty in this study may have not adequately captured individual experiences. Linkage to Canada Revenue Agency tax file data would be one approach that provides a measure of accessible income for all families.

While propensity scores (PS) helped us to identify a comparable group of families, there was a limited number of non-participants with the highest PS. Therefore, PS matching was more difficult for HFHB prenatal program participants with the highest scores. This demonstrated that the most high-risk families were enrolled in the HFHB program, but also that this may have impacted results in the direction of HFHB program participants appearing to have worse outcomes than matched non-participants.

The Australian record linkage study previously mentioned[58] found negative impacts of program participation for some outcomes. As it is unlikely for the program to negatively impact families, this may relate to the inability to identify a comparable group of non-participant families. This will be a concern for the evaluation of any program when using a record linkage study. However, better matching at the higher end of propensity scores may not be possible for this population.

Missing outcome data was another limitation that may have biased the study results. When linking to outcome data, sample sizes decreased by more than one-half for the 18-month assessment. The Healthy Toddler Assessment (HTA) is universal and is encouraged using different strategies, but participation is voluntary. The poor completion rate for the HTA may have introduced selection bias influencing study results. Those who did not complete the HTA were different than those who completed it, and the differences were more pronounced among matched non-participants who were also less likely to complete the HTA. With complete HTA data, that association may have suggested greater impacts on breastfeeding duration but also lower nutritional risks and better child development. Use of complex weights, or other causal inference methodologies, may help to provide more insight into the impact of selection biases on 18-month outcomes. In addition, sample sizes were further reduced for these analyses as we did not include any HTA data collected after March 31, 2020, given the potential impacts of COVID-19 pandemic on participation, completion and data collection.

Report card data for all school grades and for public post-secondary institutions are also available at NB-IRDT and have near complete population coverage, with data available for all children who attend public school in NB. These could be considered in future research on child development to capture a full, unbiased, population-based sample. Children born in the first year of the cohort (2012) are entering grade 7 in the 2024/25 school year; thus, over the next few years, an examination of academic achievement up to high school would be possible in the current study cohort. However, one limitation of this longer-term follow-up is a consideration of the impacts of COVID-19. While a longer time period would have also allowed for a larger sample size, changes in practices may render comparison of data pre- and post-pandemic more difficult.

4.4 Conclusions

This research study evaluates the impact of participating in the Healthy Families, Healthy Babies (HFHB) prenatal program on selected pregnancy, birth and early childhood outcomes. Overall observed program effects were small in magnitude, and did not demonstrate a positive impact of prenatal program participation. This was similar to findings of our previous research[1], which evaluated impacts of participating in the HFHB postnatal program.

Taken together, our research suggests a need for improvements to the current HFHB programming to ensure the program can achieve its intended outcomes. However, it will be important to continue to monitor longer-term outcomes among program participants (e.g., academic performance through primary and middle school), given evidence from previous research demonstrating program impacts later in childhood. By leveraging linked administrative data available through research data centres, such as the New Brunswick Institute for Research, Data and Training (NB-IRDT), the long-term outcomes of programs can be evaluated with greater efficiency. While several limitations of using administrative data are acknowledged, the ability to evaluate long-term program outcomes in large population-based samples is unparalleled.

By collaborating with government partners, the results of this research will support program modifications as they are directly relevant to decision-making. Incorporating outcome evaluation in the evaluation framework for the HFHB program going forward will be critical to derive the evidence needed to guide continuous program improvements, ensuring anticipated impacts on population health are realized.

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6. Appendix

Appendix Tables

Part 1: Program Evaluation Analysis

Part 2: Program Intensity Analysis

Part 1: Program Outcome Analysis

Table 1: Descriptive statistics for baseline characteristics of study cohort

Baseline Characteristic, % (n)	Total cohort (n=20832)	Prenatal HFHB participants (n=2011)	All non-participants (n= 15716)	Matched non-participants (n=2000)
Sociodemographic Characteristics				
Age of Mother				
Average (sd)	27.0 (5.3)	20.5 (4.0)	27.7 (4.8)	22.9 (4.0)
13-19	8.1% (1688)	49.1% (988)	3.0% (465)	22.5% (449)
20-29	60.2% (12549)	46.7% (940)	62.4% (9801)	72.9% (1457)
30+	31.7% (6595)	4.1% (83)	34.7% (5450)	4.7% (94)
Marital Status				
Married	43.8% (9127)	9.4% (190)	49.2% (7728)	10.1% (202)
Single	51.2% (10672)	87.7% (1763)	45.8% (7193)	86.6% (1732)
Other	5.0% (1033)	2.9% (58)	5.1% (795)	3.3% (66)
Has Partner	41.8% (8718)	10.0% (202)	46.4% (7292)	7.6% (151)
Immigrant	5.8% (1218)	3.2% (64)	5.4% (855)	3.6% (72)
PHPA Family Interaction Factors Score				
0	52.9% (11029)	4.0% (81)	66.3% (10419)	13.5% (269)
1 to 9	33.2% (6915)	34.1% (685)	28.1% (4411)	50.5% (1010)
10+	13.9% (2888)	61.9% (1245)	5.6% (886)	36.1% (721)
Recipient of Social Assistance	20.4% (4240)	72.0% (1447)	13.3% (2088)	64.1% (1282)
Socioeconomic Characteristics				
Area-Level Income				
$0 - $44,999	17.9% (3718)	34.0% (680)	28.2% (4407)	32.4% (648)
$45,000 - $59,999	29.3% (6082)	36.9% (738)	15.2% (2386)	39.2% (784)
$60,000+	52.8% (10944)	29.1% (582)	56.6% (8858)	28.4% (568)
Area-Level Residential Instability (Quintile)				
1st	19.2% (3994)	11.6% (232)	20.8% (3255)	11.1% (222)
2nd	19.7% (4094)	16.4% (329)	20.1% (3157)	16.8% (335)
3rd	19.6% (4068)	17.3% (347)	20.2% (3159)	19.2% (383)
4th	19.8% (4120)	20.3% (406)	19.6% (3075)	20.0% (400)

5th	21.6% (4494)	34.3% (687)	19.3% (3025)	33.0% (660)
Area-Level Economic Dependency (Quintile)				
1st	30.5% (6341)	17.8% (357)	32.4% (5083)	18.5% (369)
2nd	21.9% (4554)	22.5% (451)	21.9% (3438)	21.1% (421)
3rd	18.5% (3836)	19.3% (387)	18.5% (2900)	20.3% (405)
4th	16.1% (3337)	21.9% (438)	15.1% (2360)	20.8% (415)
5th	13.0% (2702)	18.4% (368)	12.1% (1890)	19.5% (390)
Area-Level Ethno-Cultural Composition (Quintile)				
1st	13.1% (2713)	17.6% (352)	12.3% (1931)	19.4% (388)
2nd	16.7% (3473)	16.4% (328)	17.0% (2661)	15.6% (311)
3rd	21.1% (4388)	20.7% (415)	21.5% (3366)	20.3% (406)
4th	21.2% (4412)	19.0% (381)	21.4% (3357)	20.4% (408)
5th	27.9% (5784)	26.2% (525)	27.8% (4356)	24.4% (487)
Area-Level Situational Vulnerability (Quintile)				
1st	28.0% (5816)	12.4% (249)	30.3% (4745)	12.1% (242)
2nd	21.5% (4472)	18.8% (376)	22.1% (3455)	19.9% (398)
3rd	18.9% (3922)	20.5% (411)	18.8% (2940)	20.7% (413)
4th	16.9% (3503)	22.7% (454)	15.8% (2472)	22.6% (452)
5th	14.7% (3057)	25.5% (511)	13.1% (2059)	24.8% (495)
Health-Related Characteristics				
Mental Illness	51.9% (10820)	66.9% (1346)	48.2% (7581)	64.9% (1297)
Mood/Anxiety Disorder	43.4% (9036)	53.9% (1084)	40.1% (6299)	53.7% (1073)
Asthma	12.6% (2623)	17.6% (353)	11.8% (1855)	16.4% (328)
Diabetes	1.3% (269)	1.2% (24)	1.2% (188)	1.7% (34)
Hypertension	2.3% (469)	0.8% (17)	2.3% (365)	1.1% (22)
Health-Behaviour Characteristics				
Recommended weight gain	24.6% (1981)	21.2% (135)	25.1% (1488)	20.3% (140)
Folic acid intake during pregnancy	91.8% (8276)	83.6% (611)	92.9% (6158)	87.8% (690)
Smoked before pregnancy	20.4% (1821)	54.9% (405)	16.2% (1059)	42.1% (327)
Smoked during pregnancy	11.7% (1076)	37.0% (281)	8.4% (566)	28.4% (225)

Smoked at delivery	8.0% (706)	28.2% (197)	5.7% (370)	21.6% (159)
Alcohol before pregnancy	25.0% (2169)	23.6% (168)	25.1% (1601)	24.0% (182)
Alcohol during pregnancy	1.0% (95)	1.9% (14)	0.8% (53)	1.4% (11)
Substance use during pregnancy	8.2% (772)	26.6% (202)	5.6% (387)	19.1% (155)
Health care Utilization (during pregnancy)				
Number of Physician Visits During First Trimester				
0 to 1 visits	16.8% (3498)	20.8% (418)	16.1% (2528)	19.8% (396)
2 to 4 visits	61.4% (12785)	56.0% (1127)	63.4% (9959)	57.1% (1142)
5+ visits	21.8% (4549)	23.2% (466)	20.5% (3229)	23.1% (462)
Number of Physician Visits During Second Trimester				
0 to 3 visits	16.2% (3374)	19.8% (398)	16.0% (2520)	18.2% (364)
4 to 6 visits	60.8% (12665)	54.2% (1090)	62.4% (9813)	55.1% (1102)
7+ visits	23.0% (4793)	26.0% (523)	21.5% (3383)	26.7% (534)
Number of Physician Visits During Third Trimester				
0 to 7 visits	32.7% (6806)	36.9% (742)	31.7% (4976)	35.5% (710)
8 to 10 visits	40.3% (8400)	36.5% (735)	41.6% (6537)	37.4% (747)
11+ visits	27.0% (5626)	26.6% (534)	26.7% (4203)	27.2% (543)
Used Walk-in Clinic	18.1% (3773)	18.0% (361)	17.5% (2752)	18.1% (362)
Hospitalization	6.2% (1297)	10.2% (205)	5.2% (823)	8.3% (165)

Table 2: Adjusted prevalence and measures of risk for pregnancy, birth and child health outcomes

Outcomes	All non-participants	Prenatal HFHB participants	Matched non-participants	Prenatal vs. Matched	
				Adjusted* Risk Difference (95%CI)	Adjusted* Risk Ratio (95%CI)
Pregnancy					
Anemia	1.7%	2.2%	2.4%	-0.2% (-1.1 to 0.8)	0.92 (0.61 to 1.42)
Gestational Diabetes	5.7%	5.8%	4.9%	1.0% (-0.6 to 2.5)	1.19 (0.90 to 1.58)
Gestational Hypertension	5.3%	3.5%	4.8%	-1.3% (-2.6 to 0.0)	0.72 (0.53 to 1.00)
Birth					
Preterm birth	4.5%	7.1%	5.8%	1.2% (-0.4 to 2.8)	1.20 (0.94 to 1.54)
Poor APGAR score	2.8%	4.8%	4.1%	0.7% (-0.7 to 2.0)	1.17 (0.86 to 1.58)
Large for GA	10.8%	9.4%	11.2%	-1.8% (-3.8 to 0.2)	0.84 (0.69 to 1.02)
Small for GA	5.0%	8.2%	6.9%	1.3% (-0.4 to 3.0)	1.19 (0.95 to 1.49)
Breastfeeding behaviours					
Breastfeeding initiation (HTA)	84,2%	73.2%	68.4%	4.8% (0.6 to 9.1)	1.07 (1.01 to 1.14)
Breastfeeding initiation (PerinatalNB)	87.4%	75.9%	75.8%	0.2% (-4.0 to 4.3)	1.00 (0.95 to 1.06)
Breastfeeding initiation (combined)	86.6%	76.7%	73.7%	3.0% (-0.2 to 6.2)	1.04 (1.00 to 1.09)
Breastfeeding @18 mos	9.0%	8.4%	6.2%	2.2% (-0.5 to 4.9)	1.36 (0.94 to 1.97)
Breastfeeding duration					0.97 (0.92 to 1.02)
0 to 1 mos	30.4%	58.9%	55.7%		
>1 mos to 6 mos	25.5%	23.5%	22.9%		
>6 mos to 12 mos	23.5%	7.5%	10.7%		
>12 mos	20.6%	10.1%	10.6%		
Nutritional Risk					
High risk	0.6%	2.0%	2.1%	-0.1%	0.96

				(-1.5 to 1.3)	(0.49 to 1.88)
Moderate risk	3.1%	12.0%	10.0%	2.0% (-1.1 to 5.1)	1.20 (0.90 to 1.60)
Development					
Concern identified	5.5%	10.5%	10.4%	0.1% (-2.9 to 3.1)	1.01 (0.76 to 1.34)
Potential concern identified	16.2%	32.7%	28.9%	3.9% (-0.7 to 8.4)	1.13 (0.98 to 1.32)

*All models adjusted for year of birth, health region, mother's age, marital status, had a partner, immigrant status, area-level median income, recipient of income assistance and family interaction factors score at birth.

Table 3: Descriptive statistics for propensity score variables by completion of the Healthy Toddler Assessment (HTA)

Baseline Characteristic, % (n)	Prenatal HFHB participants (n=2011)		Matched non-participants (n=2000)	
	HTA not completed	HTA completed	HTA not completed	HTA completed
Sociodemographic Characteristics				
Age of Mother				
Average (sd)	20.2 (3.6)	20.8 (4.2)	22.5 (4.0)	23.4 (4.1)
13-19	52.9% (506)	45.7% (482)	25.7% (311)	17.5% (138)
20-29	44.0% (421)	49.2% (519)	70.0% (848)	77.3% (609)
30+	3.0% (29)	5.1% (54)	4.4% (53)	5.2% (41)
Marital Status				
Married	8.8% (84)	10.1% (106)	9.9% (120)	10.4% (82)
Single	88.3% (844)	87.1% (919)	86.9% (1053)	86.2% (679)
Other	2.9% (28)	2.8% (30)	3.2% (39)	3.4% (27)
Has Partner	9.7% (93)	10.3% (109)	7.6% (92)	7.5% (59)
Immigrant	3.0% (29)	3.3% (35)	4.7% (57)	1.9% (15)
PHPA Family Interaction Factors Score				
0	4.1% (39)	4.0% (42)	9.0% (109)	20.3% (160)
1 to 9	31.4% (300)	36.5% (385)	49.5% (600)	52.0% (410)
10+	64.5% (617)	59.5% (628)	41.5% (503)	27.7% (218)
Recipient of Social Assistance	72.0% (688)	71.9% (759)	63.8% (773)	64.6% (509)
Socioeconomic Characteristics				
Area-Level Income Quintile				
$0 - $44,999	35.7% (338)	32.5% (342)	36.8% (446)	25.6% (202)
$45,000 - $59,999	33.5% (318)	39.9% (420)	34.7% (421)	46.1% (363)
$60,000+	30.8% (292)	27.6% (290)	28.5% (345)	28.3% (223)
Area-Level Residential Instability Quintile				
1st	12.3% (117)	10.9% (115)	11.3% (137)	10.8% (85)
2nd	14.9% (141)	17.9% (188)	15.0% (182)	19.4% (153)
3rd	14.4% (137)	20.0% (210)	15.3% (185)	25.1% (198)
4th	20.9% (198)	19.8% (208)	20.0% (242)	20.1% (158)
5th	37.5% (356)	31.5% (331)	38.4% (466)	24.6% (194)

Area-Level Economic Dependency Quintile				
1st	22.6% (214)	13.6% (143)	20.7% (251)	15.0% (118)
2nd	23.9% (227)	21.3% (224)	22.1% (268)	19.4% (153)
3rd	18.4% (175)	20.2% (212)	20.4% (247)	20.1% (158)
4th	20.6% (195)	23.1% (243)	19.5% (236)	22.7% (179)
5th	14.5% (138)	21.9% (230)	17.3% (210)	22.8% (180)
Area-Level Ethno-Cultural Composition Quintile				
1st	12.6% (120)	22.1% (232)	14.5% (176)	26.9% (212)
2nd	15.3% (145)	17.4% (183)	14.6% (177)	17.0% (134)
3rd	22.2% (211)	19.4% (204)	21.8% (264)	18.0% (142)
4th	19.6% (186)	18.5% (195)	21.0% (254)	19.5% (154)
5th	30.2% (287)	22.6% (238)	28.1% (341)	18.5% (146)
Area-Level Situational Vulnerability Quintile				
1st	13.1% (124)	11.9% (125)	12.8% (155)	11.0% (87)
2nd	20.0% (190)	17.7% (186)	20.6% (250)	18.8% (148)
3rd	22.3% (212)	18.9% (199)	21.3% (258)	19.7% (155)
4th	22.2% (211)	23.1% (243)	21.5% (260)	24.4% (192)
5th	22.3% (212)	28.4% (299)	23.8% (289)	26.1% (206)
Birth Timing and Location				
Year of Birth				
2012	17.8% (170)	12.2% (129)	14.8% (179)	12.9% (102)
2013	15.1% (144)	17.4% (183)	15.3% (185)	13.6% (107)
2014	14.8% (141)	16.3% (172)	12.8% (155)	16.1% (127)
2015	10.6% (101)	12.3% (130)	11.0% (133)	14.3% (113)
2016	7.9% (75)	10.8% (114)	9.7% (118)	12.1% (95)
2017	8.4% (80)	14.2% (150)	9.2% (112)	14.0% (110)
2018	7.5% (72)	11.3% (119)	8.8% (107)	10.2% (80)
2019	13.3% (127)	5.5% (58)	13.9% (169)	6.9% (54)
2020	4.8% (46)	0.0% (0)	4.5% (54)	0.0% (0)
Season of Birth				
Winter	22.3% (213)	23.0% (243)	22.3% (270)	22.8% (180)
Spring	26.3% (251)	26.8% (283)	27.5% (333)	26.6% (210)
Summer	27.3% (261)	25.8% (272)	25.9% (314)	27.0% (213)

Fall	24.2% (231)	24.4% (257)	24.3% (295)	23.5% (185)
Health Zone at Birth				
Zone 1	23.0% (220)	16.8% (177)	23.5% (285)	18.1% (143)
Zone 2	27.3% (261)	22.5% (237)	29.9% (362)	15.7% (124)
Zone 3	26.2% (250)	24.1% (254)	25.9% (314)	20.1% (158)
Zone 4	6.2% (59)	6.5% (69)	4.7% (57)	9.9% (78)
Zone 5	3.8% (36)	4.2% (44)	4.5% (54)	3.9% (31)
Zone 6	9.6% (92)	14.9% (157)	7.3% (89)	19.3% (152)
Zone 7	4.0% (38)	11.1% (117)	4.2% (51)	12.9% (102)
Health-Related Characteristics				
Mental Illness	66.8% (639)	67.0% (707)	65.7% (796)	63.6% (501)
Mood/Anxiety Disorder	53.9% (515)	53.9% (569)	54.4% (659)	52.5% (414)
Asthma	16.0% (153)	19.0% (200)	15.4% (187)	17.9% (141)
Diabetes	1.1% (10)	1.3% (14)	1.7% (20)	1.8% (14)
Hypertension	0.7% (7)	1.0% (10)	0.8% (10)	1.5% (12)
Health-Behaviour Characteristics				
Recommended weight gain	17.6% (55)	24.9% (82)	19.2% (87)	22.4% (53)
Folic acid intake during pregnancy	77.8% (267)	88.8% (347)	86.4% (432)	90.2% (258)
Smoked before pregnancy	59.1% (211)	50.9% (194)	43.4% (217)	39.7% (110)
Smoked during pregnancy	41.1% (149)	33.3% (132)	29.0% (148)	27.4% (77)
Smoked at delivery	31.8% (105)	24.9% (92)	22.4% (105)	20.3% (54)
Alcohol before pregnancy	24.3% (83)	23.1% (86)	24.7% (122)	22.5% (60)
Substance use during pregnancy	33.6% (122)	20.8% (83)	21.9% (114)	14.0% (41)
Health care Utilization (during pregnancy)				
Number of Physician Visits During First Trimester				
0 to 1 visits	22.9% (219)	18.9% (199)	22.1% (268)	16.2% (128)
2 to 4 visits	55.5% (531)	56.5% (596)	55.1% (668)	60.2% (474)
5+ visits	21.5% (206)	24.6% (260)	22.8% (276)	23.6% (186)
Number of Physician Visits During Second Trimester				

0 to 3 visits	21.0% (201)	18.7% (197)	19.0% (230)	17.0% (134)
4 to 6 visits	53.3% (510)	55.0% (580)	54.5% (661)	56.0% (441)
7+ visits	25.6% (245)	26.4% (278)	26.5% (321)	27.0% (213)
Number of Physician Visits During Third Trimester				
0 to 7 visits	39.3% (376)	34.7% (366)	34.7% (420)	36.8% (290)
8 to 10 visits	35.1% (336)	37.8% (399)	36.6% (444)	38.5% (303)
11+ visits	25.5% (244)	27.5% (290)	28.7% (348)	24.7% (195)
Used Walk-in Clinic	18.3% (175)	17.6% (186)	17.0% (206)	19.8% (156)
Hospitalization	10.3% (98)	10.1% (107)	8.424% (102)	8.030% (63)

Table 4: Descriptive statistics for pregnancy and birth outcome variables by completion of the Healthy Toddler Assessment (HTA)

Outcomes, % (n)	Prenatal HFHB participants (n=2011)		Matched non-participants (n=2000)	
	No HTA	Has HTA	No HTA	Has HTA
Pregnancy				
Anemia	2.4% (23)	2.1% (22)	1.9% (23)	2.4% (19)
Gestational Diabetes	3.8% (36)	5.7% (60)	4.5% (55)	4.7% (37)
Gestational Hypertension	2.9% (28)	3.2% (34)	4.9% (59)	5.3% (42)
Recommended weight gain	17.6% (55)	24.9% (82)	19.2% (87)	22.4% (53)
Folic acid intake during pregnancy	77.8% (267)	88.8% (347)	86.4% (432)	90.2% (258)
Smoked before pregnancy	59.1% (211)	50.9% (194)	43.4% (217)	39.7% (110)
Smoked during pregnancy	41.1%) (149)	33.3% (132)	29.0% (148)	27.4% (77)
Smoked at delivery	31.8% (105)	24.9% (92)	22.4% (105)	20.3% (54)
Substance use during pregnancy	33.6% (122)	20.8% (83)	21.9% (114)	14.0% (41)
Birth				
Preterm birth	7.5% (72)	6.1% (64)	6.6% (80)	4.4% (35)
Poor APGAR score	4.5% (43)	4.6% (49)	4.8% (58)	3.0% (24)
Large for GA	9.0% (86)	9.8% (103)	10.3% (125)	12.4% (98)
Small for GA	8.2% (78)	7.8% (82)	7.3% (88)	6.5% (51)
Breastfeeding at birth				
Breastfeeding initiation (PerinatalNB)	74.7% (272)	69.1% (273)	74.2% (380)	73.5% (211)

Part 2: Program Intensity Analysis

Table 5: Descriptive statistics of prenatal HFHB program intensity

Program Characteristic, % (n)	All prenatal participants (n=2011)	6-15 prenatal HFHB visits (n=1030)	1-5 prenatal HFHB visits (n=503)	Enrolled, but no prenatal HFHB visits (n=478)
Total prenatal HFHB visits		51.2%	25.0%	23.8%
Trimester started HFHB program				
First	41.8% (840)	64.6% (543)	13.0% (109)	22.4% (188)
Second	46.6% (937)	48.8% (457)	28.3% (265)	22.9% (215)
Third	11.6% (234)	12.8% (30)	55.1% (129)	32.1% (75)
Started HFHB prenatal program +/- 20 weeks				
Before	68.8% (1383)	62.5% (864)	14.3% (198)	23.2% (321)
After	31.2% (628)	26.4% (166)	48.6% (305)	25.0% (157)

Table 6: Descriptive statistics for baseline characteristics of prenatal HFHB participants stratified by participation status

Baseline Characteristic, % (n)	Total cohort (n=20832)	Enrolled in Prenatal HFHB, had 1+ prenatal visits (n=1533)	Enrolled in Prenatal HFHB, did not participate (n=478)	Matched non-participants (n=2000)
Sociodemographic Characteristics				
Age of Mother				
13-19	8.1% (1688)	49.2% (755)	48.7% (233)	22.5% (449)
20-29	60.2% (12549)	46.8% (717)	46.7% (223)	72.9% (1457)
30+	31.7% (6595)	4.0% (61)	4.6% (22)	4.7% (94)
Marital Status				
Married	43.8% (9127)	9.5% (146)	9.2% (44)	10.1% (202)
Single	51.2% (10672)	87.5% (1342)	88.1% (421)	86.6% (1732)
Other	5.0% (1033)	2.9% (45)	2.7% (13)	3.3% (66)
Has Partner	41.8% (8718)	10.6% (163)	8.2% (39)	7.6% (151)
Immigrant	5.8% (1218)	3.5% (53)	2.3% (11)	3.6% (72)
PHPA Family Interaction Factor Score				
0	52.9% (11029)	3.3% (50)	6.5% (31)	13.5% (269)
1 to 9	33.2% (6915)	33.1% (508)	37.0% (177)	50.5% (1010)
10+ (poorer)	13.9% (2888)	63.6% (975)	56.5% (270)	36.1% (721)
Recipient of Social Assistance	20.4% (4240)	73.7% (1129)	66.5% (318)	64.1% (1282)
Socioeconomic Characteristics				
Area-Level Income Quintile				
$0 - $44,999	17.9% (3718)	36.5% (556)	38.2% (182)	32.4% (648)
$45,000 - $59,999	29.3% (6082)	35.6% (543)	28.8% (137)	39.2% (784)
$60,000+	52.8% (10944)	27.9% (425)	33.0% (157)	28.4% (568)
Area-Level Residential Instability Quintile				
1st	19.2% (3994)	11.5% (175)	12.0% (57)	11.1% (222)
2nd	19.7% (4094)	16.8% (256)	15.3% (73)	16.8% (335)
3rd	19.6% (4068)	17.1% (261)	18.0% (86)	19.2% (383)
4th	19.8% (4120)	19.2% (293)	23.7% (113)	20.0% (400)
5th	21.6% (4494)	35.4% (539)	31.0% (148)	33.0% (660)

Area-Level Economic Dependency Quintile				
1st	30.5% (6341)	17.6% (268)	18.7% (89)	18.5% (369)
2nd	21.9% (4554)	21.3% (325)	26.4% (126)	21.1% (421)
3rd	18.5% (3836)	18.4% (281)	22.2% (106)	20.3% (405)
4th	16.1% (3337)	22.7% (346)	19.3% (92)	20.8% (415)
5th	13.0% (2702)	20.0% (304)	13.4% (64)	19.5% (390)
Area-Level Ethno-Cultural Composition Quintile				
1st	13.1% (2713)	18.7% (285)	14.0% (67)	19.4% (388)
2nd	16.7% (3473)	16.0% (244)	17.6% (84)	15.5% (311)
3rd	21.1% (4388)	20.5% (313)	21.4% (102)	20.3% (406)
4th	21.2% (4412)	18.4% (281)	21.0% (100)	20.4% (408)
5th	27.9% (5784)	26.3% (401)	26.0% (124)	24.4% (487)
Area-Level Situational Vulnerability Quintile				
1st	28.0% (5816)	12.8% (195)	11.3% (54)	12.1% (242)
2nd	21.5% (4472)	18.0% (274)	21.4% (102)	19.9% (398)
3rd	18.9% (3922)	21.3% (325)	18.0% (86)	20.7% (413)
4th	16.9% (3503)	21.9% (333)	25.4% (121)	22.6% (452)
5th	14.7% (3057)	26.0% (397)	23.9% (114)	24.8% (495)
Birth Timing and Location				
Year of Birth				
2012	10.6% (2206)	15.9% (243)	11.7% (56)	14.1% (281)
2013	13.7% (2869)	16.7% (256)	14.9% (71)	14.6% (292)
2014	13.4% (2800)	16.6% (254)	12.3% (59)	14.1% (282)
2015	12.3% (2563)	10.6% (163)	14.2% (68)	12.3% (246)
2016	12.1% (2525)	9.7% (149)	8.4% (40)	10.7% (213)
2017	12.0% (2509)	11.0% (168)	13.0% (62)	11.1% (222)
2018	11.7% (2444)	8.6% (131)	12.5% (60)	9.4% (187)
2019	11.4% (2379)	8.9% (137)	10.0% (48)	11.2% (223)
2020	2.6% (537)	2.1% (32)	2.9% (14)	2.7% (54)
Season of Birth				
Winter	23.1% (4821)	22.6% (346)	23.1% (110)	22.5% (450)
Spring	25.8% (5376)	26.5% (406)	26.8% (128)	27.2% (543)
Summer	27.3% (5676)	26.3% (403)	27.2% (130)	26.4% (527)

Fall	23.8% (4959)	24.7% (378)	23.1% (110)	24.0% (480)
Health Zone at Birth				
Zone 1	30.5% (6348)	20.7% (318)	16.5% (79)	21.4% (428)
Zone 2	24.0% (5001)	22.2% (340)	33.0% (158)	24.3% (486)
Zone 3	24.8% (5168)	25.8% (395)	22.8% (109)	23.6% (472)
Zone 4	5.6% (1170)	6.6% (101)	5.6% (27)	6.8% (135)
Zone 5	2.6% (545)	3.7% (57)	4.8% (23)	4.3% (85)
Zone 6	8.1% (1691)	12.9% (198)	10.7% (51)	12.1% (241)
Zone 7	4.4% (909)	8.1% (124)	6.5% (31)	7.7% (153)
Health-Related Characteristics (before pregnancy)				
Mental Illness	51.9% (10820)	67.2% (1031)	65.9% (315)	64.9% (1297)
Mood/Anxiety Disorder	43.4% (9036)	53.5% (820)	55.2% (264)	53.7% (1073)
Asthma	12.6% (2623)	17.6% (270)	17.4% (83)	16.4% (328)
Diabetes	1.3% (269)	0.9% (14)	2.1% (10)	1.7% (34)
Hypertension	2.3% (469)	0.7% (11)	1.3% (6)	1.1% (22)
Health care Utilization (during pregnancy)				
Number of Physician Visits During First Trimester				
0 to 1 visits	16.8% (3498)	21.1% (323)	19.9% (95)	19.8% (396)
2 to 4 visits	61.4% (12785)	56.4% (864)	55.0% (263)	57.1% (1142)
5+ visits	21.8% (4549)	22.6% (346)	25.1% (120)	23.1% (462)
Number of Physician Visits During Second Trimester				
0 to 3 visits	16.2% (3374)	20.3% (311)	18.2% (87)	18.2% (364)
4 to 6 visits	60.8% (12665)	53.6% (821)	56.3% (269)	55.1% (1102)
7+ visits	23.0% (4793)	26.2% (401)	25.5% (122)	26.7% (534)
Number of Physician Visits During Third Trimester				
0 to 7 visits	32.7% (6806)	36.1% (554)	39.3% (188)	35.5% (710)
8 to 10 visits	40.3% (8400)	37.4% (574)	33.7% (161)	37.4% (747)
11+ visits	27.0% (5626)	26.4% (405)	27.0% (129)	27.2% (543)
Used Walk-in Clinic	18.1% (3773)	19.0% (291)	14.6% (70)	18.1% (362)
Hospitalization	6.2% (1297)	10.7% (164)	8.6% (41)	8.3% (165)

Table 7: Descriptive statistics for pregnancy, birth and child health outcomes of prenatal HFHB participants stratified by participation status

Outcomes	Enrolled in Prenatal HFHB, had 1+ prenatal visits	Enrolled in Prenatal HFHB, did not participate	Matched non-participants
Pregnancy			
Anemia	2.4%	1.9%	2.1%
Gestational Diabetes	4.7%	5.0%	4.6%
Gestational Hypertension	3.0%	3.3%	5.1%
Recommended weight gain	21.4%	21.3%	20.3%
Folic acid intake during pregnancy	84.1%	82.4%	87.8%
Smoked before pregnancy	54.7%	55.3%	42.1%
Smoked during pregnancy	35.1%	42.2%	28.4%
Smoked at delivery	26.3%	33.2%	21.6%
Substance use during pregnancy	25.1%	31.6%	19.1%
Birth			
Preterm birth	6.8%	6.7%	5.8%
Poor APGAR score	4.9%	3.6%	4.1%
Large for GA	9.5%	9.0%	11.2%
Small for GA	8.0%	8.0%	7.0%
Breastfeeding			
Breastfeeding initiation (HTA)	68.5%	66.2%	67.3%
Breastfeeding initiation (PerinatalNB)	74.8%	63.8%	74.0%
Breastfeeding initiation (combined)	72.7%	67.7%	73.1%
Breastfeeding @18 mos	7.0%	5.5%	5.5%
Breastfeeding duration			
0 to 1 mos	58.3%	61.3%	55.7%
>1 mos to 6 mos	24.3%	20.1%	22.9%
>6 mos to 12 mos	7.2%	9.1%	10.7%

>12 mos	10.2%	9.6%	10.6%
Nutritional Risk			
High risk	2.3%	2.5%	2.1%
Moderate risk	11.1%	9.9%	6.9%
Developmental			
Concern identified	10.8%	12.3%	10.3%
Potential concern identified	21.8%	21.1%	17.9%

Table 8: Adjusted risk ratios for pregnancy, birth and child health outcomes stratified by program intensity variables

Outcomes	Full sample (n=2000)	1+ HFHB prenatal visits (n=1533)	7+ HFHB prenatal visits (n=753)	Enrolled before 20 weeks (n=1383)
Pregnancy				
Anemia	0.92 (0.61 to 1.42)	1.00 (0.63 to 1.58)	1.02 (0.61 to 1.72)	0.80 (0.50 to 1.31)
Gestational Diabetes	1.19 (0.90 to 1.58)	1.18 (0.87 to 1.60)	1.13 (0.77 to 1.65)	1.15 (0.84 to 1.58)
Gestational Hypertension	0.72 (0.53 to 1.00)	0.71 (0.50 to 1.02)	0.44 (0.26 to 0.77)	0.60 (0.41 to 0.88)
Birth				
Preterm birth	1.20 (0.94 to 1.54)	1.21 (0.92 to 1.58)	0.98 (0.69 to 1.39)	1.20 (0.91 to 1.59)
Poor APGAR score	1.17 (0.86 to 1.58)	1.25 (0.91 to 1.71)	1.13 (0.77 to 1.66)	1.16 (0.84 to 1.62)
Large for GA	0.84 (0.69 to 1.02)	0.84 (0.68 to 1.04)	0.85 (0.66 to 1.10)	0.88 (0.71 to 1.09)
Small for GA	1.19 (0.95 to 1.49)	1.18 (0.93 to 1.51)	1.21 (0.90 to 1.61)	1.25 (0.98 to 1.60)
Breastfeeding behaviours				
Breastfeeding initiation (HTA)	1.07 (1.01 to 1.14)	1.08 (1.02 to 1.15)	1.11 (1.04 to 1.18)	1.05 (0.99 to 1.12)
Breastfeeding initiation (PerinatalNB)	1.00 (0.95 to 1.06)	1.04 (0.99 to 1.10)	1.07 (1.00 to 1.14)	0.99 (0.93 to 1.06)
Breastfeeding initiation (combined)	1.04 (1.00 to 1.09)	1.06 (1.02 to 1.11)	1.08 (1.03 to 1.13)	1.03 (0.99 to 1.08)
Breastfeeding @18 mos	1.36 (0.94 to 1.97)	1.40 (0.95 to 2.07)	1.51 (0.97 to 2.36)	1.31 (0.87 to 1.99)
Breastfeeding duration	0.97 (0.92 to 1.02)	0.97 (0.92 to 1.03)	0.99 (0.92 to 1.05)	0.95 (0.90 to 1.01)
Nutritional Risk				
High risk	0.96 (0.49 to 1.88)	0.87 (0.42 to 1.78)	0.59 (0.24 to 1.46)	0.95 (0.46 to 1.98)
Moderate risk	1.20 (0.90 to 1.60)	1.19 (0.88 to 1.60)	1.17 (0.83 to 1.64)	1.22 (0.89 to 1.66)
Developmental				
Concern identified	1.01 (0.76 to 1.34)	0.96 (0.71 to 1.30)	0.95 (0.67 to 1.35)	0.99 (0.73 to 1.35)
Potential concern identified	1.13 (0.98 to 1.32)	1.10 (0.94 to 1.29)	1.14 (0.96 to 1.36)	1.19 (1.02 to 1.40)

*All models adjusted for year of birth, health region, mothers age, marital status, had a partner, immigrant status, area-level median income, recipient of income assistance and family interaction factors score at birth.