Mount Saint Vincent University

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Prenatal iron supplementation in Nova Scotia: an exploratory cross-sectional study of knowledge, attitudes and practices.

by

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Abstract

Introduction: Iron demands rise during pregnancy, and deficiency can lead to anemia, increasing the risk of preeclampsia, preterm delivery, cesarean section, postpartum hemorrhage, transfusion, and maternal death. For the fetus, anemia increases the risk of low birth weight, neonatal intensive care admission, and mortality. Beyond health effects, anemia imposes medical expenses and reduces productivity, burdening individuals and national economies. To meet the recommended dietary allowance (27 mg/day), Health Canada advises pregnant individuals to take multivitamins containing 16–20 mg of elemental iron. However, in 2023, 15.1% of pregnant women in Canada were anemic, and little is known about the knowledge, attitudes, and practices regarding anemia and iron supplementation in high-income countries like Canada.

Objective: To identify the knowledge, attitudes, and practices regarding iron deficiency anemia (IDA) and iron supplementation during pregnancy in Nova Scotia, and understand if they differ by adherence to national iron supplementation guidelines for pregnancy.

Methods: This exploratory study applied the Knowledge, Attitudes, and Practices (KAP) framework. Data were collected online from March to May 2025 among Nova Scotia residents aged ≥18 years who were at least five months pregnant or had given birth within the past year (n=319). Adherence to national guidelines was defined as taking ≥16 mg of elemental iron daily across all trimesters. Knowledge was assessed when correct answers exceeded incorrect ones for each topic, and attitudes were dichotomized (agree/disagree) from a five-point Likert scale. Categorical variables were analyzed using Chi-square tests, and continuous variables with independent t-tests ($p<0.05$).

Results: Overall, 62% of participants adhered to Health Canada's iron supplementation guidelines during pregnancy. Nearly all (95%) participants took a supplement, of which there were 42 unique Prenatal Micronutrient Supplements reported, with 85% taking them daily. Most products contained the recommended iron dose (mean ± SD: 26.2 ± 4.7 mg; mode: 27 mg), though 16% lacked iron entirely. Additionally, 58% of participants used an Additional Iron Supplement, averaging 97.0 ± 70.3 mg (range: 10–300 mg), most often 3–4 times per week. Physicians were the primary source of information about both IDA (56%) and prenatal supplements (53%). Participants demonstrated strong knowledge and positive attitudes, though adherence did not significantly differ by either factor.

Discussion and Conclusion: Although most pregnant individuals follow provider advice and take iron supplements daily, 16% of supplements contained no iron. Current Canadian guidelines may need to be updated to align with other international recommendations (i.e. WHO intermittent dosing), and Canadian regulatory frameworks for natural health product labeling could be reconsidered to better align with these recommendations.

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Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

ACOG - American College of Obstetricians and Gynecologists

AI - Adequate intake

CDC - Centers for Disease Control and Prevention

CCHS - Canadian Community Health Survey

CI - Confidence interval

DRI - Dietary reference intake

EAR - Estimated average requirement

FAO - Food and Agriculture Organization of the United Nations

GDP - Gross domestic product

GI - Gastrointestinal

Hb - Hemoglobin

HIC - High-income country

HIV - Human Immunodeficiency Virus

IFA - Iron-folic acid combination

IQR - Interquartile range

ID - Iron deficiency

IDA - Iron deficiency anemia

KAP - Knowledge, attitudes and practices

LIC - Low-income country

MMS – Multi Micronutrient Supplement

NHANES - National Health and Nutrition Examination Survey

NHP - Health Canada's Natural Health Products

RBC - Red blood cells

RDA - Recommended dietary allowance

SD - Standard deviation

UK - United Kingdom

UL - Tolerable upper intake level

UNICEF - United Nations Children's Fund

USA - United States of America

WRA - Non-pregnant women of reproductive age

WHO - World Health Organization

1 Introduction

During the fetal and neonatal periods, the human brain has an increased need for iron to support crucial neuronal processes that influence behaviour, affection, emotions, and cognitive functioning (1). Given the importance that anemia may have on the first 1,000 days, of life, the World Health Organization (WHO) resolved to halve the global prevalence of anemia among non-pregnant women of reproductive age (WRA) by 2030 (2). However, an alarming 15.1% of pregnant women in Canada had anemia in 2023 (3). Anemia has serious implications for both mothers and infants. In pregnancy, it can increase the risk of preeclampsia, preterm delivery, cesarean section, and postpartum hemorrhage, leading to low blood pressure, need for blood transfusion, and even maternal death (4–6). In children, anemia can lead to low birth weight, macrosomia, admission to the neonatal intensive care unit, and perinatal and neonatal mortality (5–7). In addition to health impacts, the direct and indirect financial costs of anemia due to health expenses, reduced work capacity and performance, impair both individuals and country economies (8,9).

In pregnancy, in addition to inflammation and blood hemodilution (10–12), factors such as difficulty in accessing an iron-rich diet, cultural beliefs, and gastrointestinal (GI) impacts of iron supplements (13–17), make it challenging to meet the higher iron demands of this life stage. With an increased recommended dietary allowance (RDA) of 27.0 mg/day (18,19), there is a blanket recommendation in Canada for pregnant individuals to take a multivitamin supplement with 16 to 20 mg of elemental iron (20,21). However, there is very limited information regarding the knowledge, attitudes, and practices regarding anemia and iron supplementation during pregnancy in high-income countries (HIC), and only a few studies address prenatal supplementation in Canada (22–24). This study seeks to address this gap by exploring prenatal iron supplementation practices and adherence to national guidelines of blanket iron supplementation in Nova Scotia.

2 Terminology

The terms *knowledge, attitudes* and *practices* can be interpreted in various ways. In the context of this thesis, *knowledge* was defined as the comprehension of a particular issue attained through experiences and education, including the capability to recall information and terminology, while attitudes (also called perceptions or beliefs) are the individual's understanding and interpretation of facts or experiences that have an affective component, and *practices* are defined as actions that an individual takes in real-world situations and that have the potential to retard the progression of a health condition or prevent its onset (25–27).

The terms anemia, iron deficiency (ID), and iron deficiency anemia (IDA) are sometimes used interchangeably, so their differences are summarized here. *Anemia* is characterized by a low red blood cell (RBC) count or a hemoglobin (Hb) concentration below a specific cut-off, leading to insufficient oxygen transport to the body's organs and tissues (28). *ID* is the state in which iron depletion can be reflected in low ferritin levels with preserved Hb values. *IDA* is the last stage of ID, and one form of anemia, defined as low ferritin and low Hb levels (29).

Lastly, sex and gender are often conflated in the reproductive health research literature. *Sex* is a fundamental biological factor, classified as male or female based on reproductive organs and functions that arise from the chromosomal makeup, while *gender* is used to describe how individuals perceive and represent themselves, which is influenced by social, cultural, and personal experiences (30). While participants in most studies are described – and identified – with terms like pregnant woman or lactating mother, pregnancy and lactation are not exclusive to cisgender women. Several health bodies have recently made calls to transition to more neutral language in this realm; for instance, the terms "parent", "caregiver", and "pregnant people" could be used to replace gendered words such as "mother" and "pregnant women" (31,32). However, given that language inclusiveness is not the main focus of this research, terminology within this literature review mirrors that of the literature from which information was obtained, and as such, gendered terms appear within.

3 Literature Review

Anemia is a condition in which there are too few erythrocytes, or there is a low Hb concentration within the erythrocytes, which results in a low oxygen-carrying capacity (28). It is a significant global health concern affecting nearly 2 billion people worldwide (33), with a particular impact on young children and WRA (28,33,34). Anemia causes adverse impacts on health as well as on social and economic development (35). For instance, in children, anemia can hinder cognitive development and learning capacity and have lasting effects on overall quality of life (36). In adults, it can reduce work productivity while also elevating the likelihood of unfavorable pregnancy outcomes (37,38). Globally and in HIC, including Canada, the leading causes of anemia among WRA are ID (which is the focus of this thesis), followed by chronic kidney disease, and both hemoglobinopathies and hemolytic anemias (33,34). Other etiologies include inflammation, infectious agents, pathological conditions, and hereditary factors (38).

Nearly one-third of WRA globally had anemia in 2023, a consistent figure for the last two decades (3). In Canada alone, the prevalence of anemia among WRA is 14.0% [95% confidence interval (CI): 8.2-19.8] (3). The prevalence of anemia in pregnancy in 2023 differed around the globe, with 16.8% [12.3-22.0] in HIC, compared to 41.1% [35.8-47.2] in low-income countries (LIC). The overall global prevalence of anemia during pregnancy had a slow but steady decrease over the last two decades, from 35.2% [33.2-37.1] 40.9% in the year 2003 to 35.5% [32.1-39.1] in 2023 (3). And contrasting with 18.6% [10.1-27.2] in 2003 vs. 15.1% [6.0-26.6] in 2023. Even though this 15.1% positions the condition as a mild public health concern category according to the WHO (39), Health Canada recommends blanket iron supplementation in pregnancy due to the severe outcomes of anemia on maternal and fetal health (20,21).

Addressing this high burden of anemia is a major goal of global health authorities. In 2012, the World Health Assembly announced a resolution to halve the global prevalence of anemia among WRA by 2025 (40). Then, in 2019, the United Nations Children's Fund (UNICEF) and the WHO extended this objective by an additional five years, to be reached by 2030 (2). The pace at which anemia rates are changing indicates that this goal is still likely out of reach (41), and will require substantial financial investments in iron supplementation through school-based programs (i.e. preconception), healthcare facilities, and the private market (42). However, investing in nutrition

is highly cost-effective, with every dollar spent on reducing anemia generating $12 in economic benefits in LMIC (43).

3.1 Anemia and nutritional anemias

3.1.1 Prevalence of ID and IDA

ID manifests when there is poor iron absorption or insufficient iron intake to meet the needs of the body, which can progress to IDA if untreated (35). ID and IDA are most common among subgroups with high iron requirements due to growth and development (young children, pregnant women), high iron losses (menstruating WRA, postpartum hemorrhage), and individuals in LMIC where iron-rich foods are often difficult to obtain (44). Despite the various underlying factors of anemia, IDA stands out as the most prevalent and significant type (45), accounting for 66.2% [95% CI: 65.5–66.8] of total anemia cases, with approximately 825 million cases among women globally in 2021 (33). Using data from the Canadian Health Measures Survey cycles 3-6 (2012–2019), the prevalence of ID (ferritin <15 µg/L; n=655) was 18.2% [15.4, 21.1] while IDA (ferritin <15 µg/L and Hb <120 g/L; n=209) was 5.7% [3.9, 7.4] among Canadian WRA aged 19-50 years (46). Among WRA in Canada (n=3,612; <50 years), ferritin levels (µg/L [95 CI]) were significantly higher among white participants (35.4 [33.3, 37.7]) compared with Black (24.0 [17.4, 33.1], p=0.01) and South Asian participants (23.5 [17.2, 32.3], p=0.02) (47).

Although there are no specific prevalence reports from the WHO regarding the prevalence of ID or IDA in pregnancy globally or in Canada, smaller studies suggest that ID is a concerning issue for this population (48). National Health and Nutrition Examination Survey (NHANES) data from the USA report that 16.3 ± 1.3% of pregnant women have ID (49). In a 5-year retrospective cohort study of pregnant women in Ontario (n = 25,880; 13 to 54 years old (median: 31 years)), 23.8% were ID (ferritin: <15 mg/L), and 8.3% of the participants who had at least one Hb assessment in any point during pregnancy (n=34,034) were anemic (Hb <105 g/L). IDA was not assessed (50). This estimate of ID is lower than the 49.4% reported among pregnant women in an inner-city tertiary care center in Toronto that serves a low- socioeconomic population (n=1,307, ferritin <15µg/L) (51,52).

3.1.2 Other causes of anemia

Although ID is thought to be the main nutritional cause of anemia, deficiencies in other essential micronutrients such as folate, vitamin B12, vitamin A, and riboflavin can also cause anemia (38). For instance, given the vital role of folate in cell division, folate deficiency can lead to impaired erythropoiesis, and in turn, anemia (38). Once detected, nutritional deficiencies are often highly manageable and treatable since they can usually be corrected with supplementation (29).

It is also important to note that not all anemia is caused by nutritional deficiencies (38). Inflammation hinders the production of RBC and reduces their lifespan (12). This type of anemia can be found among patients with conditions such as autoimmune diseases, cancers, human immunodeficiency virus (HIV), diabetes, inflammatory bowel disease, renal diseases (53). Infection etiologies could include bacterial, viral, and protozoan, with malaria being the primary worldwide infectious factor leading to anemia (54), primarily in tropical regions of the world (55). Another cause of anemia is genetic Hb disorders, inherited genetic variations in DNA that lead to blood disorders such as thalassemia, sickle cell disease, and hemolytic anemia (56). Hemolytic anemia also occurs as a result of autoimmune diseases, bone marrow failure, blood transfusion failure, medications, or infections (57). In summary, anemia has several etiologies, each contributing to the complexity of its diagnosis and treatment.

3.1.3 Iron metabolism

After consumption, iron is transported from the duodenal lumen through a divalent metal transporter (DMT-1) (58). Once absorbed, iron is released into the bloodstream for transportation to other body tissues or stored as ferritin (58), a key biomarker for iron status that will be described in more detail below (see *3.1.5 IDA assessment)*.

Ferroportin is the only known protein to facilitate the transportation of iron from the cells to the bloodstream and is a crucial component in iron regulation (59). Iron balance is exclusively regulated by iron absorption, as no innate mechanism exists for excreting excess iron (60). While menstruation will result in blood and, therefore, iron loss, this is halted in pregnancy. To maintain balance within the body when levels are elevated, hepcidin is produced in the liver, inhibiting iron absorption through the mucosa (61). Hepcidin binds to ferroportin in specific

cells, such as enterocytes, macrophages, and hepatocytes, resulting in iron storage within these cells, hence preventing its release into the bloodstream (58). Conversely, a decrease in hepcidin would increase iron absorption in the duodenum (60).

When ferroportin is active, iron passes to the bloodstream, and ferric iron can be bound to transferrin to be transported to areas with a high need for iron, such as the bone marrow for erythropoiesis (60). While erythropoiesis is ongoing and impacted by multiple factors, it is primarily regulated by erythropoietin, a hormone secreted by the kidney in response to cellular hypoxia (62). The major component of erythrocytes is Hb (56). A Hb molecule has four subunits: two alpha chains and two beta chains, each of which surrounds the heme molecule where iron is contained (63). One of the leading roles of Hb is to facilitate the transportation of oxygen from the lungs by reversibly binding to a ferrous iron atom in each heme section and then releasing oxygen to the tissues (63,64).

Iron regulation adapts in response to pregnancy; hepcidin levels decrease to meet the body's higher iron requirements during the antenatal period, leading to a nine-fold increase in intestinal iron absorption from early to late pregnancy (44).

3.1.4 Cutoffs for anemia

The WHO established cut-offs for anemia using Hb as the biomarker (39,65) (see **Table 3.1**). The most common testing method to assess Hb values in population-based studies is a single capillary drop using handled devices such as hemoglobinometers. However, significant differences in anemia prevalence have been found when comparing this method with the gold-standard automated hematology analyzer for Hb measurement using venous blood (66). The variation of results puts in question whether the current capillary tests used for estimating the prevalence of anemia in community settings are accurate or if venous samples should be collected, even if this means reducing the sample size (67). Although this debate is ongoing, current cut-offs are indented for use and interpretation from any Hb assessment, regardless of blood sample type (venous or capillary) or analysis technique (39).

Table 3.1 Hemoglobin levels (g/L) to diagnose anemia at sea level in a non-smoker population[a,b] (39,68).

		Anemia		
Population group	**Normal**	**Mild**	**Moderate**	**Severe**
WRA (15 – 65 years)	≥ 120	110-119	80-109	<80
Pregnant women (first trimester)	≥ 110	100-109	70-99	<70
Pregnant women (second trimester)	≥ 105	95-104	70-94	<70
Pregnant women (third trimester)	≥ 110	100-109	70-99	<70

a: For people who smoke, Hb values should be adjusted by -6 to -3 according to the number of cigarettes smoked per day. More information is available here: https://www.who.int/publications-detail-redirect/9789240088542 (39).
b: These cut-offs are applicable between 0 and 499 meters above sea level. Nova Scotia has an approximate average elevation of 41 meters above sea level (69).

The WHO first published anemia cutoffs in 1968 using data predominately from a white population, deriving statistical cutoffs as below the 5th percentile of healthy individuals' Hb concentrations (70) rather than considering clinical symptoms in setting these diagnostic criteria (71). These cutoffs were most recently updated in 2024. Cutoffs are still statistically derived, although from a more racially diverse population, and other changes include splitting up cutoffs during pregnancy by trimester, as suggested by the Centers for Disease Control and Prevention (CDC) (72) and the American College of Obstetricians and Gynecologists (ACOG) (73)), and stating that Hb cutoffs should not be adjusted for infection, inflammation, or ethnicity (39).

On the other hand, Hb cutoffs should be adjusted for high altitude and smoking. At higher altitudes, the reduction in oxygen partial pressure leads to a decrease in arterial oxygen saturation (74). Living at higher altitudes triggers compensatory mechanisms by increasing Hb levels to mitigate the reduction in oxygen reaching their tissues (74). As such, Hb cutoffs are standardized to an elevation range of 1-499 meters above sea level (39). For smokers, the Hb value should be adjusted by -3 g/L when the number of cigarettes smoked per day is 1-10, by -5 g/L when it is between 10 and 19 cigarettes, and by -6 g/L when the number is more than 20 cigarettes (39).

3.1.5 IDA assessment

ID occurs in stages, and anemia is a late-stage indicator of its presence (29). For instance, initially, iron stores become depleted (low ferritin, but sufficient Hb), with the progression to IDA when both ferritin and Hb are low (29). The recommended cut-off value of ferritin to define

ID in pregnancy is <15 μg/L in the first trimester, and there is no discussion of differential cutoffs for other trimesters (75). Ferritin is an acute-phase protein that increases in concentration in response to infection or inflammation; therefore, biomarkers including C-reactive protein (CRP) or alpha-1 acid glycoprotein (AGP), and correction factors should be applied to assess whether changes in ferritin concentrations are truly reflective of ID (8,75). Furthermore, assessing ID during pregnancy is challenging due to the physiological changes in hormones, blood composition, hemodynamics (75) where both pro- and anti-inflammatory reactions occur to ensure the correct functionality for fetal development and, later, for the expulsion of the baby at parturition (76).

Despite the critical consequences of ID in pregnancy, hemoglobin and ferritin are not routinely assessed, and IDA in pregnancy often goes undiagnosed (50,52). For instance, a retrospective study in Ontario to assess ID screening during pregnancy (n=44,552) describes that only 6 out of 10 women underwent a ferritin test, and only 76% of women had at least one hemoglobin test done throughout pregnancy (50). The absence of ferritin testing may be attributed to its exclusion from the universal standard of care and its incorporation by only some HCPs in their routine assessment (77,78). In Nova Scotia, the Reproductive Care Program clinical practice guideline notes that ferritin assessment during pregnancy should only be assessed based on specific risk factors, clinical signs of anemia, or Hb <110 g/L (79). ID is considered during pregnancy when serum ferritin <30 ug/L, and IDA and severe IDA when Hb 80-110 g/L and Hb <80 g/L, respectively, in addition to ferritin <30 ug/L (80).

3.2 Anemia and IDA in pregnancy

3.2.1 Anemia in pregnancy: causes and risk factors

In pregnancy, the higher metabolic demand for circulation to support fetal growth and development confers a progressive increase in blood volume by approximately 45% throughout pregnancy (10). Although more plasma than RBC, this increase necessitates higher iron intakes for erythrocyte mass expansion. The creation of RBC is regulated according to iron stores through erythropoietin (11), and iron supplementation contributes to its formation (81). Since plasma volume is greater in proportion than the RBC mass, it leads to “physiological anemia” due to hemodilution (10). Hence, there are different cut-offs for anemia during this life stage

(39). Iron levels at conception are key to determining the risk of anemia; for instance, anemia risk is higher if heavy menstruation, gastrointestinal (GI) diseases that impact iron absorption, short intervals between pregnancies, or poor iron nutrition limit iron reserves entering pregnancy (73). Additionally, in early pregnancy, there can be lower compliance with iron-containing supplements due to adverse GI effects such as nausea and vomiting (82). In fact, iron-related side effects are common throughout pregnancy increasing the chances of developing IDA (83). For example, constipation happens because a large proportion of iron is unabsorbed in the intestine, with osmosis driving water out of the lower GI tract, resulting in firmer, more compact feces that are difficult to pass (84). Also, excessive iron can promote the proliferation of harmful bacteria at the expense of beneficial bacteria, altering the intestines' microbiome and leading to inflammation (85) and GI upset (86). Certain methods have been recommended to mitigate these side effects, such as taking lower doses, splitting supplements to consume several times in one day, or taking doses on alternate days. Such approaches help increase fractional iron absorption (87,88) while reducing the risk of GI issues (88,89). Finally, blood loss ≥1 litre within 24 hours of delivery is another cause of anemia in the perinatal period (90).

Non-health factors such as socioeconomic status, adverse side effects of supplemental iron, and the cost and accessibility to both supplements and iron-rich foods could also influence the risk of anemia in pregnancy (13–15,91). Negative effects of iron supplementation (13) include constipation, after-taste, general sickness or other GI events, which decrease adherence to iron-containing supplements (92). Some high bioavailable sources of iron, such as pork, beef and fish, are deemed taboo, and iron-rich foods such as beans were averted, especially in lower-income countries (93). Also, accessibility issues increase the risk of being anemic in food-insecure households where an economic barrier exists to obtain high-iron bioavailable foods (15,16). This adds to the fact that women could be experiencing lower intake of nutrient-rich foods due to inequitable food distribution compared with males living within their households (15,17).

3.2.2 Adverse outcomes of anemia in pregnancy

ID and IDA during pregnancy are linked to adverse outcomes for both mothers and children (50,94). According to UNICEF, during the fetal and neonatal periods, the brain has an increased need for iron to support crucial neuronal processes that influence behaviour, affection, emotions,

and cognitive functioning (1). Newborn infants born to mothers with low ferritin at delivery present with low serum ferritin levels as well (95,96), suggesting limited fetal iron reserves *in utero* (95). A systematic review and meta-analysis (5) conducted across 37 countries showcased a higher risk of adverse birth outcomes among pregnant women with Hb ≤110 g/L at any point in pregnancy (OR [95% CI]), including: low birth weight (1.42 [1.31−1.55]), preterm birth (1.36 [1. 26-1.46]), stillbirth (1.49 [1.15−1.92]), perinatal mortality (1.73 [1.32−2.26]), neonatal mortality (1.49 [1.19−1.87]), postpartum hemorrhage (1.84 [1.42−2.37]), preeclampsia (1.84 [1.31-2.59]), and need for transfusion (6.57 [3.59−12.00]), as compared to non-anemic pregnant women with Hb >110 g/L (5). Additionally, Drukker et al. reported higher risks of adverse outcomes when women presented with anemia at delivery (n= 75,660, Hb<110 g/L), including cesarean section (1.30 [1.13-1.49]), preterm delivery (1.54 [1.36-1.76]), macrosomia (1.23 [1.12-1.35]), 5-min Apgar <7 (2.21 [1.84-2.64]), and admission to the neonatal intensive care unit (1.28 [1.04-1.57] (6).

During childbirth, blood loss can lead to outcomes from low blood pressure to maternal death (4). Postpartum anemia is linked with fatigue, depression, and impaired mother-child interaction (97), which in turn may negatively impact children's behaviour and development (1). Other factors can also impact child development. For instance, a cohort study conducted in South Africa examined the correlation between antenatal maternal anemia and brain structures in children (n=147; age: 34 ± 2 months, 57% male, Hb < 110 g/L) using magnetic resonance imaging scans. Authors reported that even though the overall brain volume of children born to anemic mothers remained unaffected, even mild anemia in the mother had an adverse impact on specific brain regions (the basal ganglia nuclei and corpus callosum) responsible for motor skills, executive functioning and visuospatial aptitude (98).

In addition to adverse health outcomes, IDA throughout motherhood and across the lifecycle is also critical to socioeconomic outcomes, including school performance, work capacity (99), and countries' gross domestic product (GDP) (8,9). For children, these estimates account for the cost of prevented child mortality (42), and the future loss of productivity in adulthood due to cognitive deficits caused by early ID (99), healthcare costs for complications such as preterm delivery (99). In India, ID resulted in annual production losses of $24 billion in 2013, equivalent to 1.3% of GDP (8), which is a considerable amount of money that could otherwise be spent on

other development initiatives and future policies. In HIC, a lack of awareness of ID could also be driving economic costs. While data from HIC are limited, a recent analysis of the impact of ID among women aged 15-44 years in Australia estimated an annual productivity loss of $6.62 billion, equivalent to 0.35% of the GDP, which translates to an average individual annual loss of $2,850 (100). In Switzerland, a cross-sectional study (n=1,010 WRA aged 18–50 years, mean age 33.5, 92.4% Swiss nationality) revealed that about one-third of women with ID were initially misdiagnosed and treated for conditions like depression, burnout, anxiety, and chronic fatigue (101). These misdiagnoses led to additional costs related to extended ID symptoms that hindered daily activities, as well as costs for treatment of these other conditions (101).

3.3 Iron requirements in pregnancy

3.3.1 Dietary recommendations for iron in pregnancy

Iron is the nutrient most commonly deficient in human diets, especially in women and children (102). The dietary reference intakes (DRI) from the National Academy of Medicine (formerly the Institute of Medicine) (2006), have four values (103):

1. *Estimated average requirement (EAR):* The median daily nutrient intake estimated to meet the requirements of half of healthy individuals in a given life stage and sex group.
2. *Recommended dietary allowance (RDA):* The mean daily nutrient intake estimated to meet the requirements of nearly all (97-98%) healthy individuals in a given life stage and sex group.
3. *Adequate intake (AI):* Set when there is insufficient data to establish an EAR and RDA, the AI is a derived nutrient intake expected to meet or exceed the needs of most individuals in a given life stage and sex group.
4. *Tolerable upper intake level (UL):* The maximum mean daily nutrient intake amount that is unlikely to pose a risk of adverse health effects to nearly all individuals in a given life stage and sex group.

The RDA ranges from 18.0 mg/day among WRA to 27.0 mg/day during pregnancy (see **Table 3.2**) (18). Most of the body's daily iron requirements are fulfilled by recycling iron from

senescent RBC, with a small amount of this mineral being absorbed through dietary intake (58,102).

Table 3.2 Dietary reference intakes (DRIs) for iron by life stage group (18)

Life stage group		DRI (mg/day)		
		EAR	RDA	UL
WRA	19 to 50 y	8.1	18.0	45.0
Pregnancy	19 to 50 y	22.0	27.0	45.0

WRA: Women of reproductive age. EAR: Estimated average requirement. RDA: Recommended dietary allowance. UL: Tolerable upper intake level.

Dietary iron can be found in two forms: heme and non-heme iron. Heme iron is highly absorbable, derived from Hb and myoglobin in animal tissues (104) such as beef, oysters, liver, poultry, tuna, and salmon. Non-heme iron is found in plant-based products such as whole grains, legumes, nuts, dried fruits, vegetables and fortified cereals (104). The bioavailability of heme iron is estimated at 15–35%, while non-heme iron bioavailability ranges from 2% to 20% (105). For instance, a balanced diet with 2500 kcals and 90g of protein can have around 2mg of heme iron and 15mg of non-heme iron, with only 1.5 mg being absorbed (105). The absorption rate of the mineral will also be influenced by the iron status of the individual (106).

After ingesting iron, dietary trivalent ferric iron is converted into its divalent form, ferrous iron (58). Iron is transported from the duodenal lumen through a divalent metal transporter (DMT-1), which can be inhibited by other divalent metal ions such as copper and zinc due to its lack of specificity for iron, resulting in the competitive inhibition of its absorption (102). Bioavailability enhancers include ascorbic acid (e.g. lemon and bell peppers) (105) and consumption of heme iron from muscle tissue (104). Common absorption inhibitors include oxalic acid (e.g. raw spinach and chocolate), tannins (e.g. black tea), polyphenols (e.g. coffee), and calcium (e.g. calcium carbonate supplements) (104). However, the main inhibitor is phytate (found in seeds, nuts, legumes, and unprocessed whole grains), which shows a negative effect even in low concentrations, which could be mitigated by utilizing diverse cooking methods (e.g. soaking, germinating, fermenting, heating) or adding phytase (106). In line with this, a recent analysis of Canadian Health Measures Survey (2009–2017) data found significantly higher ferritin levels

(mean [95% CI]) among premenopausal women (n = 3,612) who consumed red meat 7 or more days per week (41.9 [35.2, 49.8] μg/L) compared to none (24.5 [19.6, 30.7] μg/L, p<0.001], and significantly lower ferritin when grains were consumed 3 or more times a day (26.1 [20.8, 32.6] μg/L), compared with once or fewer times a day (37.9 [33.7, 42.6] μg/L; p=0.003] (47).

Iron intakes are not often met among WRA and pregnant women, even in HIC. For instance, a systematic review found that dietary iron consumption was inadequate among pregnant women in India, China, Australia, Japan, Canada, Portugal, and Pakistan in 10 out of 11 studies that evaluated nutritional values. (19). In Canada, 24-hour dietary recalls from the Canadian Community Health Survey 2015 (n=2,869) indicate that nearly one-third of females between 19 and 50 years old (including pregnant women) have iron consumption from food sources below the EAR (107). This low iron intake cannot simply be attributed to plant-based diets in Canada. Although Health Canada actively encourages the consumption of plant-based proteins more often than animal sources (108), the most recent national data indicate that only 5% of Canadians >2 years old regularly exclude animal products from their diets (109). If individuals consume a primarily plant-based diet (non-heme iron sources only), Health Canada guidelines recommend doubling recommended iron intakes given the lower bioavailability (110).

Low socioeconomic status also drives dietary choices, and, in turn nutrient quality of foods, given the high price of iron-rich animal-source foods (111). Approximately one in five families are food insecure in Canada (112), which can increase the risk of anemia and IDA (16). Furthermore, as mentioned earlier, inequitable food distribution in the household could affect pregnant women, lowering their caloric and mineral intakes (15,17).

Given that iron requirements from dietary sources are not always met, iron supplementation is often needed to meet the RDIs (see Table 3.2).

3.3.2 Perinatal iron supplementation

Preventative iron supplementation in pregnancy is an established intervention to prevent IDA and subsequent adverse outcomes. The most recent Cochrane review (2015) reported that any daily oral supplements containing iron significantly reduced maternal ID, IDA, and anemia at term, compared to no iron or a placebo, as follows (risk ratio [95% CI],n): ID by 57% (0.43

[0.27-0.66], n=1256), IDA by 67% (0.33 [0.16-0.69, n=1088], and anemia by 70% (0.30 [0.19 - 0.46], n=2199) (113).

Although effective, recommendations for blanket iron supplementation in pregnancy are not universal. The WHO recommends a daily supplementation of 400 μg (0.4 mg) of folic acid combined with 30–60 mg of elemental iron during pregnancy, noting that in regions where 40% of pregnant women are anemic (classified as a severe public health problem) the higher dose is preferred (114). A weekly dose of 2800 μg of folic acid and 120 mg of elemental iron is also recommended in areas where anemia prevalence during pregnancy is <20% (as the case of Canada) or when daily iron intake is not well tolerated due to side effects (115). For antenatal iron provided within a prenatal multiple micronutrient supplement, the WHO provide guidance for high-risk regions, so in HIC, each jurisdiction is left to its own to decide the best course of action, leading to varying policies (114). For example, the United States of America (USA) recommends 30mg/day (72), whereas the United Kingdom (UK), and Germany do not recommend routine iron supplementation of pregnant women (116,117). In Canada, where anemia is considered a mild public health problem, Health Canada recommends blanket prenatal supplementation of 16 to 20 mg of elemental oral iron per day (20,21). To determine the optimal amount of iron needed to result in a low prevalence (less than 3%) of inadequate iron intake among pregnant women, Cockell et al. (2009), proposed a method derived from statistical calculations using data from the Canadian Community Health Survey (CCHS) Cycle 2.2 on Nutrition, in combination with DRIs for iron. The study found that a daily supplemental iron intake of 16 mg. is considered both effective and safe without increasing the prevalence of excessive iron intake (118).

Data suggest that prenatal supplements are commonly consumed by pregnant women in Canada and constitute a great portion of daily iron intake (24,119). In 2009, the Public Health Agency of Canada reported that 89.7% [88.9-90.5%] of women took a multivitamin in the first 3 months of pregnancy, although iron contents were not specified (119). Between 78-92% of pregnant women are estimated to take prenatal multivitamins in the USA (120).

Beyond blanket supplementation recommendations, clinical guidelines exist to treat ID or IDA in pregnancy (80), and in HIC will usually range between 60-120 mg/day (72,116). In Nova Scotia, the recommended therapeutic iron dosage according to the treatment plan from its Reproductive

Health Program ranges from 60 mg of elemental iron orally every 2 days for ID (Hb > 110 g/L and ferritin < 30ug/L), to intravenous iron treatment for severe IDA (not specific dose mentioned) (80). Although it is argued that intravenous therapy may be employed more routinely to facilitate the expedited and safe replacement of iron (94), such guidelines are beyond the scope of this thesis, which has a public health focus.

3.3.3 Prenatal iron supplementation in Canada

Pregnant women have access to a wide range of prenatal multivitamins. While it is recommended that women in Canada take a multivitamin supplement that includes 16 to 20 mg of elemental iron (20,21), commercially available supplements contain a range of doses. **Table 3.3** documents the iron formulation and dosage for some prenatal vitamins sold in Canada, which were taken from the Canadian Brand Recognition Program of the Society of Obstetricians and Gynaecologists (SOGC) (121), natural and non-prescription health product directorate (122) and best sellers found in online retailers (123,124), to reflect some different salts and dosages on the market. While several brands include iron doses at or near the RDA for pregnant women, it is notable that prenatal gummies do not often include this mineral, likely because iron has a strong smell, metallic flavour, as well as a bitter, sour and astringent taste that can emerge in such a matrix (125).

Table 3.3 Iron formulation and dosage contained in some of the commonly available prenatal supplements (121–124)

Brand Name	Serving size (per day)	Pharmaceutical form	Iron type	Iron per serving, mg	Price per month, $[a]
Centrum prenatal Tablets	1	Tablet	Ferrous fumarate	27	6
Jamieson Prenatal + DHA	1	Softgel	Ferrous fumarate	27	12
Equate Prenatal Multivitamin + DHA	1		Iron (II) fumarate	27	6
NESTLÉ Materna Prenatal Multivitamin Supplement	1	Tablet	Ferrous fumarate	24	8
Ritual Prenatal	2	Capsules	Ferrous Bisglycinate	18	63
MegaFood Baby & Me 2 Prenatal Vitamin & Minerals	4	Tablet (mini)	Fermented iron bisglycinate	18	68
Jamieson Prenatal Chewable	1	Chewable tablet	Saccarated Iron oxide	16	12
Centrum Prenatal Multigummies with DHA and Folic Acid	2	Gummy	None	0	17
OLLY Prenatal Gummy Supplement	2	Gummy	None	0	24
First Response Prenatal Gummy Multivitamin	2	Gummy	None	0	9
Centrum Prenatal Gummies	2	Gummy	None	0	17

a: Prices as of May 2025 from major online retailers.

Taking iron-containing supplements may not be enough to prevent ID. A recent study by Cochrane et al., conducted in British Columbia, highlights that ID risk can progress among healthy, low-risk women throughout pregnancy, even with regular iron supplementation (126). In this study, all participants took an iron-containing multivitamin before baseline assessment (8-21 gestational weeks), which was replaced by the study prenatal multivitamin containing 27 mg of elemental iron (ferrous fumarate) until delivery. Ferritin levels decreased from baseline (median [interquartile range; IQR]: (49 μg/L [28-49 μg/L]) to endline (17 μg/L [12-24 μg/L]; p=<0.001) and there was an increase in ID prevalence from 8% at baseline (n=60) to 41% at endline (n=54, p=<0.001, ferritin <15 ug/L), although no patients presented with anemia. This

suggests that iron deficiency can persist even when consuming a standardized multivitamin containing the recommended 27 mg of iron daily (126). In a similar vein, an Irish study with 629 participants (98% Caucasian), recently showed that the prevalence of ID (ferritin <15ug/L) increased in pregnancy from 4.5% in week 15 to 51.2% in week 33 ($p<0.001$) with a lower chance of reaching ID if an iron-containing supplement was taken before or at early stages of pregnancy (OR [95% CI]: 0.57 [0.39-0.82]) (127). Another, albeit less common, school of thought worth noting is that iron stores may simply be lower as a normal physiological response in pregnancy, and, as such, could be normally repleted in the following months or years after parturition (128).

Regarding the dose, the amount of iron ingested could significantly differ by trimester (22). The Alberta Pregnancy Outcomes and Nutrition (APrON) study showed that the total amount of iron (mean ± SD, in mg), from vitamin and mineral supplements increased from 28 ± 17 (n=136) during the first, 30 ± 21 (n=575) during the second, and 39 ± 33 (n=516; $p<0.001$) during the third trimester as the type of product ingested from multivitamins to iron alone shifted as pregnancy advanced (22).

Beyond the dose, the effectiveness of iron in prenatal multivitamins may be limited due to low bioavailability in the presence of absorption competitors such as calcium (126), the type of iron, and, importantly, low adherence to supplements for several reasons, such as adverse GI events (87). Another consideration for adhering to this Health Canada recommendation could be economic. Although there are some stand-alone programs, such as the Sobeys Pharmacies *Baby Be Healthy Program* (129) which distributes free prenatal vitamins (including 27 mg of ferrous fumarate) in Canada, prenatal supplements are sold over the counter and are not included in routine public standard care. The price of a month's supply of prenatal supplements could vary from CAD $6 to CAD $68 (Table 3.3), which could limit adherence among low-income or vulnerable individuals.

3.3.4 Knowledge, attitudes and practices of prenatal iron supplementation

Information regarding knowledge, attitudes and practices (KAP) of iron supplementation during pregnancy in HIC is limited, and primarily explored through qualitative research (15,130,131). Results from qualitative studies can provide an in-depth understanding of how public health

initiatives are directly linked to people's attitudes, beliefs, behaviours, and factors that influence adherence to supplementation regimes (132). In general, these studies report that mothers have some knowledge about the causes and symptoms of anemia (15,130), some of the associated risks of anemia for the mother and baby (15), and the benefits of iron supplementation (130). There seems to be less knowledge of the side effects of iron supplements (130,133), the importance of iron in pregnancy (15), and insufficient knowledge sharing or counselling from their health care providers (HCP) regarding anemia and iron (15,134).

A qualitative study of 14 mostly high socioeconomic status, older, white pregnant or recently pregnant women in Ireland examined the experience of anemia and iron supplementation in pregnancy (130). Women in this study had a general idea of ID being potentially negative during pregnancy, but exact health effects for either mother or baby were very limited. For instance, participants were able to identify some symptoms of low iron levels, including dizziness, shortness of breath, and fatigue, which they said could remain postpartum. Some women were aware of dietary sources of iron as well as inhibitors and facilitators of its absorption. Both forgetfulness and the adverse GI side effects of iron supplements, especially constipation, nausea, and dark stools, adversely impacted compliance among these participants. Conversely, motivations for taking iron supplements included wishing to avoid a blood transfusion, fear of untreated ID, and to improve their baby's health (130).

Two quantitative studies of prenatal iron supplementation in HIC were published in recent years. In Sweden, researchers sought to assess if the public health guidance of iron supplementation in pregnancy (which was 100 mg at the time of the study), was being followed by pregnant women (n=901; mean age 30 years) (13). The majority (85%) reported taking any iron-containing supplement during pregnancy, half taking it daily. Healthcare provider advice was deemed important: 64% of women adhered to the supplementation after being advised on consumption by their midwife, compared to only 19% adherence from the group of women that did not receive such advice ($p<0.01$). Women perceiving anemia as common were more likely to use supplements (91%) compared to those who did not (75%, $p<0.05$). Side effects were reported by 46% as the main reason for discontinuing supplements, yet only 11% cited this as the primary reason for non-compliance, while 31% stopped taking supplements because they felt it was no longer necessary (13).

In a 2015 study in Germany, 66% of pregnant women (n=207, median age 32 years, 89% German origin, 59% with a university degree) reported using iron supplements during pregnancy, from which most (85%) did it because of an ID or anemia diagnosis (117). However, this sample may be skewed, as midwives assisted with participant recruitment, potentially increasing participation among women requiring medical intervention. Additional reasons for supplementation included following a vegetarian diet, and learning about the benefits of iron during pregnancy (117).

A recent study done in Vancouver showed that 90% of women (n=500) who were either pregnant or trying to conceive took a prenatal supplement, of whom 83% took it daily. Most of the participants in the pregnant group (n=250) took iron in the form of ferrous fumarate (60%) (23).

Although research is scant, these findings suggest a multifaceted rationale for supplementation, or a lack thereof, among pregnant women in HIC. Given the important adverse outcomes of IDA in pregnancy, more detailed investigations of drivers of prenatal iron supplementation are warranted, particularly among a more socioeconomically diverse sample in HIC.

3.4 Research gap

Despite widespread public initiatives to raise awareness of iron supplementation during the perinatal period (114,114,116,135), and the WHO goal of reducing the anemia prevalence globally (2,40), 15.1% of pregnant women are anemic in Canada, affecting the health and quality of life for both women and their babies (5,50,94–97). Although current qualitative studies offer some insights, most research in this realm focuses on women in LIC. In addition, little was known about adherence to iron supplementation guidelines in HIC, with not a single study in Nova Scotia. While a 2009 survey established that 89.7% [88.9-90.5%] of women took a multivitamin in the first 3 months of pregnancy, it is unclear how much, if any, iron was in these supplements (119). Furthermore, no detailed data existed in Canada on the relationship between adherence to national iron supplementation guidelines for pregnancy and knowledge and attitudes regarding iron and IDA.

Due to these factors, there was a need to obtain comprehensive quantitative data to understand the public health dynamics in this region. A broad approach could help to identify the underlying factors contributing to the approximately 1 in 7 pregnant women experiencing anemia in pregnancy in Canada (3). In addition, updated estimates of prenatal iron supplementation practices are needed in this population, as current Canadian estimates are 15 years old (119). Such information is vital to inform future public health interventions to improve maternal health and optimal health, growth, and neurodevelopment in the first 1,000 days (1).

4 Methods

4.1 Study objectives

The objectives of this research were as follows:

1. To assess the adherence to Health Canada guidelines for oral iron supplementation in pregnancy among Nova Scotians.

2. To identify the knowledge, attitudes, and practices regarding IDA and iron supplementation during pregnancy in Nova Scotia, and understand if they differ by adherence to national iron supplementation guidelines for pregnancy.

4.2 Study design

This was an exploratory study designed to collect quantitative data regarding iron supplementation and IDA during pregnancy. The design was based on the framework of knowledge, attitudes and practices (KAP) studies, which have been employed in diverse healthcare contexts due to their targeted scope and cost-effectiveness compared to other social research methodologies. This methodology states that knowledge and attitudes directly affect preventive practices, hypothesizing that patients are most likely to adopt behavioural changes and improve health outcomes after educational interventions (26,27).

The information was collected via an online questionnaire (e.g. LimeSurvey), that meets Tri-Agency Research Data Management standards (136). The survey included questions related to socio-demographics and health, as well as KAP related to iron supplementation and IDA. As described in **Section 2** (Terminology), the terms anemia, iron deficiency, and iron deficiency anemia are sometimes used interchangeably, especially by the lay public; therefore, we used IDA as a blanket term in the research tool.

4.3 Tool

No specific validated tool was found to assess the objectives of this research. Therefore, a novel questionnaire was created, drawing from other relevant work, including a questionnaire originally developed for a cross-sectional study in Germany, which assessed iron

supplementation during pregnancy (117), and from Module 6, related to IDA, from the "Guidelines for Assessing Nutrition-Related Knowledge, Attitudes, and Practices" published by the FAO (26). Additional questions were be included to gather relevant insights on our topic of study (20,21,28,39,137).

4.4 Study setting

This study was conducted in Nova Scotia, one of the four Canadian provinces on the Atlantic coast (138). The province is home to over 145 ethnic groups, including the Mi'kmaq, African Nova Scotians, and Acadians (139), with an estimated population of 1,072,545 inhabitants (140). Nova Scotia has around 5.5% of the population identifying as Indigenous, and 7.5% as immigrants (141). Nearly 80% of the population lives in urban districts, with Halifax, the capital, being the most densely populated location, accounting for nearly half of the total population (139,142) and also the economic and cultural center of the Canadian Maritime Region (143). The province recorded approximately 8,000 new births in 2022 (144), with the mother's mean age at delivery being 31 years old (145). Most of the population (57%) is married or living in common law, two-thirds of the population aged 25 to 64 years has a post-secondary certificate, diploma or degree (66%) (141), and the median income of a family is $91,000 ($78,000 after tax) (146).

4.5 Ethical considerations

This study was reviewed and approved by the MSVU Research Ethics Board under the file number 2024-204 (see Appendix A). Interested individuals were directed via a URL or QR code on an online ad or poster, which led them to the welcome page of the online questionnaire that explained the study. Participants then answered questions regarding their eligibility, and provided implied consent to participate by clicking "Next page". They were then launched to the online survey. Alternatively, if one or more of the individual's responses on this page indicated that they were not eligible, they were redirected to a page that thanked them, and informed them that they were not eligible to participate. At the end of the online survey, which took about 30 minutes to complete, participants were thanked for their participation and given the opportunity to be redirected to a page where they could enter their email address for a chance to win 1 in 3

$50 gift cards. Note that we did not collect the IP addresses of participants, and protect the survey against multiple entries & bots by collecting cookies and employing a CAPTCHA.

The data collected through this online survey remained anonymous and confidential. Participants were able to withdraw their consent to participate in the study at any point without consequences. All data is kept secure on password-protected computers and/or secure servers accessible only to members of the research team.

4.6 Participants

4.6.1 Eligibility criteria

Inclusion criteria:

1. Individuals who were at least 5 months pregnant, or had given birth within the last 12 months,
2. Resided in Nova Scotia for at least 5 months of their pregnancy,
3. Aged 19 years or older,
4. Proficient in English,
5. Had access to an electronic device with an Internet connection to complete the online survey.

Rationale for eligibility criteria:

The eligibility period was established from month 5 of pregnancy to account for at least half of pregnancy, and extended up to 12 months after parturition for the sake of relevancy to yield better recall, since periods longer than 2 years after parturition could be less reliable according to the WHO and UNICEF (91). Since we sought results from Nova Scotia pregnancy practices, individuals who lived in the province for at least half of their pregnancy were included. Participants were required to be the age of majority to consent to participate in the study for consent for themselves. Additionally, they had to be proficient in English and have access to an electronic device, as the survey was conducted online in English.

4.6.2 Sample size

Given the paucity of data in this area, the sample size for this study was estimated by assessing the percentage of participants in other similar studies and using a goal to collect data from a portion of the recently pregnant women in Nova Scotia.

As noted earlier in this document, only two quantitative studies have explored prenatal iron supplementation practices in HIC, one from Sweden (n=901) (13), and another in Germany (n=207) (117). Given the wide disparity in sample sizes, these could be better assessed as a proportion of the annual births in these countries: this accounts for 0.9% for Sweden (100,000 births in 2023) (147) and <0.05% in Germany (693,000 births in 2023) (148). Based on these percentages, and given the success of other online surveys conducted among perinatal women by our research team (e.g. Fry et al. 2021), we expected to collect data from a larger proportion of this target population than these other HIC-based studies (149). A total of 319 individuals participated in this study, accounting for 4% of the approximately 8,000 infants that are born annually in Nova Scotia (144).

4.6.3 Recruitment

Both convenience and snowball sampling methods were used to reach eligible individuals. Recruitment was targeted by advertisements on social media platforms through paid campaigns using demographic keywords to reach the target population. Also, we posted the recruitment poster on relevant motherhood and pregnancy Facebook community groups in the province. To reach a breadth of potentially eligible individuals from harder-to-reach groups (e.g. low-income, newcomers), participants were encouraged to share the poster with individuals in their network. The recruitment strategy captured the highest possible representativeness of the entire province in urban and rural areas.

4.7 Data analysis

Data analysis was performed using IBM Statistical Package for Social Sciences (SPSS) Statistics for Windows (version 29.0.2.0) (171). The significance level for all inferential statistical tests was $p<0.05$. Descriptive statistics were computed for the participant's demographic information such as age, geographical location within Nova Scotia, marital status, level of education, parity, and household's income level, as well as for health information such as diagnosis of IDA, and dietary pattern. Categorical variables are shown as n (%), and continuous variables as mean ± SD and range (min. – max.). Inferential statistics are described below, by objective.

4.7.1 Objective 1. To assess the adherence to Health Canada guidelines for oral iron supplementation in pregnancy among Nova Scotians.

Practices

The primary outcome was to assess whether participants adhered to prenatal supplementation guidelines set out by Health Canada; that is, daily consumption of a Prenatal Supplement containing 16-20 mg of elemental iron, throughout pregnancy (21). To find out the type of supplement taken, participants were asked to submit a photograph of the supplement's bottle; if that was not available, then the name of the supplement(s) was requested, and only if the participant didn't recall that information, the final option was to select their supplement from a list of the most common prenatal supplements in the province to assist with recall. After determining the supplement, researchers imputed the exact iron dose and formulation to ensure accuracy. A participant was considered adherent to the guidelines using filters on Microsoft Excel if each of the 3 parameters were met: iron dose was ≥16mg, the frequency of supplementation was daily (which could also be met if participants took two different iron-containing supplements on alternate days), and the supplement was taken during all three trimesters of pregnancy (or for pregnant individuals who had not yet entered the third trimester, for their entire pregnancy to date).

Other practices assessed included: the reasons participants started and stopped taking the mineral (13,117), the sources of information they had regarding iron supplementation, and a calculation of the cost per month of the brand(s) taken.

4.7.2 Objective 2. To identify the knowledge, attitudes, and practices regarding IDA and iron supplementation during pregnancy in Nova Scotia, and understand if they differ by adherence to national iron supplementation guidelines for pregnancy.

Based on the literature review, the way participants perceive IDA and iron supplementation could influence supplementation (26,150). In addition, previous studies have identified different prenatal supplementation practices by demographic characteristics, including age, level of education, self-reported racial group, place of birth, and lifestyle (13,117,151). We decided to assess whether participants' knowledge and attitudes of IDA differ by practice, defined as a binary variable of adherence or non-adherence to Health Canada's recommendations regarding iron supplementation (described above; self-reported consuming >16 mg (152), daily, throughout pregnancy). All data for this objective were then compared by adherence to iron supplementation. Categorical variables were assessed using Chi-square tests, while continuous variables were analyzed using independent t-tests, and, where applicable, post hoc Bonferroni tests were conducted to determine where significant associations occurred.

Knowledge

Knowledge was focused on assessing if participants had an understanding of symptoms, causes, risks, outcomes of, and prevention of IDA, as has been assessed in previous research (13,117,153). This section was assessed through partially categorized questions as per the FAO guidelines (26). Each question had a set of correct options, plus “other”, and “don’t know”. The answers were then given 1 point if they were correct and subtracted 1 point if they were not. Participants overall answers were coded as “know” if the final number was above 0, or “don’t know” if the numeric value was negative.

Attitudes

Attitudes were assessed using a 5-point Likert scale, with participants responding to statements from strongly disagree to strongly agree (26,154). Statements included the severity perception of IDA in pregnancy, the importance of iron supplementation (13,15,117), and cost (91). Results were collapsed into "disagree" when their responses showed any level of disagreement (1 or 2), "neutral" (3), or "agree" when they showed any level of agreement (4 or 5), or directly "I don't know", and displayed as mean ± SD.

4.8 Scope

While IDA is concerning during preconception and pregnancy, it is less of an issue during lactation due to iron stabilization post-delivery. This stabilization occurs as iron is recycled from pregnancy-related erythrocyte expansion and reduced iron loss from postpartum amenorrhea, leading to homeostasis (44). To date, there are no specific Hb cut-offs for the postpartum period (48) and neither the CDC nor WHO recommend blanket iron supplementation postpartum (72,135). Given the greater importance for iron supplementation prenatally, lack of Health Canada recommendations for postpartum iron supplementation, and lower risks of anemia postpartum, this thesis focuses on the impact of iron supplementation during pregnancy.

4.9 Planned dissemination of findings

The results of this dissertation will be shared with Research Nova Scotia as stipulated in the Scotia Scholars Master's Award *Grant/Award Holder's Guide* (155). Participants were told that a lay summary of results will be available at www.mamalab.ca in 2026. Results from this research will also be presented at an academic nutrition conference (e.g., *Science Atlantic Nutrition & Foods Conference*, or *Canadian Nutrition Society Annual Conference*) in 2025 and published in a peer-reviewed journal (e.g., *Maternal & Child Nutrition*, or *Applied Physiology, Nutrition, and Metabolism*).

5 Results

5.1 Participants characteristics

Demographic characteristics are presented in **Table 5.1**. Overall, 319 individuals were enrolled, with a mean ± SD age of 32.0 ± 4.1 years. Over half (55%) had given birth within the past 12 months, while those currently pregnant had a mean gestational age of 31.5 ± 5.7 weeks. Most participants were from the Central Zone of Nova Scotia (68%), identified as White (89%), and were married or living in a common-law relationship (96%). Nearly all had post-secondary education (95%), with most at the undergraduate or graduate level (70%) and over half reported an annual household income before tax exceeding $100,000 (62%). The main care providers during pregnancy were obstetrician/gynecologists and family doctors (65% and 28% respectively). Nearly all participants had their iron status tested (97%), from which half indicated they had been diagnosed with anemia during pregnancy (49%), with most diagnoses occurring during the second and third trimesters (58% and 26%, respectively).

Table 5.1 Characteristics of study participants

Characteristics	**n**[1]	Mean ± SD (min-max) or n (%)[2]
Age, *years*	289	32.0 ± 4.1 (19-45)
Gender, *woman*	307	305 (99)
Racial or cultural group	305	
White		271 (89)
Indigenous		15 (5)
Black		13 (4)
Mixed race[3]		20 (7)
Other[4]		26 (9)
Geographic location within Nova Scotia	308	
Central Zone		208 (68)
Eastern Zone		36 (12)
Western Zone		36 (12)
Northern Zone		28 (9)

Table 5.1 (continued).

Highest educational attainment	307	
High school (any or completed)		18 (6)
College		76 (25)
Undergraduate		109 (36)
Graduate or professional degree		104 (34)
Annual household income before tax, *CAD$*	306	
Less than $64,999		48 (16)
$65,000 to $100,000		68 (22)
$100,000 to $149,999		81 (26)
$150,000 or more		109 (36)
Marital status	307	
Married or common law		294 (96)
Other[5]		13 (4)
Participant type	319	
Gave birth within the last 12 months		175 (55)
Currently pregnant		144 (45)
Pregnancy stage, weeks	139	31.5 ± 5.7 (20-42)
Parity, *multiparous*	304	172 (57)
Main care provider	319	
Obstetrician/gynecologist		206 (65)
Family doctor		90 (28)
Midwife		19 (6)
Nurse practitioner		4 (1)
Iron assessed by a health care provider, yes	307	297 (97)
Diagnosed with anemia	297	
Yes		146 (49)
First trimester	146	24 (16)
Second trimester	146	84 (58)
Third trimester	146	38 (26)
No		146 (49)
Does not know		5 (2)
Diet Type	319	
Mixed diet		300 (94)
Vegetarian/Vegan		19 (6)

[1]*n* differs due to participants skipping some questions. [2]Percentages may not add to 100% due to rounding.
[3]Categories not mutually exclusive; n=20 participants selected more than one racial or cultural group. [4]Other racial groups included: Latin (n=6), East Asian (n=6), Middle Eastern (n=4), South Asian (n=4), Southeast Asian (n=6).
[5]Other marital status included: Single (n=11), divorced (n=1), in a relationship (n=1).

5.2 Iron compliance practices

Table 5.2a shows that 197 participants (62%) met the Health Canada iron recommendations during pregnancy of dose, frequency, and timing. **Table 5.2b** displays that nearly all participants took a Prenatal Micronutrient Supplement (95%), and while in most cases supplements contained the recommended amount (mean ± SD: 26.2 ± 4.7 mg, mode: 27 mg), 16% did not contain any iron at all. Most (85%) of the participants took the supplement on a daily basis, starting either preconception (68%) or during the first trimester (31%), and in most cases stopping after giving birth (80%). In contrast, 58% took an Additional Iron Supplement containing 97.0 ± 70.3 mg (range: 10-300 mg), with most taking it 3–4 times per week (55%), starting mainly in the second and third trimesters (52% and 21%, respectively), and ending supplementation after giving birth (75%).

Table 5.2a Participants' iron supplementation practices during pregnancy

		Overall daily iron dose[1]		**Prenatal Micronutrient Supplement**		**Additional Iron Supplement**
Characteristic	**n[2]**	n (%)[3]	**n[2]**	n (%)[3]	**n[2]**	n (%)[3]
Dose, mean ± SD (range), *mg*	294	77.4 ± 72.3 (0-327)	276	30.0 ±10.6 (0-45)	172	97.0 ± 70.3 (10-300)
Dose, median [IQR[4]]	294	40 [27-166]	276	27 [23-27]	172	150 [19-150]
Dose, mode, n (%)	-	-	276	27, 147 (53)	172	150, 88 (51)
Dose, ≥ 16mg	294	271 (92)	276	231 (84)	172	168 (98)
Dose 16-20 mg	294	*21 (7)*	276	*23 (8)*	172	*39 (23)*
Dose 20.1-45 mg	294	*126 (43)*	276	*208 (75)*	172	*26 (15)*
Dose >45 mg	294	*124 (42)*	276	*0 (0)*	172	*103 (60)*
Dose <16mg	294	*23 (8)*	276	*45 (16)[5]*	172	*4 (2)[6]*
Frequency, *daily*	313[7]	267 (85)	300[7]	246 (82)	178[7]	56 (31)
Initiated before or during the first trimester	313[7]	302 (96)	301[7]	298 (99)	177[7]	48 (27)

[1]Based on merging the information from both: the Prenatal Micronutrient Supplement and the Additional Iron Supplement. [2]*n* differs due to participants skipping some questions. [3]Expressed in n (%), except if otherwise specified in the characteristics section. [4]abbrev. IQR=Interquartile Range [5]Gummies=43(95%), Capsules=2(5%). [6]Platinum Naturals Easy Iron, Spatone, Naka Heme, New Roots Heme Iron. [7]Excluded if didn't start.

Table 5.2b Participants' iron supplementation practices during pregnancy

	Prenatal Micronutrient Supplement		Additional Iron Supplement	
Characteristics	**n**[1]	n (%)[2]	**n**[1]	n (%)
Took supplement, *yes*	318	301 (95)	311	179 (58)
Frequency	300		178	
Daily		246 (82)		56 (31)
3 to 4 times a week		37 (12)		97 (55)
< 3 times a week		15 (5)		17 (10)
Unable to determine		2 (1)		8 (4)
Duration				
Initiated Supplementation	301		177	
Preconception		205 (68)		21 (12)
First trimester		93 (31)		27 (15)
Second trimester		3 (1)		92 (52)
Third trimester		0		37 (21)
Stopped Supplementation	301	73 (24)	177	84[3] (47)
First trimester	73	1 (1)	84	0
Second trimester	73	6 (8)	84	3 (4)
Third trimester	73	8 (11)	84	8 (10)
After parturition	73	58 (80)	84	63 (75)
Unable to determine	-	-	84	10 (12)

[1]n differs due to participants skipping some questions. [2]Percentages may not add to 100% due to rounding. [3]Unable to determine stop time, included.

5.3 Additional supplementation practices

In approximately half of the cases, the reason for starting a Prenatal Micronutrient Supplement was medical advice (51%). Among the 5% who chose not to take a Prenatal Micronutrient Supplement, the main reason was fear of experiencing side effects (47%; see **Table 5.3**). Adverse effects accounted for 14% of the reasons for discontinuation, with nausea the most common side effect. From the 318 who responded, if they took a prenatal micronutrient supplement, 17 participants never took any (5%), and from those 17, almost half (47%) didn't start a prenatal supplement because of fear of side effects.

Although participants reported using 42 unique Prenatal Micronutrient Supplements, the top five brands accounted for 65% of supplements consumed, and they were purchased mainly in person, at a pharmacy (34%) or a grocery store (32%). The average monthly expenditure on a Prenatal Micronutrient Supplement was CAD $15.0 ± 14.3 (range 2.1–72.7). Conversely, 52% of individuals who started an Additional Iron Supplement did so primarily because of an iron-deficiency diagnosis and 40% stopped mainly because of attainment of normal iron status. Of those who never took an Additional Iron Supplement, 58% mentioned that it was because the Prenatal Micronutrient Supplement provided sufficient iron. Among side effects attributed solely to the Additional Iron Supplement, constipation ranked highest, followed by dark stools. The monthly cost of an Additional Iron Supplement was CAD $21.3 ± 14.8 (range $1.9–112.5), with most purchasers obtaining it at a pharmacy (78%).

5.3 Participants' additional iron supplementation practices during pregnancy

Characteristics	Prenatal Micronutrient Supplement		Additional Iron Supplement	
	n[1]	Mean ± SD and range, or n (%)[2]	**n**[1]	Mean ± SD and range, or n (%)[2]
Reasons for initiating supplementation	301		178	
Health professional advice		154 (51)		67 (38)
Health Canada recommendation		36 (12)		1 (1)
Heard that extra iron is needed in pregnancy		30 (10)		2 (1)
Family or friends'advice		23 (8)		2 (1)
To increase folate intake		21 (7)		-
Because of an iron deficiency diagnosis		10 (3)		92 (52)
To complement the iron obtained from the Prenatal Micronutrient Supplement		0 (0)		9 (5)
Other		27 (9)[3]		5 (3)[4]
Reasons for stopping supplementation	73		78	
Keep forgetting		18 (25)		6 (8)
No longer need it		16 (22)		7 (9)
It caused side effects		10 (14)		15 (19)
Iron status was normal		7 (10)		29 (37)
Other		22 (30)[5]		21 (27)[6]
Never take a supplement	318	**17** (5)	319	**132** (41)
Fear of side effects	*17*	8 (47)	*132*	11 (8)
Tastes bad	*17*	2 (12)	*132*	1 (1)
Prenatal Micronutrient Supplement was enough	*17*	0 (0)	*132*	76 (58)
Didn't need it	*17*	0 (0)	*132*	19 (14)
Health professional didn't recommend it	*17*	0 (0)	*132*	10 (8)
Normal iron levels/no anemia	*17*	0 (0)	*132*	6 (5)
Unable to determine	*17*	4 (24)	*132*	2 (2)
Other	*17*	3 (18)[7]	*132*	7 (5)[8]
Experienced side effects, *yes*	296	65 (22)[9]	175	85 (49)[9]
Nausea		54 (83)		33 (39)
Constipation		22 (34)		64 (75)
Multiple side effects		22 (34)		52 (61)
Dark stools		7 (11)		39 (46)
Heartburn		6 (9)		15 (18)
Diarrhea		1 (2)		5 (6)
Vomit		2 (3)		0 (0)

Table 5.3 (continued).

Supplement Brands[10]	276			
Jamieson		58 (21)		
Centrum[11]		64 (23)		
Materna		35 (13)		
Baby be Sobeys FREE		21 (8)		
First Response gummies[12]		21 (8)		
Other[13]		77 (28)		
Iron component type	231		147	
Ferrous Fumarate		176 (76)		8 (5)
Iron Bisglycinate		25 (11)		16 (11)
Saccharated Iron Oxide		14 (6)		0 (0)
Ferrous Sulfate		0 (0)		19 (13)
Polydextrose-Iron Complex		0 (0)		89 (61)
Other		16 (7)[14]		15 (10)[15]
Location of purchase	296		175	
In-person at a pharmacy		102 (34)		136 (78)
In-person at a grocery store		95 (32)		16 (9)
Online retailers in Canada		49 (17)		14 (8)
Free program		23 (8)		0 (0)
Other		27 (9)[16]		9 (5)[17]
Monthly expenditure, *CAD$*	255	15.0 ± 14.3 (2.1-72.7)[18]	127	21.3 ± 14.8 (1.9 -112.5)

[1]*n* differs due to participants skipping some questions. [2]Percentages may not add to 100% due to rounding. [3]Other Reasons for initiating a Prenatal Micronutrient Supplement: media (n=16), previous education (n=6), follow a vegan/vegetarian diet (n=2), still breastfeeding (n=2), unable to determine (n=1). [4]Other Reasons for initiating an Additional Iron Supplement: media (n=1), malabsorption (n=2), followed a vegan diet (n=2). [5]Other reasons for stopping a Prenatal Micronutrient Supplement: it tasted bad (n=5), it was too expensive (n=4), stopped breastfeeding (n=4), the Additional Iron Supplement was enough (n=4), doctor's advice (n=2), unable to determine (n=2), started an iron infusion (n=1). [6]Other reasons for stopping an Additional Iron Supplement: started an iron infusion (n=5), too expensive (n=7), doctor's advice (n=3), the Prenatal Micronutrient Supplement was enough (n=3), the supplement tasted bad (n=2), stopped breastfeeding (n=1). [7]Other reasons for not taking a Prenatal Micronutrient Supplement: forget (n=1), prefer to take individual micronutrients (n=1), it was too expensive (n=1). [8]Other reasons for not taking an Additional Iron Supplement: received iron infusion (n=4), it was too expensive (n=2), chose iron-rich foods instead (n=1). [9]Total % higher than 100% because participants were allowed to choose multiple responses, and results are not mutually exclusive.[10]Additional Iron Supplements brands were not included because most brands were not shared by participants (ie. provided only the generic iron salt name). [11]Centrum gummies included (n=8). [12]First Response gummies do not contain any iron. [13]Prenatal Micronutrient Supplements could be found on **Appendix C**. [14]Other iron component types in the Prenatal Micronutrient Supplement: Iron Glycinate (n=8), Iron Citrate (n=6), Iron mineral bound S. cerevisiae (n=1), Iron Amino Acid Chelate (n=1).[15]Other iron component type in the Additional Iron Supplement: Iron Pyrophosphate (n=6), Ferrous Glucanate (n=5), Heme Iron Polipeptide (n=2), Ferrous Succinate (n=1), Iron Polysaccharide (n=1).[16]Other locations of purchase of the Prenatal Micronutrient Supplement: online retailers outside Canada (n=10), specialized health/supplement stores (n=17). [17]Other locations of purchase of the Additional Iron Supplement: specialized health/supplement stores (n=7), online retailers outside Canada (n=2). [18]Supplements that were part of a free program were excluded from this calculation.

5.4 Knowledge

In general, participants seemed to be knowledgeable about health-related information regarding IDA in pregnancy, with the highest levels of awareness related to its causes and prevention (93% and 92%, respectively; (see **Table 5.4**). Doctors were the main source of information about both IDA (56%) and supplements in pregnancy (53%). One in six women (21%) reported having no source of information about IDA.

5.4 Knowledge about iron deficiency anemia in pregnancy

Correct knowledge[1]	**n**	**n (%)**
Recognizes symptoms of IDA in pregnancy	319	271 (85)
Recognizes causes of anemia in pregnancy		298 (93)
Recognizes ways of preventing IDA in pregnancy		294 (92)
Recognizes maternal health risks of IDA in pregnancy		222 (70)
Recognizes neonatal health risks of IDA in pregnancy		166 (52)
Recognizes early childhood health risks of IDA		201 (63)

Information Source	**Main source of information about:**	
	IDA (n=317)[2]	**Supplements** (n=319)
Doctor	179 (56)	169 (53)
Internet/Google search	34 (11)	57 (18)
Other health care professionals	21 (7)[3]	39 (12)[4]
Friends/family/acquaintances	5 (2)	14 (4)
Social media	4 (1)	9 (3)
Other sources	6 (2)[5]	12 (4)[6]
None	68 (21)	19 (6)

[1]Knowledge was categorized by awarding 1 point for each correct answer and subtracting 1 point for each incorrect response, from multiple selection options. The final numerical answers were coded as "know" if positive or "don't know" if the numeric value was negative.[2]*n* differs due to participants skipping some questions. [3]Other health care professionals as main source of information regarding IDA: midwife (n=9), nurse (n=7), naturopath (n=3), pharmacist (n=1), dietitian (n=1). [4]Other health care professionals as main source of information regarding Supplements: midwife (n=13), nurse (n=9), naturopath (n=6), dietitian (n=6), pharmacist (n=5). [5]Other sources of information regarding IDA: prior education (n=4), media (n=2). [6]Other sources of information regarding Supplements: media (n=6), prior education (n=6).

5.5 Attitudes

Figure 5.1 reveals that, overall, participants agree that IDA is common in pregnancy (83%) and that it has detrimental effects on maternal health (81%), and infant health to a slightly lesser extent (64%). While they agree that iron supplementation has a positive impact on the health of both mothers and babies (84% and 74%, respectively), one-third acknowledged that it is hard to remember to take the supplement (35%).

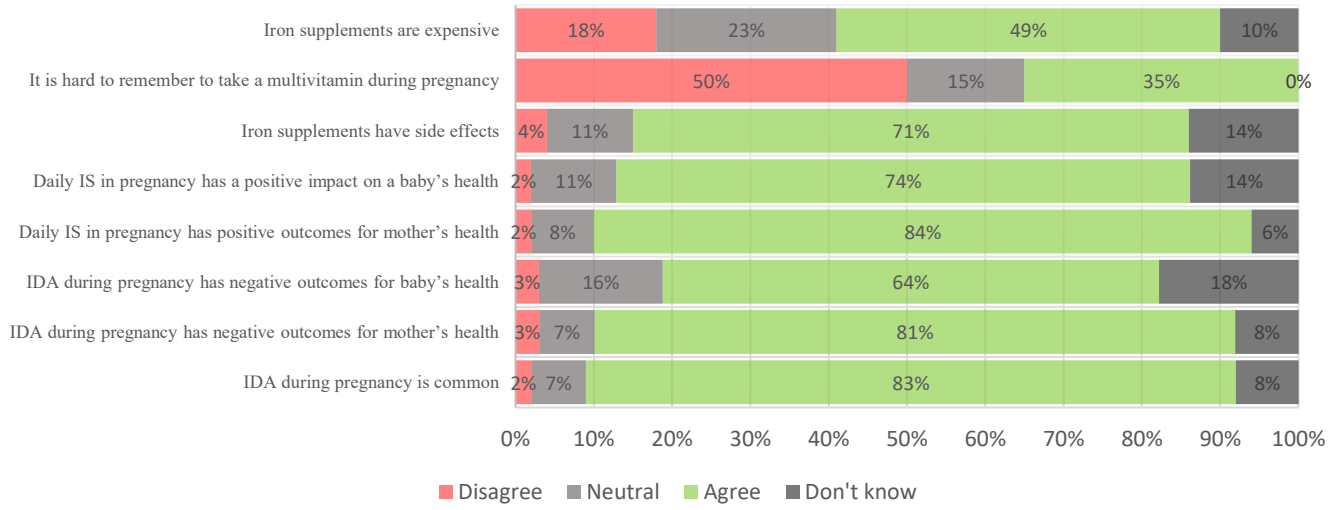

Figure 5.1 Attitudes about prenatal supplementation and iron deficiency anemia[1,2]

[1]Attitudes were assessed using a 5-point Likert scale, with participants responding to statements from 1=strongly disagree to 5=strongly agree (collapsed into disagree (1 or 2), neutral (3), or agree (4 or 5), or *I don't know*. [2] abbrev: Iron Supplementation, I.S.; IDA, Iron Deficiency Anemia.

5.6 Association of demographic characteristics with compliance

Adherence with Health Canada iron supplementation guidelines in pregnancy was significantly higher among older participants (32.5 ± 4.1 years) compared to younger participants (31.3 ± 4.2, p=0.02; (**Table 5.6**). Respondents living in the Central Zone of Nova Scotia were more compliant than those residing in the rest of the province (68% vs. 52%, respectively, p=0.01). Participants with a higher level of education (completed undergraduate or graduate degree) were significantly more likely to be compliant than high school graduates (p<0.05), as were wealthier participants (>$150,000 more compliant than <$65,000; p>0.05). There were no differences in compliance by racial or cultural group, marital status, parity, diet type, or anemia diagnosis.

Table 5.6 Association between sociodemographic factors and compliance with Health Canada recommendations for iron supplementation in pregnancy

Characteristic	**n**[1]	**Compliant** Mean ± SD or n (%)[2]	**Non-compliant** Mean ± SD or n (%)	**p**[3]
Age, years	289	32.5 ± 4.1	31.3 ± 4.2	0.02
Racial or cultural group	305			0.41
White		171 (63)	100 (37)	
Other[4]		19 (56)	15 (44)	
Geographic location within NS	308			0.01
Central Zone		141 (68)[a]	67 (32)	
Rest of Nova Scotia[5]		52 (52)[b]	48 (48)	
Highest educational attainment	307			<.001
High school (any or completed)		4 (22)[a]	14 (78)	
College		42 (55)[a,b]	34 (45)	
Undergraduate		74 (68)[b]	35 (32)	
Graduate or professional degree		73 (71)[b]	31 (30)	
Annual household income before tax, CAD$	306			0.003
Less than $64,999		20 (42)[a]	28 (58)	
$65,000 to $100,000		43 (63)[a,b]	25 (37)	
$100,000 to $149,999		49 (60)[a,b]	32 (40)	
$150,000 or more		79 (72)[b]	30 (28)	
Marital status	307			0.06
Married or common law		188 (64)	106 (36)	
Other[6]		5 (38)	8 (62)	

Table 5.6 (continued).

Parity	304			0.23
Primiparous		88 (67)	44 (33)	
Multiparous		103 (60)	69 (40)	
Main care provider	319			0.46
Obstetrician/gynecologist		126 (61)	80 (39)	
Family doctor		58 (64)	32 (36)	
Midwife		12 (63)	7 (37)	
Nurse practitioner		1 (25)	3 (75)	
Diagnosed with prenatal anemia	292[6]			0.89
Yes		91 (62)	55 (38)	
No		87 (60)	59 (40)	
Diet Type	319			0.18
Mixed diet		188 (63)	112 (37)	
Vegetarian/Vegan		9 (47)	10 (53)	

[1]*n* differs due to participants skipping some questions. [2]Percentages may not add to 100% due to rounding. [3]Categorical variables were analyzed using Chi-square tests, and continuous variables using independent t-tests, followed by a Bonferroni-adjusted post hoc test where applicable ($p<0.05$). Values in the same column with different letters differ significantly from each other. [4]Other racial or cultural group: Indigenous, Black, Latin, East Asian, Middle Eastern, South Asian, Southeast Asian. [5]Other Geographic location within NS: Eastern, Northern and Western zones.[6]Other Marital status: single, divorced, in a relationship. [6]Participant who didn't know if they had anemia were excluded from this calculation.

5.7 Association between knowledge of IDA and compliance

Compliance with Health Canada prenatal iron supplementation recommendations did not differ by knowledge, nor participants' main source of information about supplementation in pregnancy **(Table 5.7)**.

Table 5.7 Association between knowledge about iron deficiency anemia and compliance with Health Canada recommendations for iron supplementation in pregnancy (n=319)[1]

Knowledge/Compliance	n (%)[2]	Compliant	Non-compliant	p
Recognizes causes of anemia in pregnancy	298 (93)			0.99
Yes		184 (62)	114 (38)	
Recognizes ways of preventing IDA in pregnancy	294 (92)			0.30
Yes		184 (63)	110 (37)	
Recognizes symptoms of IDA in pregnancy	271 (85)			0.60
Yes		169 (62)	102 (38)	
Recognizes the health risks of IDA in pregnancy for themselves	222 (70)			0.98
Yes		137 (62)	85 (38)	
Recognizes the health risks of IDA in young children	201 (63)			0.98
Yes		124 (62)	77 (38)	
Recognizes the health risks of IDA in pregnancy for their newborn	166 (52)			0.08
Yes		110 (66)	56 (34)	
Primary source of information about supplements	**n (%)[2]**	**Compliant**	**Non-Compliant**	**p**
Doctor	169 (53)	116 (69)	53 (31)	0.09
Internet/Google search	57 (18)	33 (58)	24 (42)	
Other health care professionals[3]	39 (12)	22 (56)	17 (44)	
Friends/family/acquaintances	14 (4)	7 (50)	7 (50)	
Social media	9 (3)	6 (67)	3 (33)	
Other sources[4]	12 (4)	6 (50)	6 (50)	
None	19 (6)	7 (37)	12 (63)	

[1] Categorical variables were analyzed using Chi-square tests. Compliance with Health Canada Supplementation Guidelines were statistically significant when $p<0.05$. [2]Non-compliance is not shown but is the remaining value of the compliant counterpart shown in italics under each knowledge statement. [3]Other Health care professionals: Nurse, pharmacist, midwife, naturopath, dietitian. [4]Other: Magazines/brochures/books, prior education.

5.8 Association between attitudes regarding IDA and compliance

Of the 63% of participants who were compliant with Health Canada iron supplementation guidelines in pregnancy, a significantly higher proportion (77%) disagreed with the statement "It is hard to remember to take a Prenatal Micronutrient Supplement during pregnancy" (compared with 44% who agreed, p<0.001; see **Table 5.8**). Beyond this, no other attitudes differed significantly by compliance.

Table 5.8 Association between attitudes and compliance with Health Canada recommendations for iron supplementation in pregnancy[1]

Attitude[2]	**n[3]**	**Compliant** n (%)[4]	**Non-compliant** n (%)	**p**
Iron deficiency anemia during pregnancy is common	261			0.31
Agreement	*255 (98)*	161 (63)	94 (37)	
Iron deficiency anemia during pregnancy has negative outcomes for mother's health	260			0.13
Agreement	*242 (93)*	159 (64)	91 (36)	
Iron deficiency anemia during pregnancy has negative outcomes for baby's health	205			0.26
Agreement	*195 (95)*	131 (67)	64 (33)	
Daily iron supplementation in pregnancy has positive outcomes for mother's health	266			0.18
Agreement	*259 (97)*	174 (67)	85 (33)	
Daily iron supplementation in pregnancy has a positive impact on a baby's health	234			0.37
Agreement	*228 (97)*	154 (68)	74 (32)	
Iron supplements have side effects like constipation and heartburn	231			0.90
Agreement	*220 (95)*	136 (62)	84 (38)	
It is hard to remember to take a prenatal multivitamin during pregnancy	262			<0.001
Agreement	*107 (41)*	47 (44)[a]	60 (56)[b]	
Iron supplements are expensive	203			0.78
Agreement	*149 (73)*	97 (65)	52 (35)	

[1] Categorical variables were analyzed using Chi-square tests.Values in the same row with different letters differ significantly from each other. [2]Attitudes were assessed using a 5-point Likert scale; here, categories were collapsed into disagree (1 or 2) or agree (4 or 5). [3]*n* differs due to participants skipping some questions, or responding 'neutral' (3) or 'I don't know' on Likert scales. [4]Percentages may not add to 100% due to rounding.

6 Discussion

6.1 Summary

Among the 319 study participants, 62% were adherent to Health Canada guidelines, which recommend the consumption of a daily supplement containing 16–20 mg of elemental iron throughout pregnancy (21). Overall, 95% of participants consumed a Prenatal Micronutrient Supplement, all of which contained either at least 16 mg, or no iron whatsoever (16%, primarily in gummy formulations). Participants reported consuming 42 distinct Prenatal Micronutrient Supplements, three-quarters of which contained ferrous fumarate as the iron source. The top five brands (Jamieson, Centrum, and Nestle Materna, Baby be Sobeys (Free program), First Response Gummies) accounted for 73% of use. Additionally, 52% reported taking an Additional Iron Supplement beyond their prenatal vitamin (data not shown). No significant association was found between knowledge, attitudes, and adherence to Health Canada prenatal iron supplementation guidelines, likely because adherence was fairly high and overall participants were quite knowledgeable about IDA.

To our knowledge, this study is the first in Canada to assess adherence to prenatal iron supplementation guidelines using a KAP framework. The discussion that follows examines adherence patterns (dose, frequency, timing), compares findings with prior research, and concludes with strengths, limitations, and implications for future policy and research.

6.2 Dose

Iron requirements increase substantially during pregnancy, primarily to support maternal blood volume expansion, placental development, and fetal growth (21). As a result, the RDA increases from 18 mg for women of reproductive age to 27 mg during pregnancy (110). To meet these increased requirements, Health Canada recommends a daily multivitamin containing 16–20 mg of elemental iron (21). However, this guidance remains ambiguous, as it does not clarify whether this range represents a minimum threshold, an optimal target, or a strict limit. In this study, dose adherence was defined as a daily intake of at least 16 mg of elemental iron, a threshold informed by broader international recommendations from the WHO (30–60 mg) (156) and the CDC (30 mg) (72). Based on this criterion, 92% of participants were considered dose-adherent. However,

if a strict interpretation of the 16–20 mg range were applied, only 7% would be categorized as adherent, and 84% would be labeled as taking an "excessive" dose (>20 mg), despite aligning with other evidence-based guidelines.

When examining only the iron-containing Prenatal Micronutrient Supplement (84%, n=276), the mean ± SD dose of iron was 26.2 ± 4.7 mg (range: 16–45 mg), a value that surpasses Health Canada's guideline. However, emerging research suggests that the minimum requirement of 16 mg could actually be too low to maintain adequate iron status of pregnant Canadians (126). Similarly, Milman et al. conducted a trial among 427 healthy pregnant women in Denmark, comparing daily doses of 20, 40, 60, and 80 mg of elemental iron from gestational week 18 onward. Although baseline values were similar between groups, by weeks 32 and 39, the 20 mg group had significantly lower median serum ferritin and hemoglobin and a higher prevalence of iron deficiency compared with higher-dose groups. Authors concluded that 40 mg was the lower adequate dose, suggesting that that the Canadian minimum dose of 16 mg/day may require re-evaluation (157).

At the same time, safety of high iron doses must be considered. Combined daily intake from Prenatal Micronutrient Supplement and other iron-containing supplements in our study averaged 77.4 ± 72.3 mg, with a median (IQR) of 40 (27–166; n = 294, min = 0, max = 327). Results varied widely and although therapeutic doses >60 mg are expected under clinical supervision (18,81), exceeding the tolerable upper intake level (UL) of 45 mg can lead to side effects like gastrointestinal discomfort, reduced zinc absorption (18), oxidative stress, and alterations in gut microbiota (86). Another important concern is hemoconcentration, a condition characterized by elevated hemoglobin levels, which has been associated with low birth weight and preterm birth (158,159). For instance, Casanueva et al. (2006) found that among non-anemic, singleton, mid-term pregnant women (n=56), daily supplementation with 60 mg iron, 200 µg folic acid and 1 µg of vitamin B_{12} yielded a prevalence of 18% hemoconcentration (Hb: >135 g/L) at week 36 (mean 135.8 ± SD 10.0, range=109–161), which was correlated with low birth weight and premature delivery (159).

The potential adverse outcomes of both over- and under-dosing iron in this critical window underscore the continued need to reassess current iron supplementation guidelines. For example,

the National Academy of Sciences (formerly, the Institute of Medicine) iron recommendations, last published over two decades ago, established an UL of 45 mg for pregnancy based on data from non-pregnant women, because there was insufficient data at that time on the potential adverse effects of doses below 100 mg on pregnancy (110). In contrast, the WHO's current recommendation for daily iron supplementation is set to 30-60 mg (156), exceeding the current UL, and would likely align with optimal dosing ranges if these guidelines were updated to reflect current research. Given the substantial progress made in the last two decades regarding iron metabolism (58,85,160), dosing strategies (88,113,128,157), supplementation schedules (88,89,159), and related maternal health outcomes, which have already informed changes to broader maternal health guidelines (114,156,161), a revision of iron DRIs is likely also warranted.

6.2.1 Special Considerations for Vegetarians and Vegans

Iron deficiency is a well-recognized concern for individuals following vegetarian or vegan diets, as these groups face an increased risk of anemia given that dietary iron is consumed in the less bioavailable non-heme form (110). In the current study, 6% (n = 19) of participants followed a vegetarian or vegan diet, which is consistent with the national prevalence of approximately 5% (109). Among them, only 9 (47%) participants adhered to the general Health Canada iron supplementation recommendations during pregnancy. However, the National Academy of Sciences sets iron requirements for vegetarians at 1.8 higher than for individuals with mixed omnivorous diets, due to the lower bioavailability of non-heme iron (110). This raises concern given that these standard guidelines acknowledge an increased need in demand but do not provide specific dosage adjustments for individuals following plant-based diets, suggesting that an even greater proportion could be at risk of low iron status. This finding suggests the need for targeted interventions, potentially including messaging for even higher daily iron supplement doses to support this nutritionally vulnerable population.

6.2.2 Regulatory Context

A startling 16% of products consumed by participants in this study, marketed as prenatal multivitamins, contained no iron whatsoever. The vast majority of these iron-lacking supplements were gummy formulations (n= 43/45), predominantly First Response (n = 22), Centrum Gummies (n = 8), and Olly (n = 6), and 2 in the form of capsules. Importantly, this lack of iron is not disclosed on the front-of-pack label, meaning that consumers cannot simply assume that "prenatal multivitamins" contain all the micronutrients required to support maternal and fetal health. The frameworks governing supplement sales in Canada is outlined below.

In Canada, nutrient supplements fall under Health Canada's Natural Health Products (NHP) framework (162). The framework for prenatal supplements does not require that iron be included; only folic acid is mandatory (162). This creates a gap: a product can be marketed as a "prenatal multivitamin" without having iron, despite Health Canada recommendations that pregnant individuals consume supplements containing both "0.4 mg of folic acid and 16 to 20 mg of iron"(163). For example, the gummy supplements most frequently purchased by our participants (see Appendix A) had front-of-pack labels reading, "Prenatal Gummies" followed by "Multivitamin with Folic Acid," emphasizing the benefits of folic acid. Only in small print on the back of the package were messages that read "No iron added, gentle on stomach" (bolded) and later "Daily iron intake is recommended for a healthy pregnancy" (not bolded). It is possible that participants in our study did not realize that they were missing a key micronutrient from these gummies, as fewer than half of these women consumed an additional iron-containing supplement (n=20 of 43, data not shown).

To add to this confusion, separate NHP regulations regarding "multiple micronutrient supplements" require a minimum of 1.4 mg iron per serving, a dose well below the Health Canada pregnancy-specific recommendation of at least 16 mg (21). The only specific labelling guidelines for iron are for high loses: the most recent guidelines (2023) require warning labels when a product contains more than 35 mg iron (due to side effects) or more than 250 mg (for child safety) per serving. Given the apparent mis-match between guidance and regulation, NHP regulations for prenatal vitamins should likely be re-vamped to align with Health Canada's prenatal iron supplementation guidance (21,162).

Given the critical role of iron of maternal and fetal health, there is a need to strengthen regulatory guidelines for prenatal supplements in Canada. These guidelines should establish a clear regulations for “prenatal supplements”, requiring minimum and maximum dosages for both essential nutrients, folic acid and iron. Such measures would help ensure that pregnant individuals are not misled by incomplete formulations during this critical period of development.

6.3 Adherence to Recommended Frequency

When considering Prenatal Micronutrient Supplements alone, 82% of participants reported taking them daily. This proportion is high, and in line with the 83% figure for daily multivitamin use observed in a 2024 Vancouver study assessing supplementation practices among women who were either pregnant (n = 250) or planning to conceive (n = 250) (23).

When including all participants who took either a Prenatal Micronutrient Supplement and/or an Additional Iron Supplement, daily intake increased slightly to 85%. This higher percentage reflects the fact that some participants taking extra iron followed intermittent-day schedules (65%), which is common for high-dose formulations (44,89). Among the 46 (of 313) participants who started any supplement, but not on a daily basis, 83% achieved the total recommended dose (data not shown), suggesting that strict daily dosing requirements may act as a barrier to adherence. These findings underscore the potential of intermittent iron supplementation, which is discussed below.

6.3.1 Rationale for Intermittent Iron Supplementation

Intermittent iron supplementation, defined as taking iron one to three times per week on non-consecutive days, has been studied for more than 30 years (89). In 2012, the WHO issued a guideline recommending intermittent iron and folic acid supplementation for non-anemic pregnant women. This guideline strongly advises a weekly dose of 120 mg of elemental iron and 2800 μg of folic acid, initiated as early as possible and continued throughout pregnancy in countries where anemia prevalence is <20%, as is the case of Canada (3), only in the absence of diagnosed anemia (161). The rationale is grounded on the physiological mechanisms of iron absorption: hepcidin, a hormone that blocks iron absorption, remains high for 24 hours after iron intake, thus reducing absorption from a subsequent daily dose. Allowing a longer interval

between doses allows hepcidin levels to normalize and enables intestinal lining regeneration, in turn enhancing iron absorption. Additionally, intermittent dosing helps prevent the absorption of other minerals from being inhibited and reduces gastrointestinal side effects such as nausea and constipation (164).

Evidence supporting this approach includes a Cochrane review (n=5490 women, 21 studies) comparing daily versus intermittent supplementation (89). The review found no significant differences in key infant outcomes such as low birthweight (average risk ratio (RR) [95% CI]) = (0.82 [0.55 - 1.22]; n=1898), premature birth (1.03 [0.76 - 1.39]; n=1177), or neonatal death (0.49 [0.04 - 5.42]; n=795). With regards to maternal outcomes, intermittent regimens did not increase the risk of anemia at term (1.22 [0.84 - 1.80]), but did reduce the risk of elevated hemoglobin >130 g/L (0.53 [0.38 - 0.74]; n = 2616) and side effects (0.56 [0.37 - 0.84]; n = 1777) (89).

Additional evidence comes from a recent randomized controlled trial in Switzerland that evaluated the effect of oral iron doses on hepcidin response, iron absorption, and biomarkers in 54 healthy, non-anemic, non-pregnant women with iron depletion (18–45 years; Hb >11.7 g/L; ferritin ≤20 μg/L) (165). The study found that hepcidin levels increased significantly within 24 hours after doses of 80, 160, and 240 mg ($P<.05$), but not after 40 mg, and that this elevation was no longer statistically significant at 48 hours. With increasing dose, fractional iron absorption decreased ($p<0.001$), while absolute iron absorption increased ($p<0.001$). In absolute terms, researchers showed that a sixfold increase in dose (40 mg vs. 240 mg) resulted in only a threefold increase in absolute absorption (6.7 mg vs. 18.1 mg) (165). Authors thus concluded that spacing iron supplementation by 48 hours at doses ≥60 mg improves fractional absorption, challenging earlier beliefs that mucosal block lasted 5–6 days (164,165). Overall, these findings support intermittent supplementation in non-pregnant women. However, studies in pregnancy are needed given the different iron requirements and physiological changes that may alter hepcidin-mediated absorption inhibition and fractional absorption during this life stage, potentially impacting outcomes. At present, however, the WHO guidelines recommend a weekly dose of 120 mg for non-anemic populations (161), applying this framework in Canada may require re-evaluation in light of this recent evidence on optimal timing and dosing. Implementing such strategies, whether preconceptionally or during pregnancy, could help reduce side effects and

improve adherence. However, this would need modifications to current Canadian guidelines and the establishment of clear dose specifications for non-daily regimens (e.g., 60 mg thrice weekly versus 16-20 mg daily). Substantial evidence and policy discussions will be essential to support any changes to public health recommendations.

6.4 Timing

6.4.1 Initiation

Health Canada does not explicitly specify the optimal timing for initiating or discontinuing iron supplementation, but states that "16 mg per day *throughout* pregnancy would be effective and safe" (21). This wording implies supplementation should continue at least until parturition, however, judging the initiation cut-off is more challenging: should adherence be defined by starting supplementation when pregnancy is first detected, usually around 5.5 weeks of gestation (165), the time of first prenatal visit (usually week 6-10), by ultrasound confirmation (ideally at 7-12 weeks) (79), or preconceptionally?

The WHO proposes preventative iron supplementation among women who could become pregnant. In such a program, supplements are distributed weekly to all menstruating women (60 mg iron plus 2,800 µg folic acid) for 3 consecutive months, followed by a 3 month break, and repeated, a strategy shown to improve hemoglobin and ferritin concentrations, and reduce anemia prevalence (164). This approach is particularly relevant because pregnancies can occur outside of "planned" timelines (119). Since insufficient preconception iron reserves are more difficult to correct during pregnancy, even with therapeutic doses (167), reinforcing the importance of optimizing iron status pre-pregnancy could preventatively support higher demands (168).

In our study, most participants began taking a Prenatal Micronutrient Supplement before conception (68%) or during the first trimester (31%), typically following healthcare provider advice. Additional Iron Supplements were introduced later, most commonly in the second trimester (52%) or third (21%), primarily after an iron deficiency diagnosis (52%). This pattern is expected, as iron is typically recommended for all pregnant women at their first prenatal visit, regardless of biomarker status. Deficiencies are often identified during the second routine

hemoglobin assessment in the second trimester (79) a period when iron requirements rise sharply due to blood volume expansion and declining hemoglobin levels (168). This timing coincides with the highest prevalence of anemia and the resulting need for higher, therapeutic doses of iron (80,114).

When considering overall iron supplementation practices, 99% of participants in this study started within either the first trimester (31%) or preconception (68%). The latter proportion is lower than the 86% who started before pregnancy reported in the Vancouver study (23), were half of participants were actively trying to conceive, a difference likely attributable to greater pregnancy planning in that cohort. To our knowledge, these are the only 2 studies assessing iron supplementation practices during pregnancy in Canada. Both suggest that Health Canada's recommendations for prenatal supplementation are being partially implemented, and timing of initiation does not appear to be a major determinant of adherence.

6.4.2 Discontinuation

Discontinuation was rare in our study: only 4% of participants stopped all iron supplementation during pregnancy, indicating that once supplementation is initiated, adherence generally persists.

It is notable that side effects are often cited as one of the main reasons for poor adherence to iron supplementation regimens in the literature, especially in low-income and low-education settings (169). However, in our study, the most frequently reported reasons for stopping the Prenatal Micronutrient Supplement were forgetfulness (25%), perceived lack of need (22%), and then side effects (14%; n = 73), with nausea and constipation being the most commonly reported adverse effects. Still, since discontinuation itself was not a major determinant of overall non-compliance, it is not surprising that none of these reasons were significantly associated with non-adherence.

It is likely that the specific iron supplement consumed drives side effects and eventual discontinuation. For instance, a Swedish study involving 901 pregnant women, 134 midwifes and 50 senior obstetricians, assessed adherence to public health guidance on iron supplementation and reported that nearly half of pregnant individuals (46%) discontinued an iron-containing supplement due to side effects (13). This occurred despite their study population

sharing similar characteristics to ours (White, highly educated, and economically advantaged), with the main difference being that at the time of their study, Sweeden's public blanket supplementation guideline recommended 100 mg/day. In contrast, most participants in our study took a Prenatal Micronutrient Supplement containing a quarter of the Swedish dose (27 mg, 53%). Even among participants in our study taking an Additional Iron Supplement (the most common dose was 150 mg (51%)), the leading reason for discontinuation among this group was normalization of iron status (40%, n = 78). While participants experienced more than double the prevalence of side effects compared to those using only a Prenatal Micronutrient Supplement (49% vs. 22%), this was not a major reason for discontinuation of supplementation. The most commonly reported adverse effect for participants taking an Additional Iron Supplement was constipation (75%), followed by multiple side effects (61%), which is expected since higher doses increase the risk of gastrointestinal intolerance due to iron accumulation in the intestines (87), as previously discussed.

Fetal health appeared to outweigh maternal discomfort in our study, suggesting that women were willing to tolerate mild side effects to maintain adherence. This reflects the view of pregnancy as a period to adopt healthier behaviours, largely driven by the desire to protect the baby and minimize risks for themselves and their family. This is reinforced by the desire to meet societal expectations and avoid judgment, which may further strengthen motivation to continue supplementation despite discomfort (170).

6.5 Other Findings About Supplementation Practices

Ferrous fumarate was the most common iron salt, accounting for the salt in 76% of Prenatal Micronutrient Supplements taken by our participants. Iron salts are commonly used in supplements, with ferrous forms generally considered more bioavailable than ferric forms (87). Ferrous fumarate, in particular, offers a higher elemental iron content compared to other salts, enabling smaller pill sizes (171). It is also widely available and cost-effective, although it may be less well tolerated than newer formulations such as iron–amino acid chelates, nanoparticle iron, or enteric-coated and slow-release forms, which are typically more expensive (172).

We also found that participants took 42 different Prenatal Micronutrient Supplements, which highlights the overwhelming number of choices available to consumers. Crawford et al. (2023)

report that, according to the NIH Office of Dietary Supplements' Dietary Supplement Label Database (DSLD) as of August 2022, there were 718 products on the market labeled as "prenatal" with three-quarters being multivitamin/mineral supplements (172).

This wide variety can add stress during a period already full of information overload and decision fatigue. A qualitative study in New Zealand reported that women feel anxiety when choosing supplements given societal pressure and the overwhelming abundance of health information (173). Since prenatal micronutrients are sold over the counter, displaying key messages on front-of-pack labels, or educating individuals on how to read prenatal nutrition facts tables could help improve confidence into identifying better choices that align with their needs (174).

In addition to promoting informed decision-making, public health efforts could further support maternal nutrition by providing free access to standardized formulations that are tailored to the Canadian context, as recommended by the WHO (114). Many low-income settings globally promote the use of the United National International Multiple Micronutrient Antenatal Preparation (UNIMMAP) supplements, which contain 15 micronutrients, including 30 mg of iron and 400 µg of folic acid (175). Through our study, we mapped that a free prenatal supplement option was offered by a private initiative through Sobeys Pharmacies (including Lawtons Drugs), as part of their Baby be Healthy program (129). These supplements were accessed by 7% of our study population, across all income levels (data not shown), signaling interest in this kind of support. Integrating such standardized formulations into Canada's public health system could offer a reliable alternative to over-the-counter products, reducing choices for pregnant individuals while ensuring nutritional adequacy to a broader extent (114,173).

6.6 Attitudes and Knowledge

The KAP framework was employed in the current study given that knowledge and attitudes can strongly influence health behaviours and outcomes, particularly when supported by educational interventions (13,26,27). The impact of knowledge on behaviour is well illustrated by the Maternity Experiences Survey in Canada, which reported that 69% of participants who were aware that folic acid prevents birth defects began supplementation before conception, compared with only 18% of those who were unaware (119). Although this finding concerns folic acid, it is

relevant given that both folic acid and iron supplementation are explicitly recommended in Canada during pregnancy, and no prior studies have specifically examined iron adherence in this context.

In our study, most participants demonstrated correct knowledge about IDA, particularly its symptoms (85%), causes (93%), and prevention (92%). However, awareness of specific risks associated with maternal IDA during pregnancy, the neonatal period, and childhood was lower (70%, 52%, and 63%, respectively). These gaps are important because IDA is linked to severe complications such as maternal death (4–6), as well as long-term effects such as fatigue, depression, and impaired bonding, which may negatively affect child development and behaviour (97). Iron also plays a critical role in fetal brain development, influencing later cognitive and motor skills, emotional regulation (1,98), which in turn can impact educational and economic outcomes later in life (99).

Despite the hypothesis that knowledge would be a predictor of beneficial practice (27,176), it did not influence adherence to Health Canada prenatal iron supplementation guidelines in our study, likely because both knowledge and adherence were high. Similarly, most attitudes assessed were not associated with adherence, with one notable exception: forgetfulness. Women who agreed that remembering to take a prenatal multivitamin was difficult were significantly more likely to be non-adherent (56%) compared to adherent (44%; $p<0.001$). Forgetfulness was also the most frequent reason reported for discontinuing Prenatal Micronutrient Supplements (25%). This is consistent with prior research from Sweeden and Ireland identifying forgetfulness as a key barrier to adherence (13,130). Practical strategies such as assigning specific days and times for supplement intake (i.e. taking iron with dinner on Mondays, Wednesdays and Fridays) (177), could help establish consistent habits and improve compliance.

An unexpected finding of this study was the limited impact that side effects had on practice, as agreement that supplements could cause side effects did not significantly impact adherence. Nevertheless, fear of adverse effects was cited by 8 of the 17 (47%) respondents who avoided Prenatal Micronutrient Supplements, and by 11 of the 130 (8%) of those who didn't take Additional Iron Supplements. Supporting this, the Swedish study mentioned earlier, found that

although 32% of participants perceived side effects as a negative consequence from previous iron supplementation experiences, only 11% cited this as a reason for non-adherence (13).

6.6.1 Main source of information

Although online resources and social media are increasingly used for health information (178), when it came to IDA and supplementation guidance fewer than 5% of our participants identified social media as their main source of information, and fewer than 20% relied primarily on other online platforms. Health care professionals were by far the main source of information for both IDA and prenatal supplementation (56% and 53% of participants, respectively). This finding aligns with other literature suggesting that women rely in the pregnancy advice given by their healthcare provider. For example, the quantitative study from Sweeden showed that 49% of women started taking a supplement based on their midwife's advice, and the extent to which women believed their midwife valued supplement use influenced their likelihood of adherence (13). This underscores the critical role of the messages delivered by health care providers in shaping patient behaviour.

Canada lacks standardized guidelines regarding the transition between levels of prenatal care. Ideally, pregnancies with low obstetric risk should be managed by primary care providers such as midwives or family physicians, while specialized obstetric care should be reserved for higher-risk cases, depending on the size and resources of each community (137). Our findings show that participants were mostly attended by obstetricians/gynecologists (65%), family doctors (28%), and midwives (6%) which is similar to the national finding of 2009: obstetricians/gynecologists were reported as the main prenatal care providers for 58% of pregnancies in Canada, followed by family physicians (34%) and midwives (6%) (119). Even though our study shows that the public health care messages provided by health care professionals are generally effective in supporting adherence, there remains room for better nutrition training for physicians. An American study assessing KAP for plant-based diets among 5,000 obstetricians/gynecologists (2024) reported that 72% considered their nutrition training insufficient, as most received less than 10 hours of formal instruction during medical school, and only a minority (34%) received 1-10 hours during residency; notably, 39% had no additional nutrition education (179). Despite this, 82% provided brief nutritional counseling during appointments, and fewer than 25% referred patients to a

nutrition specialist (179). Given that optimal nutrition (including iron supplementation) plays a key role during the prenatal period (104), it is imperative that the medical curriculum integrates more nutrition training (180), enhancing specialized nutrition training during residence years (179), and increase time to counsel patients about this subject (179). In addition, improved referral rates and/or access to dietitians could provide specialized support to pregnant individuals (181).

6.7 Future directions

6.7.1 Phrasing considerations for updating current Health Canada guidelines

The prenatal iron supplementation guidelines outlined by Health Canada in the *Prenatal Nutrition Guidelines for Health Professionals* (2009) suggesting that women "look for a multivitamin that provides 16–20 mg of iron per daily dose" are somewhat ambiguous, potentially causing issues in three areas. This phrasing implies a rigid dosage range of no less than 16 mg and no more than 20 mg, creating a narrow 4 mg window that may be difficult to meet in practice, and importantly, may be insufficient for the general population as well as specific vulnerable groups like vegans (21,110). The guidelines do not clearly state when supplementation should begin or end. Although the word "*throughout*" is included in one paragraph of the guideline, it is not part of the core message. Finally, the terminology should be updated to use a more inclusive term, such as "prenatal micronutrient supplement," rather than "multivitamin." The latter is often used interchangeably by consumers to describe products containing both vitamins and minerals (21,137,163) and could lead to confusion for manufacturers and consumers. This is particularly important in the Canadian context given that NHP regulations require prenatal supplements contain only folic acid, and multivitamins contain only 1.4 mg iron (162). These aspects will be explored in depth below.

6.7.2 Recommendations for dosage, frequency and initiation time

The Canadian recommendation for 16-20 mg iron supplementation throughout pregnancy differs from other international recommendations, including the daily 30 mg to 60 mg recommended by the WHO (156) or the daily 30 mg suggested by the USA (72). Recent research by Milman et al. (n=427 healthy pregnant women in Denmark) outlined that a dose of 20 mg could be too low to

improve iron biochemical response as it resulted in significantly lower median serum ferritin and hemoglobin concentrations, and a higher prevalence of iron deficiency, compared with 40, 60, and 80 mg doses of elemental iron as ferrous fumarate (157).

Another policy change to consider is intermittent iron supplementation in pregnancy, which is as effective as daily supplementation, with less risk of hemoconcentration and adverse effects (89). The intermittent scheme proposed by the WHO for non-anemic pregnant women where anemia prevalence is <20%, like Canada (3). , is a weekly dose of 120 mg of elemental iron and 2800 μg of folic acid (156). These calls for non-daily iron supplementation are also supported by a Cochrane review (n=5490 women, 21 studies), that reported no significant differences in key outcomes such as low birthweight, premature birth, neonatal death, or risk of anemia at term, but did reduce the risk of hemoconcentration and side effects (89).

Identifying the maximum allowed dose is an important consideration. The National Academy of Sciences does not adhere to a fixed schedule for updating the DRIs. Instead, re-evaluations are undertaken when new information from scientific evidence warrants a revision (182). The current iron DRIs were published more than 20 year ago, and with the UL of 45 mg based on data from non-pregnant populations because of limited pregnancy data at that time (110). Given the abundance of novel research in the areas of prenatal iron metabolism (58,85,160), dosing strategies (88,113,128,157), and supplementation schedules (88,89,159), it may be useful for the DRI Committee to meet and potentially to inform updated national and even global guidelines.

Regarding the optimal starting period, improving iron reserves before conception is beneficial to prevent pregnancy IDA (167), so prophylactic iron could serve as an opportunity to support women's health during the reproductive years. One example of such a strategy is the WHO guidance that proposes a regimen of 60 mg iron plus 2,800 μg folic acid for periods of 3 consecutive months, every 3 months (164). In line with existing folic acid messaging, iron supplementation could similarly be encouraged for anyone who could become pregnant, recognizing that conception does not always follow planned timelines (119).

In sum, updated guidelines could recommend starting iron supplementation with a prophylactic weekly supplement on an alternating 3 month schedule (164), and once pregnancy was detected, current guidelines could increase in dose but not necessarily every day, for example 60 mg on

alternating days (versus current 16-20 mg daily). However, further research is warranted to establish the exact recommendation in the Canadian context.

6.7.3 Recommendations for NHP framework

Given the suggestions above, it is vital that any content in the *Prenatal Nutrition Guidelines for Health Professionals* guideline be mirrored in the NHP framework, which governs supplement labeling in Canada. Currently, NHP regulations do not require products marketed as "multivitamins", including those intended for prenatal use, to contain iron, despite this being a critical nutrient during pregnancy. In addition, at present, NHP permits products to meet iron labeling requirements with as little as 1.4 mg per serving, a value that contradicts current recommendations for pregnancy. Finally, if a prenatal product is intentionally formulated without the minimum recommended amount of iron (i.e. 16-20 mg for pregnancy; 1.4 mg otherwise), it would be useful for a front-of-pack label to clearly indicate this. A warning statement should be included to alert consumers that the product may not meet the nutritional needs associated with pregnancy.

6.7.4 Special considerations for health care professionals

Given that healthcare providers were the main source of both IDA and iron supplementation information in this study, it is essential that providers engaging with pregnant individuals are sufficiently trained on nutrition messaging. More nutritional training in the medical school curriculum is warranted (180), specially during residence years (179), as some prenatal health professionals received as little as 10 hours of formal training (179). In addition, more frequent consults with, and improved access to, dietitians could allow for more specialized support for pregnant individuals (181).

6.8 Strengths and Limitations

6.8.1 Strengths

This is the first Canadian study specifically designed to evaluate adherence to Health Canada's iron supplementation guidelines during pregnancy, while also examining the influence of knowledge and attitudes on supplementation practices.

The study achieved a sample size of 319 participants, accounting for an estimated 4% of the approximately 8,000 annual births in Nova Scotia (144). This is a considerably larger sample representation compared to similar quantitative studies conducted in other HIC, such as those from Sweden (n=901, 0.9%) (13), and Germany (n=207, <0.05%) (117). Recruitment extended over all four of Nova Scotia's health zones, reached by an extensive social media campaign that included targeted advertisements, maximizing participant diversity even in hard-to-reach areas and enhancing the representativeness of the study population. Another strength lies in the quantitative approach employed, which allowed for objective measurements of adherence and supplementation practices. This contrasts with prior literature, where most investigations in HIC rely solely on qualitative data. Finally, this research contributes to public health policy discussions by identifying opportunities to better align guideline recommendations, product labeling practices, and real-world maternal behaviours within the Canadian context.

6.8.2 Limitations

Although efforts were made to diversify the participant pool (strategies described above), the study population was mostly made up of older, white, well-educated, and affluent women. As such, some of the findings may be statistically significant but not clinically meaningful given the homogenous nature of this group (e.g. 'older' women (by 1 year) were more compliant with Health Canada supplementation guidelines, 32.5 ± 4.1 vs 31.3 ± 4.2 years, p=0.02). Future studies could employ purposeful recruitment strategies to ensure young, low-income women are captured to understand whether iron supplementation practices actually differ by sociodemographic characteristics. The retrospective, self-reported nature of data collection in this study introduces potential recall bias, particularly among the postpartum participants, since this period is often characterized by sleep deprivation, exhaustion, and emotional changes which can impair memory accuracy (101,104). Although we attempted to mediate recall bias by providing visual aids featuring common supplement brands as recommended by the WHO (91), this limitation should be considered. Social desirability bias is another possible limitation, since participants could have been reluctant to disclose non-compliance with iron supplementation (156). To mitigate this, we emphasized that the questionnaire was completely anonymous and responses could not be traced back to individual participants, reducing the likelihood of biased reporting and encouraging more honest and accurate answers. Finally, the study did not explore

whether participants were aware of Canadian guidelines for prenatal iron supplementation or whether iron content influenced brand selection, which could be relevant to understanding if participants believed they were taking the correct dose, especially among those consuming gummies that typically lacked iron, or the supplements that exceeded the UL.

7 Conclusions

This study provides valuable insights into prenatal iron supplementation knowledge, attitudes and practices among Nova Scotians. Encouragingly, 62% of participants adhered to Health Canada's recommendations regarding iron intake during pregnancy, and the majority relied on healthcare providers as their main source of information for guidance. However, our findings also raise several concerns as 16% of participants reported using Prenatal Micronutrient Supplements that contained no iron at all, most commonly in gummy formulations marketed for pregnancy. With 42 distinct prenatal supplements identified in this study, the variability in formulations, dosing, and labelling highlights the need for more robust regulatory oversight to help consumers make informed choices. Finally, this study enhanced our understanding of the discrepancy between recommended and actual iron supplementation intakes in pregnancy. Most participants who consumed iron in their supplements took more than the recommended 16-20 mg daily dose, with many consuming more than the UL of 45 mg. It is unclear whether this is actually of concern for overconsumption given the extensive body of literature showing the safety of high prenatal doses, and various blanket recommendations ranging from 30-60 mg daily from other national and global health agencies. Given the growing body of evidence in this area, Health Canada should likely revisit these prenatal recommendations, with appropriate adjustments to regulatory frameworks (i.e. NHP labelling) to follow.

In conclusion, we hope the findings of this study contribute to ongoing conversations aimed at refining national guidelines, enhancing patient education, and promoting evidence-based approaches to iron supplementation during pregnancy to improve maternal and fetal health outcomes across Canada.

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9 Appendices

Appendix A MSVU Ethic's clearance

MOUNT SAINT VINCENT UNIVERSITY

University Research Ethics Board (UREB)

CERTIFICATE OF RESEARCH ETHICS CLEARANCE

☐	☐	☐	☒	☐
Clearance	Secondary Data Clearance	Renewal	Modification	Change to Study Personnel

REB Protocol #:	2024-204		
Effective Date	March 5, 2025	Expiry Date	March 4, 2026
Title of project:	Prenatal iron supplementation in Nova Scotia: an exploratory cross-sectional study of knowledge, attitudes and practices		
Researcher(s):	Kyly Whitfield		
Supervisor (if applicable):	n/a		
Co-Investigators:	Devora Goldberg; Linda Mann; Kelsey Cochrane		
Version :	1		

The University Research Ethics Board (UREB) has reviewed the above-named research proposal and confirms that it respects the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* and Mount Saint Vincent University's policies, procedures and guidelines regarding the ethics of research involving human participants. This certificate of research ethics clearance is valid for a period of **one year** from the date of issue.

Researchers are reminded of the following requirements:	
Modification to Protocol	Any changes to the approved protocol must be reviewed and approved by the UREB prior to their implementation. Form: REB.FORM.002 Info: REB.SOP.404 Policy: REB.POL.003
Changes to Research Personnel	Any changes to approved persons with access to research data must be reported to the UREB immediately. Form: REB.FORM.002 Info: REB.SOP.404 Policy: REB.POL.003
Annual Renewal	Annual renewals are contingent upon an annual report submitted to the UREB prior to the expiry date as listed above. You may renew up to four times, at which point the file must be closed and a new application submitted for review. Form: REB.FORM.003 Info: REB.SOP.405 Policy: REB.POL.003
Final Report	A final report is due on or before the expiry date. Form: REB.FORM.004 Info: REB.SOP.406 Policy: REB.POL.003
Privacy Breach	Researchers must inform the UREB immediately and submit the Privacy Breach form. The breach will be investigated by the REB and the FOIPOP Officer. Form: REB.FORM.015
Unanticipated Research Event	Researchers must inform the UREB immediately and submit a report to the UREB within seven (7) working days of the event. Form: REB.FORM.008 Info: REB.SOP.404 Policy: REB.POL.003
Adverse Research Event	Researchers must inform the UREB immediately and submit a report to the UREB within two (2) working days of the event. Form: REB.FORM.007 Info: REB.SOP.404 Policy: REB.POL.003

*For more information: http://www.msvu.ca/ethics

Brenda Gagné
Research Ethics & Compliance Officer
University Research Ethics Board

166 Bedford Hwy, Halifax, Nova Scotia, Canada, B3M 2J6
T: 902-457-6350 | ethics@msvu.ca

Appendix B Consent form

Welcome! Thank you for your interest in our study about iron supplementation in Nova Scotia.

Why are we doing this study?

While there is research globally exploring people's knowledge of anemia and attitudes and practices around prenatal iron supplementation, little is known about these topics during pregnancy in Canada, or specifically in Nova Scotia. We want to gather this information from individuals who spent at least half of their pregnancy in our province. Insights could be useful to inform future health supports for pregnant individuals in Nova Scotia.

Who is conducting the study?

This study is led by Dr. Kyly Whitfield in the Milk and Micronutrient Assessment (MAMA) Lab in the Department of Applied Human Nutrition at Mount Saint Vincent University (MSVU). Other researchers are Devora Goldberg (student, MSVU), Prof. Linda Mann (MSVU), and Dr. Kelsey Cochrane (University of Saskatchewan). We have no conflicts of interest to report.

Who can participate in this study?

To participate in this study, you must:

- Be 19 years or older,

- Be at least 5 months pregnant, or have given birth within the last 12 months,

- Resided in Nova Scotia for at least 5 months of your pregnancy, and

- Be able to complete a survey online, in English

What does participation look like?

This is an online survey that can be completed on a computer, mobile phone, or tablet. You will be asked questions about yourself and your household, your pregnancy (and birth, if you have already delivered your baby), and then questions about anemia and iron supplementation.

It should take you about 20 minutes to complete the survey. As a 'thank you' for your time, you can enter a draw for a chance to win 1 of 3 $50 gift cards to a store of your choice. Your odds of winning one of the gift cards is based on the number of people who participate in this study (we aim to recruit about 400 people). We'll provide instructions on how to enter this draw at the end of the survey. Importantly, the draw process is separate from the survey, so the e-mail address you provide for the draw will not be connected to the study data in any way, will be stored separately, and will be destroyed after gift cards have been awarded.

Participation in this survey is voluntary. You are free to skip any question(s) you prefer not to answer, except those confirming your eligibility. If at any point you wish to withdraw from participation, simply close the survey window in your browser. If you choose to withdraw, you will still have the opportunity to be entered into the draw for a gift card. Simply click "Next page" at the bottom of your screen until you

reach the final survey page, where you will be redirected to the draw page. Any data collected up until you withdraw will be saved for analysis.

Risks and Benefits

The study is considered low risk. For instance, during the survey you may reflect on anemia and its health effects on mothers and children, and pregnancy loss, which could be upsetting. Since reflecting on your personal health information may be distressing, you may prefer to complete the questionnaire in a private area. At the end of the survey we will provide you with a list of resources in case you want to learn more, or want to speak with a public health nurse about any concerns. You will not receive direct benefits from participating in this study. We hope that lessons learned from this study can be used to inform future health supports for pregnant individuals in Nova Scotia.

Keeping study information safe

Your confidentiality will be respected. The online survey platform will automatically generate a unique study number for you as a participant in this study. Only this number will be used on any research-related information collected about you during the course of this study, so that your identity as a participant in this study will be kept confidential. Survey data will be saved on the secure, password-protected Mount Saint Vincent University cloud server for a period of 5 years, accessible only to the members of the research team directly involved in analysis.

Note that 'cookies' will be collected, and you will be asked to complete a CAPTCHA by the online survey platform in order to prevent repeat entries and 'bots' from entering fake data.

This study has received ethics clearance from the Mount Saint Vincent University Research Ethics Board (MSVUREB #2024-204). If you have any questions or would like further information concerning this research, please do not hesitate to contact Dr. Kyly Whitfield, the Principal Investigator, at mama.lab@msvu.ca. If you have questions about how this study is being conducted and wish to speak with someone who is not directly involved in the study, you may contact the MSVU Research Office by e-mail at research@ msvu.ca.

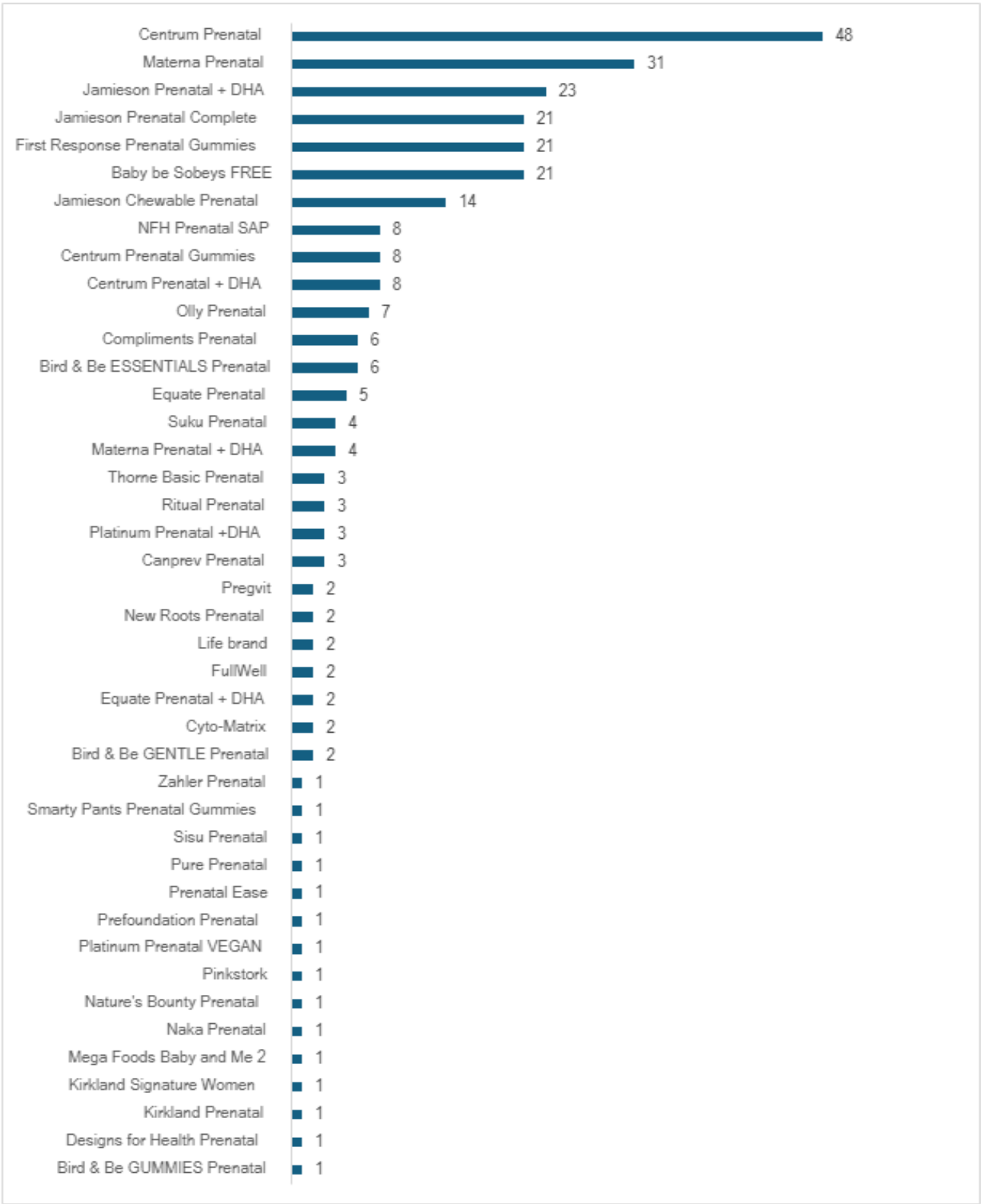
Do you want to hear the results?

If you are interested in reading about what we learned from this study, please check for an update at www.mamalab.ca in late Fall 2025.

By answering and submitting the survey questions it is assumed that you are giving consent to participate in this research.

To begin, please click next.

Appendix C Frequencies of Prenatal Micronutrient Supplements taken(n=276)



Appendix D Sample of a Label from a Prenatal Micronutrient Supplement (Gummy)

Iron information was purposely highlighted so it is easier to find