Examining Cesarean Birth among Women of Advanced Maternal Age in Nurse-Midwifery Care

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ABSTRACT

Background: Cesarean Birth (CB) has been consistently rising worldwide especially among women of advanced maternal age (AMA) group. The Robson 10-Group Classification System (TGCS) facilitates assessment and comparison of CB rates among groups of women with similar obstetrical characteristics. In nurse-midwifery care where women are typically healthier and willing to have vaginal birth, it is unknown whether women of AMA have higher CB rate compared to women of non-AMA and what antecedents lead them to have CB.

Purpose: To increase our understanding of the antecedent events and/or indicators that result in CB in women of AMA in nurse-midwifery care, specifically focusing on any differences in women of AMA compared to their younger counterparts.

Design: Secondary analysis of an observational cohort datasets

Setting: Oregon Health & Science University (OHSU) Hospital and University of Michigan Health Systems (UMHS) Hospital

Participants: Women birthing in midwifery care at either OHSU from 2012-2019 or UMHS from 2009-2019

Results: CB rates of women of AMA were higher than those of their younger counterpart (18.30% for AMA vs. 15.10% for non-AMA). Main contributors to CB of both groups were similar, but the order of these contributors was different. While the order of main contributor among women of AMA was Robson Group 5 [multiparous women with previous CB] followed by Robson Group 2 [nulliparous women with labor induced/prelabor CB] then Robson Group 1 [nulliparous women with spontaneous labor], the order of the main contributor to CB among women of non-AMA was Robson Groups 1, 2, and 5, respectively. Also, induction of labor and prelabor CB (Robson Groups 2 and 4) mediated the relationship between AMA status and CB.

Conclusion: The CB rates of women cared by midwives were lower than those of women cared by other types of healthcare providers. Using Robson TGCS to examine CB provides understanding of antecedents to CB of women in each age group. Future studies should investigate factors influencing successful vaginal birth after cesarean among women of AMA.

Keywords: Cesarean Birth, Advanced Maternal Age, Robson 10-Group Classification, Midwifery Care

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CHAPTER ONE

BACKGROUND & SIGNIFICANCE

The rate of cesarean birth (CB) continues to increase worldwide (Betran et al., 2016; Betran et al., 2021). While this increase may reflect improved access to this often life-saving intervention, it is important to note that CB rates higher than 10-15% may not be associated with improvements in maternal/child outcomes and could introduce harm (Betran et al., 2015; Ye et al., 2014). Many countries have reported CB rates higher than 20% (Vega, 2015), including the United States (U.S.) where the CB rate was 31.8% in 2020, with variations reported by state (e.g., 28.8% in Oregon; 32.5% in Michigan) (Centers for Disease Control and Prevention [CDC], 2022; Osterman et al., 2021). Thailand, Turkey, and Brazil revealed even higher CB rates of ~49% in 2017 (Anekpornwattana et al., 2020), ~51% in 2017 (Eyi & Mollamahmutoglu, 2021), and ~56% between 2014 and 2017 (Rudey et al., 2020), respectively, with CB rates in Brazil rising rapidly from 2015 to 2017, from 47% to 56% (Rudey et al., 2020). Even though the trend of low-risk CB in the U.S. among first-time mothers with term, singleton pregnancy, and fetal cephalic presentation was decreasing, the CB rate of this population increased slightly from 25.6% in 2019 to 25.9% in 2020 (Martin, Hamilton, & Osterman, 2021) and remain markedly higher than the recommended rate from the World Health Organization (WHO).

The underlying concern related to these trends is the possibility that rising numbers may reflect a rise in medically unnecessary CB. When a CB is medically unnecessary, it does not improve maternal and/or neonatal outcomes (Betran et al., 2016) but, in contrast, incurs both short- and long-term risks/adverse outcomes for the mother and/or neonate (Antoine & Young, 2020). For example, in the short-term, women undergoing CB experience higher maternal morbidity and mortality with longer birth hospitalization and recovery time (Sandall et al., 2018).

Further, adverse outcomes associated with CB include chronic pain, abnormal placentation, ectopic pregnancy, uterine rupture, preterm birth, and stillbirth in a subsequent pregnancy (Antoine & Young, 2020; Sandall et al., 2018). The short- and long-term adverse outcomes for neonates are also numerous and include differences in neonatal hormonal, physical, medical, and microbiome exposure, as well as altered immune development (Montoya & Georgiou, 2020; Sandall et al., 2018). When CB is performed as a life-saving intervention, these short- and long-term adversities are reasoned tradeoffs; however, when CB is medically unnecessary, the adversities represent overt harm.

While current attention is clearly and correctly focused on the rapidly increasing CB rates worldwide, there is another noteworthy trend – the parallel rise in the rate of pregnant women of advanced maternal age (AMA), which is typically defined as women who are 35 years of age or older at delivery. Today, there are many reasons for women to delay childbearing, including an increase in success of contraceptive use, seeking financial and/or career security before having children, pursuit of higher education, and/or biophysical challenges (e.g., infertility) (Hammarberg & Clarke, 2005; Mills et al., 2011; Molina-García et al., 2019). However, pregnant women of AMA are considered a high-risk pregnancy due to an increase in adverse maternal and/or neonatal outcomes associated with increasing maternal age, such as preterm delivery, low birth weight, and prolonged labor (Laopaiboon et al., 2014; Ngowa et al., 2013; Nguanboonmak & Sornsukolrat, 2019). Further, pregnancies in women of AMA are also more likely to result in a CB, which, as noted earlier, has its own set of adverse outcomes (Bayrampour & Heaman, 2010; Pukale et al., 2016; Walker & Thornton, 2020). In 2019, findings from a systematic review and meta-analysis investigating adverse outcomes of pregnant women of AMA, revealed that both women aged 35-40 years old and women aged over 40 years old had a higher risk for elective

CB than women aged 20-34 years old [for women ≥35 years odds ratio [OR]: 1.96; 95% CI: 1.54 - 2.50, I^2 = 100%; >40 years OR: 1.42; 95% CI: 1.22-1.67, I^2 = 97%] (Pinheiro et al., 2019). Accordingly, any study of CB needs to acknowledge AMA as a potential contributor when exploring maternal/neonatal outcomes. Moreover, to understand which antecedent events or indicators contribute to CB in the AMA population, as well as which individuals have differences in the obstetric characteristics (e.g., parity, mode of labor onset, number of fetus), studies examining CB should not be solely focused on comparing overall CB rates based on maternal age, but include a system to classify and control women based on their obstetric characteristics to understand which ones influence CB rates among women of AMA.

In response to global concerns and tracking of rising CB rates, the WHO proposed the use of the Robson 10-Group Classification System (TGCS) as a global standard for assessing, monitoring, and comparing CB rates within/across healthcare facilities and population groups around the world in 2015. Previously, Torloni and colleagues (2011) identified 27 different CB classification systems being used worldwide and determined the Robson TGCS was the most informative approach. Identifying and using a standardized classification system, like the Robson TGCS, enables comparisons of variations in antecedent events and/or indicators for CB, rather than focusing only on overall CB numbers/rates (Robson, 2001). For example, the Robson TGCS categorizes women based on perinatal characteristics, including parity, obstetric history, onset and course of labor and delivery, gestational age, number of fetuses, and fetal position, with each woman classified to belong in only one of the 10 mutually exclusive groups based on these perinatal characteristics. However, as detailed as the Robson TGCS categories are, maternal age is not considered.

Since the WHO recommendation, increasing numbers of studies now using the Robson TGCS when reporting about CB rates; however, most have not examined TGCS group distribution by maternal age (Abdulrahman et al., 2019; Anekpornwattana et al., 2020; Harrison et al., 2020; Montoya & Georgiou, 2020; Vogel et al., 2015). To date, only one cross-sectional study examined CB using Robson TGCS among women of AMA in Canada (Janoudi et al., 2015). They found that CB rates increased in women of AMA with CB rates in age 20-34, 35-40, and over 40 years old being 26.2%, 35.9%, and 43.1%, respectively. Moreover, they found that Robson Group 5 [multiparous women with a previous CB] was the primary contributor to CB among women of AMA. This finding provides a glimpse into what may be the primary contributor to rising rates for women of AMA specifically - *repeat* CB.

There are a variety of obstetric caregivers (e.g., CNM, MD) and birth settings (e.g., home birth, birthing center, hospital); yet, in studies using Robson TGCS, most did not identify the type of caregiver and/or the birth settings, or type of health-related facility. These contextual omissions are interesting because there is evidence that there are clear differences in pregnancy and birth outcomes, including CB rates, between obstetric and midwifery care and across birth settings (Merz et al., 2020; Sandall et al., 2016). For example, women being cared for by a midwife may have lower rates of CB due to the type/amount of supportive care before and during delivery, which emphasizes non-intervention during healthy pregnancy or physiologically normal birth (International Confederation of Midwives [ICM], 2014; Merz et al., 2020). Women in midwifery care are often very committed to vaginal birth and minimal or non-intervention during childbirth, which may contribute to higher vaginal birth outcomes as well (Doherty, 2010; Souter et al., 2019). One U.S. study compared CB rates, by applying Robson TGCS between settings with and without midwives (Smith et al., 2020). The authors noted that the overall CB rates in birth settings, where there is collaboration between physicians and midwives, were lower than in settings where there are no midwives on the interprofessional team (26.1% vs. 33.5%, $p<.001$). They also reported that CB rates among women belonging to Robson Groups 2, 5, 8, and 10, in birth settings with midwives, were lower than those in settings without midwives (Smith et al., 2020). In another recent study examining CB rates using Robson TGCS among women under the care of midwives in Ireland (Hanahoe, 2020), the author reported CB rates less than 10% and identified Robson Group 2 [nulliparous women with induction of labor or prelabor CB] as the primary contributor out of eight Robson Groups. Of note, however, was this study focused on CB among all-aged women and excluded two Robson Groups - women allocated to Robson Group 5 [multiparous women with previous CB] and Robson Group 8 [multiple gestation], as women in these two groups were not under the care of midwives in the clinical care setting. Collectively, these studies provide very limited insight regarding CB rates among women of AMA who receive their care from midwives, using Robson TGCS in particular.

Besides maternal age, there are other potential maternal and fetal/neonatal characteristics which are associated with higher risk for CB. For example, Non-Hispanic Black and Asian women have higher rates of CB in lower risk pregnancy groups compared to Non-Hispanic White women, suggesting women's experiences vary between racial/ethnic identity groups; however, specific causes are still under investigation (Hedderson et al., 2021; Valdes, 2020). Additionally, there is evidence that too short/too long interpregnancy interval (IPI), a high pre-pregnancy body mass index (BMI), as well as excessive total weight gain (TWG) during pregnancy, having preeclampsia and/or gestational diabetes mellitus (GDM), and/or neonatal macrosomia are also associated with higher risk of CB (Araujo Júnior et al., 2017; Boriboonhirunsarn & Waiyanikorn, 2016; Chen et al., 2020; Dude et al., 2021; Gorgal et al., 2012; Ishaque et al., 2019; Kominiarek & Peaceman, 2017; Munim & Maheen, 2012; Pacher et al., 2014; Rietveld et al., 2017; Shen et al., 2017). To date, it is not known whether any/all of these maternal/neonatal characteristics are equally distributed across women in Robson TGCS Groups or among women of AMA and/or their younger counterparts in the same Robson TGCS Groups (which have already controlled for main obstetric characteristics) It is crucial to explore which maternal/neonatal characteristics are differentially distributed by age within the same Robson Groups. The findings from this comparison have the potential to provide insights about the specific or unique antecedent events or indicators putting women of AMA at higher risk for CB.

Finally, women of AMA typically have more medical complication and/or adverse birth outcomes, including preeclampsia, GDM, or stillbirth, when compared to younger women (Pinheiro et al., 2019; Waldenström et al., 2015). Accordingly, previous studies have recommended induction of labor for women of AMA at 38-39 weeks of gestation to prevent the occurrence of stillbirth and adversities from medical complications (Glick et al., 2021; Howell & Blott, 2021; Spiegelman et al., 2017; Walker & Thornton, 2016). This recommendation may lead providers to admit women of AMA for labor induction *before* spontaneous labor begins. Of note, however, is the induction of labor can potentially increase the risk for CB when comparing with spontaneous labor (Davey & King, 2016; Thorsell et al., 2011). While we know that both AMA status can be a factor used for considering if the women should have labor induced or not, it is unclear whether particular Robson Groups, related to induction of labor or prelabor CB, mediate the association of AMA status and CB, or not.

The overall objective of this study was to increase our understanding of the antecedent events and/or indicators that result in CB in women of AMA in midwifery care/settings, specifically focusing on any differences in women of AMA compared to their younger counterparts. Conducting a secondary data analysis, we compared CB rates within and across Robson TGCS Groups in (1) women of AMA (≥ 35 years old), and (2) women of non-AMA (<35 years old) using the 2007-2019 Certified Nurse-Midwife (CNM) Clinical Data Repository in two U.S. states (i.e., Oregon; Michigan). The long-term goal of the study is to increase safe and appropriate access to CB worldwide, while continuing to support vaginal delivery and reduce medically unnecessary CB, especially among women of AMA.

The specific aims of the study were to:

1. Determine overall CB rates for women in midwifery care/settings:
    a. By AMA status (e.g., AMA [≥ 35 years old] vs. non-AMA [<35 years old])
    b. Across Robson TGCS Groups, and
    c. Between AMA and non-AMA status within TGCS Groups

Rationale: Completing this aim is the first step in gaining more insight into the distribution of CB across the maternal age spectrum in midwifery care/settings.

H1.1: The CB rates would be higher in women of AMA/AMA will increase the odds of CB.

H1.2: The CB rates and the relative contribution to overall CB among women in certain Robson Groups (e.g., 1, 2, & 5) would be higher than those of women in other Robson Groups.

H1.3: The frequency of AMA would be higher in certain Robson Groups (e.g., 1, 2, & 5) as well as the CB rates and the relative contribution of CB among AMA women compared to non-AMA (younger) women.

2. Compare and contrast selected maternal (e.g., race/ethnicity, IPI, pre-pregnancy BMI, TWG during pregnancy, preeclampsia, GDM), and neonatal (e.g., macrosomia) characteristics for women in midwifery care/settings:

a. Between AMA and non-AMA status across the analytic sample

b. Across Robson TGCS Groups 1-5, and

c. Between AMA and non-AMA status within Robson TGCS Groups

Rationale: Understanding and identifying potential risk factors for CB among women of AMA and/or within specific Robson TGCS Groups has the potential to allow midwives to develop tailored approaches to obstetric care.

H2.1: Women of AMA would demonstrate higher levels of the selected maternal and neonatal characteristics that increase the risk for CB when comparing to women of non-AMA.

H2.2: Certain Robson TGCS groups would demonstrate higher levels of the selected maternal and neonatal characteristics that increase the risk for CB comparing to other Robson Groups.

H2.3: In each specific Robson TGCS Group, women of AMA would demonstrate higher levels of the selected maternal and neonatal characteristics which possibly put them at the higher risk for CB when comparing to women of non-AMA.

3. Explore the role of each Robson TGCS Group (1-4) as a mediator between AMA status and CB for women in midwifery care/settings:

a. Among nulliparous women: Robson Group (1 & 2) as a mediator, and

b. Among multiparous women: Robson Group (3 & 4) as a mediator

Rationale: Given women of AMA are typically considered as higher risk for stillbirth and having complications during pregnancy, they are recommended to have induction of labor or elective CB at 38-39 weeks of gestation (Glick et al., 2021). If particular Robson Groups related to induction of labor are on the pathway linking AMA and CB rates, this can reflect co-morbidities of AMA women (e.g., hypertension, obesity) prompting labor induction recommendations and/or the role of labor induction itself.

H3.1: Robson Group 2 would mediate the relationship between AMA status and CB rates among nulliparous women of AMA.

H3.2: Robson Group 4 would mediate the relationship between AMA status and CB rates among multiparous women of AMA.

Summary

This study sought to provide new understanding about the antecedent events and contributors to CB using Robson TGCS for women receiving midwifery care, especially women of AMA who are known to have a higher risk of CB. In addition, this study examined selected maternal and neonatal characteristics to identify any variable distribution between AMA and non-AMA women across analytic sample and within the Robson TGCS Groups. Lastly, this study explored the potential mediating role of certain Robson Groups on the association between AMA status and CB rates. Findings from this study can be used to inform ongoing efforts to develop interventions that support vaginal delivery, with a special focus on women of AMA.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides the background, foundation, and scaffolding for the specific aims, as well as how these aims address the gaps in the literature and ultimately contribute to knowledge development. The chapter begins with a brief overview of cesarean birth (CB), including the definition/types, global rise in CB rates, previously identified adverse short- and long-term effects of CB on maternal and neonatal/child health, and those maternal and neonatal characteristics that are potentially associated with an increased risk for CB. This overview is followed by a description of the Robson 10-group classification system (TGCS), which is a relatively new standardized approach to use in the documentation of CB (World Health Organization [WHO], 2015). The focus on the TGCS represents part of the novel approach used in this dissertation to understand CB in women receiving perinatal care from midwives. A second part of the novel approach is the study's focus on women of advanced maternal age (AMA). Accordingly, the chapter addresses inconsistencies in statistical reporting surrounding women of AMA in the past, as well as establishing the definition of AMA for this study. Following these descriptions is the global trend of delayed childbearing that is one contributor to the rising rate of AMA pregnancies and an overview of what is currently known about AMA pregnancies, including previously identified pregnancy, birth, and postpartum outcomes. The chapter concludes with a brief discussion of midwifery practices and how these practices may interact with CB rates. Ultimately, the focus for this study is on gaining insight into which antecedent events or indicators contribute to CB in women of AMA in two midwifery practices in the U.S.

Overview of Cesarean Birth (CB)

Definition/Types of CB

When researching cesarean birth (CB), it is important to understand the variations in definitions/types as each variation highlights the subtleties encountered when trying to interpret CB rates and the antecedent events and/or indicators for CB. At its core, CB is the delivery of fetus through laparotomy and hysterotomy, respectively; this definition excludes abdominal pregnancy, removal fetus from the abdominal cavity with an uterine rupture, which represent a totally separate entity (Cunningham et al., 2019a). The various types of CB include emergency or unplanned, elective or planned, and primary or repeat. *Emergency* or *unplanned* CB occurs in emergency situations as a lifesaving measure for the mother and/or fetus. Controversially, if CB is performed *before* the onset of labor or is scheduled based on a decision during the antenatal period, it is acknowledged as an *elective* or *planned* CB (Javaid et al., 2017). The type of CB can also be classified using the history of CB. When a CB occurs for the first time in a woman's life, it is considered to be a *primary* CB (Saha & Chowdhury, 2011). On the other hand, if the CB is a repeat event, completed in a woman who experienced a CB in the past, it is identified as a *repeat* CB (Wollmann et al., 2018). For multiparous women with prior history of CB who attempt to deliver vaginally in their subsequent pregnancy, it is referred to as trial of labor after cesarean (TOLAC). If these women are successful with vaginal delivery after TOLAC, it is called the vaginal birth after cesarean (VBAC) (The American College of Obstetricians and Gynecologists [ACOG], 2017).

Rising global rates of CB

Rates of CB are rising around the world within/across high-, middle-, and low-income countries. A recent study exploring global and regional CB trends (*N*=154 countries) revealed that the overall CB rate from 2010 to 2018 was 21.1%, but ranged from 5% in sub-Saharan Africa to 42.8% in Latin America and the Caribbean (Betran et al., 2021). They also found that the greatest increases in CB rates were Eastern Asia, Western Asia, and Northern Africa, and that the projected CB rate across the world will be 28.5% by 2030. While this increase may reflect improved access to this often life-saving intervention, it is important to note that CB rates higher than 10-15% are no longer associated with improvements in maternal/child outcomes and may actually be doing harm (Betran et al., 2015; Ye et al., 2014).

According to the United States (U.S.) National Vital Statistics Reports, the overall CB rate in the U.S. was 31.7 % in 2019 (Martin, Hamilton, Osterman, et al., 2021), although individual state CB rates varied from 21.6% in Alaska to 38.5% in Mississippi. There were also regional variations in CB rates, with Southeastern U.S. states with higher rates and Northwestern (NW) states with lower rates (Centers for Disease Control and Prevention [CDC], 2021). Although the NW states had lower rates, such as Oregon (28.8%), these rates were still higher than the optimal rate of 10-15% recommended by WHO (CDC, 2022). This finding was also true for states in other regions of the U.S, including Michigan (32.5%). The U.S., specifically these two states (i.e., Michigan; Oregon), are the focus of the current study; however, it is important to note that similar trends are occurring worldwide.

Outside of the U.S., Brazil had one of the highest global CB rates between 2014-17 at 56% (Rudey et al., 2020). Across Asia, the United Arab Emirates (UAE) CB rates were 33% in

2016 (Abdulrahman et al., 2019), well above overall U.S. numbers, but less than Thailand and Turkey whose CB rates were ~49% in 2017 (Anekpornwattana et al., 2020) and ~51% in 2017, respectively (Eyi & Mollamahmutoglu, 2021). In Oceania, Australia's CB rate in 2019 was 36% (Australian Institute of Health and Welfare, 2021). Further, this global trend of CB rates, which are well beyond the rate recommended by WHO and rising, is one of many health concerns around the world. While CB can be a lifesaving measure for the mother and/or neonate if needed, it is important to note that when the CB rates are higher than the optimal rates (10-15%), CB is no longer associated with improvements in maternal/child outcomes and may actually be doing harm to mothers/neonates (Antoine & Young, 2020; Betran et al., 2015; Sandall et al., 2018; Ye et al., 2014).

Adverse effects of CB on maternal and neonatal/child health

When medically unnecessary, CB does not improve maternal and/or neonatal outcomes and it is not related to decreased maternal and/or neonatal mortality (Betran et al., 2016). In contrast, CB carries short- and long-term risks/adverse outcomes for the mother and/or neonate (Antoine & Young, 2020). The adverse effects on *maternal* health include an increased risk of mortality (Chongsuvivatwong et al., 2010; Esteves-Pereira et al., 2016; Fahmy, et.al.,2018; Gupta & Saini, 2018; Kallianidis et al., 2018; Sandall et.al., 2018; Vadnais & Sachs, 2006), morbidity (Dillen et al., 2010; Korb et al., 2019; Sandall et al., 2018), longer birth hospitalization and recovery time (Cegolon et al., 2019; 2020; Liu et al., 2018), as well as chronic pain (Antoine & Young, 2020; Borges et al., 2020; Sandall et al., 2018; Weibel et al., 2016), abnormal placentation (Antoine & Young, 2020; Cheng & Lee, 2015; Sandall et al., 2018), ectopic pregnancy (Basu et al., 2015; O'Neill et al., 2014), uterine rupture (Donati et al., 2021), preterm birth (Antoine & Young, 2020; Sandall et al., 2018; Zhang et al., 2019), and stillbirth in subsequent pregnancy (ACOG, 2020b; O'Neill et al., 2014).

In addition to maternal adverse effects, the short- and long-term adverse effects for the *neonate* include differences in gut microbiome exposure (Azad et al., 2013; Jakobsson et al., 2014), delayed lung fluid absorption (Cunningham et al., 2019b; Martelius et al., 2013), and altered immune development (Montoya & Georgiou, 2020; Sandall et al., 2018), as well as obesity later in childhood (Montoya & Georgiou, 2020; Sandall et al., 2018; Sevelsted et al., 2015). Children delivered by CB have a significantly higher risk for obesity, up to the age of five years old (Keag et al., 2018), and a higher risk of developing Type 2 Diabetes (T2DM) in adulthood compared to those who were born vaginally (Chavarro et al., 2020).

Maternal/neonatal characteristics linked with increased risk for CB

Maternal Characteristics

Maternal characteristics that appear to place women at increased risk for CB include advanced maternal age (AMA), racial/ethnic minority group (e.g., Non-Hispanic Black, Asian), too short/too long interpregnancy interval (IPI), high pre-pregnancy body mass index (BMI), excessive total weight gain (TWG), preeclampsia, and the development of gestational diabetes (GDM). We discuss the current literature on each of these characteristics, as each will also be assessed in this study.

Advanced Maternal age (AMA). Pregnancy for women of AMA is associated with several adverse pregnancy outcomes, including an increased risk for CB (Rydahl et al., 2019). One systematic review (*N*=21 studies) examining the relationship between AMA and CB among both nulliparous and multiparous women indicated that nulliparous women of AMA had 1.44-

2.27 times higher risk for CB, and multiparous women of AMA had 1.63-2.76 higher risk for CB compared to younger women (Bayrampour & Heaman, 2010). This review also analyzed the relative risk for CB from the studies not identifying the parity of women and showed that women of AMA had 1.39-1.65 higher risk for CB (Bayrampour & Heaman, 2010). In addition, a more recent meta-analysis examining adverse pregnancy outcomes of women of AMA showed that, compared to women aged 20-34 years, women 35-40 years old had 1.96 fold higher chance of CB (Odds Ratio [OR]: 1.96; 95% Confidence interval [CI]: 1.54-2.50, $I^2 = 100\%$) and women over 40 years old had 1.42 higher chance of CB (OR: 1.42; 95% CI: 1.22-1.67, $I^2 = 97\%$) (Pinheiro et al., 2019). Although multiple studies have reported that AMA is associated with an increase in CB (Liabsuetrakul et al., 2019; Pukale et al., 2016; Sydsjö et al., 2019a; Verma et al., 2016; Walker & Thornton, 2020), the understanding about which specific groups of this population contribute to higher CB rate is very limited: Most studies examined CB rates were across the total AMA group and did not use a standardized tool to group women by similar obstetric characteristics before determining the CB rates. Further, the specific factors or personal characteristics that predispose women of AMA to higher risk for CB were under investigated.

Racial/ethnic minorities. Although the CB rate is rising among women across the world, there are different CB rates for race/ethnicity groups. A recent cohort study investigating maternal race/ethnicity and the associated risk of CB among low-risk women in the U.S., revealed that non-Hispanic Black, Asian/Pacific Islander, and Hispanic women were more likely undergo CB compared to non-Hispanic White women, with adjusted Odds Ratio [aOR]: 1.37; 95% CI: 1.28-1.45, aOR: 1.11; 95% CI: 1.07-1.16, and aOR: 1.12 95% CI; 1.07-1.16, respectively (Hedderson et al., 2021). Another study by Stark and colleagues (2021) examined the association between maternal race/ethnicity and risk for primary CB in nulliparous women in the U.S. and discovered that non-Hispanic Black women had the highest CB rate (28.2%) among all the nulliparous women. Their study also showed an increased risk for CB among non-Hispanic Black, Asian, and Hispanic women compared to non-Hispanic White to be aOR: 1.53; 95% CI: 1.26-1.86, aOR: 1.39; 95% CI: 1.16-1.66, aOR: 1.30; 95% CI: 1.16-1.66, respectively. These two U.S. studies focused on low-risk nulliparous women, which limits generalizability; yet, both findings suggest a potential racial/ethnic effect. It is important to note that none of these studies explored if/how women of AMA and their non-AMA counterparts are distributed within/across various race/ethnicities.

Too short/too long interpregnancy interval. Interpregnancy interval (IPI) is the duration between one live birth or pregnancy loss and a woman's subsequent pregnancy. The WHO recommended optimal IPI should be at least 24 months after a live birth (WHO, 2007), as there is an increase in risk of adverse outcomes associated with intervals of less than 18 months and significantly more risks (e.g., uterine rupture, low birth weight) with intervals of less than 6 months between one birth and the start of the next pregnancy (ACOG, 2019). The IPI serves as an obstetric indicator identifying potential risks of adverse maternal and neonatal outcomes, including the increased risk for CB, especially among women with recurrent short IPIs (Weiss et al., 2021). One Nigerian cross-sectional design study comparing feto-maternal outcomes between pregnancy women with short IPI (<24 months) and those with normal/optimal IPI (at least 24 months) found that women with short IPI were more likely to have CB comparing to women with normal/optimal IPI (45.5% vs. 38.0%); however, this difference was not statistically significant (Bassey & Johnson, 2019). This latter study had a relatively small total sample size (*N*= 410), which might not yield accurate findings. Moreover, the study was conducted in Nigeria where the contraception is underused, which results in higher prevalence of shorter IPI

(Blackstone & Iwelunmor, 2017). Therefore, the finding from this study might not accurately imply to CB outcomes among women in the U.S. where contraception is readily available.

While these risks can occur with too short of an IPI, there are other risks associated with too long of an IPI. For example, one large retrospective cohort study (*N*=18,503) compared CB rates of women with just under the optimal IPI (18-24 months) to women with an extended or very long IPI (>59 months) and nulliparous women. Women who fell within the recommended IPI (24-59 months) were excluded. In this study, women with extended or very long IPIs had significantly lower CB rates than nulliparous women (12.2% vs. 14.3%, aOR: 0.50; 95% CI: 0.40-0.70); yet, significantly higher CB rates than women with an IPI of 18-24 months (12.2% vs. 6.3%, aOR: 2.20; 95% CI: 1.60-3.10) (Ishaque et al., 2019). Another large retrospective cohort study (*N*=36,653) from the Netherlands, investigated the association between IPI and the success rate of TOLAC among women who had a prior CB. They found that women with an IPI of 24 months or longer had a lower success rate of TOLAC compared to women with an IPI of 12-24 months, meaning the longer the IPI the higher the chance of having a second CB (Rietveld et al., 2017).

While these studies included women across the maternity age spectrum, they did not report differences by maternal age group; however, a large cohort study (*N*=148,544) specifically examined women of AMA (Schummers et al., 2018). They found that short IPIs appear to be related to an increase in risk for adverse pregnancy outcomes for women of all ages; risk for short IPIs may be greater for women of AMA; and fetal and infant risks may be greater for younger women. This study's findings suggest that IPI is an important variable to include in studies exploring maternal age-related risk for CB. To date, no one has reported if women of AMA fall more frequently into either short or normal/optimal IPIs.

Pre-pregnancy BMI. BMI is one index indicating a woman's overall physical health status and related health risks. A woman's pre-pregnancy BMI can also be an indicator predicting pregnancy outcomes. Obese pregnant women are not only at an increased risk of developing complications during the childbearing period (e.g., preeclampsia, gestational diabetes mellitus, pulmonary embolism), but also increased CB rates (Nurul-Farehah & Rohana, 2020). One study, conducted in Pakistan examined the association between pregnancy weight gain, pre-pregnancy BMI, and pregnancy outcomes, found that women, whose pre-pregnancy BMI was classified as obese (BMI $\geq$ 30 kg/m^2), had 1.4 times higher chance of CB than women with normal pre-pregnancy BMI (BMI 18-25 kg/m^2) (OR:1.44; 95% CI: 1.17-1.78) (Munim & Maheen, 2012). In a prospective cohort study conducted in Taiwan, examining the association between pre-pregnancy BMI, pregnancy weight gain, and perinatal outcomes, overweight (BMI 25-30 kg/m^2) and obese (BMI $\geq$ 30 kg/m^2) women were more likely give birth via CB compared to normal weight women, with aOR: 1.57; 95% CI: 1.41-1.79, and aOR: 2.70; 95% CI: 2.16-3.36, respectively (Chen et al., 2020). However, these studies did not explore maternal age as a confounding variable.

When looking specifically at maternal age and risk for obesity, the data are mixed. In one prospective cohort study that specifically assessed maternal age-related effects in the subgroups of underweight, overweight, and obese women in Poland, researchers discovered that women aged 35 years and older were more significantly obese (12.9% vs. 8.3%) and overweight (21.5% vs. 16.2%) compared to women aged <35 years (Lewandowska et al., 2020). However, Canadian researchers, comparing demographic and obstetric characteristic of primiparous women of AMA, found that there was no significant difference in having BMI >24.9 kg/m^2 between women of AMA (aged $\geq$ 35 years old) and women aged 20-29 years (p=.81) (Bayrampour & Heaman, 2011). The findings from these studies about overweight and obesity varied by age, meaning the data are still inconsistent. Also, these studies were conducted outside the U.S. and did not identify settings to where women were admitted. Therefore, the findings from these studies do not generalize to pre-pregnancy BMI between women of AMA and women of non-AMA cared by midwives in the U.S.

Excessive total weight gain. Maternal total weight gain (TWG) during pregnancy is also linked to adverse maternal and neonatal outcomes. Excessive or inadequate TWG can impact pregnancy outcomes, as well as types of birth. Excessive TWG is defined as weight gain over the IOM recommendation as 1.0 – 1.3 pounds/week for BMI < 18.5 kg/m^2; 0.8–1.0 pounds/week for BMI 18.5–24.9kg/m^2; 0.5–0.7 pounds/week for BMI 25.0–29.9kg/m^2; and 0.4–0.6 pounds/week for BMI ≥30 kg/m^2. One U.S. study examining the association between TWG and perinatal outcomes found that women with excessive TWG had higher odds of CB (aOR: 1.24; 95% CI: 1.09-1.41) (Dude et al., 2021). Another U.S. study (Kominiarek et al., 2018) analyzing birth data from 25 hospitals, reported that, compared to women with optimal TWG, nulliparous women with excessive TWG were more likely to experience CB (aOR: 1.44; 95% CI: 1.31– 1.59), as were multiparous women with excessive TWG (aOR: 1.26; 95% CI: 1.13–1.41). Outside the U.S., Canadian researchers found that women aged 20-29 years were more likely to gain weight over 16 kgs during pregnancy than women of AMA (OR: 0.58; 95% CI: 0.44-0.76) (Bayrampour & Heaman, 2011). To date, findings regarding differences in TWG across maternal age is limited, and the last finding has not been duplicated; however, it might point to younger women being underweight when they become pregnant or to older women already more likely to be overweight when they become pregnant, as reported in the previous section on pre-pregnancy BMI (Lewandowska et al., 2020).

Preeclampsia. Preeclampsia is a hypertensive disorder that typically arises after 20 weeks of gestational age (ACOG, 2022b). There are several risk factors and predeterminants of preeclampsia, including nulliparity, multi-gestation pregnancy, and women of AMA, as well as in-vitro fertilization or other forms of assisted reproductive technology, and maternal comorbidities, including pre-pregnancy BMI greater than 30 (Karrar & Hong, 2022). One study comparing pregnancy outcomes of gestational hypertension and preeclampsia found that preeclampsia was significantly associated with an increase in risk for CB (aOR:2.21; 95% CI: 1.66-2.95), whereas gestational hypertension was not (Shen et al., 2017). A retrospective cohort study examining the modes of delivery between term pregnant women with and without preeclampsia showed that the elective CB rate was significantly higher in women with preeclampsia (p=.019) (Pacher et al., 2014). Another study comparing risk factors and outcomes of gestational hypertension and preeclampsia among women birthing in Canada reported the rates of gestational hypertension and preeclampsia of women of AMA were not significantly different from those of women of non-AMA, which contrasts with current understanding of risk (Shen et al., 2017), while a Swedish study assessing the impact of maternal age on obstetric and neonatal outcome found that the likelihood of preeclampsia was higher in the older maternal age, supporting current understanding (Blomberg et al., 2014). It is challenging to conclude if there is a difference in prevalence of preeclampsia by maternal age because the results from the previous studies are mixed. Also, these findings were from women cared in a hospital where physicians/obstetricians have authority to provide care to women with high-risk pregnancy, and those high-risk women are typically referred to. On the other hand, women cared for in midwifery settings are typically healthier and it may be easier to discern whether/how AMA status influences preeclampsia. Therefore, it is important to explore if there is a difference in prevalence of preeclampsia between AMA and non-AMA in midwifery settings.

Diabetes mellitus during pregnancy/Gestational diabetes mellitus (GDM). GDM is a metabolic disorder related to glucose intolerance with first recognition during pregnancy (ACOG 2022a). While the prevalence of GDM varies between countries, ranging from 17.3 to 25.5% in the U.S., down to 13.2% in Germany, and 11.5% in pooled prevalence among Asian countries (Gojnic et al., 2022). One important outcome associated with the development of GDM is an increased risk for a CB. For example, one study in Thailand found that the emergency CB rate among women with GDM was significantly higher than the rate of CB in women without GDM (aOR: 1.89; 95% CI: 1.03-3.48). They also noted cephalo-pelvic disproportion (CPD) was more likely to be an indication for CB among women with GDM (p=.036) (Boriboonhirunsarn & Waiyanikorn, 2016). In addition, a retrospective study conducted in Portugal indicated that women with GDM had 1.52 times higher risk for emergency CB than women without GDM (adjusted Risk ratio [aRR]: 1.52; 95% CI: 1.06-2.16) (Gorgal et al., 2012). Moreover, there appears to be a slight increase in risk for GDM in women of AMA. In a more recent cross-sectional study assessing adverse obstetrical and perinatal outcomes among women of AMA in Northern Ethiopia discovered that 1.6% of women of AMA developed GDM during pregnancy, whereas there was only 0.8% of women of non-AMA having GDM (Mehari et al., 2020). Another recent meta-analysis, Li and collegues (2020) showed that GDM risk exhibited a linear relationship with maternal age ($P_{\text{trend}} < 0.001$). For each one-year increase in maternal age from 18 years, GDM risk for the overall population, Asian, and Europid increased by 7.90%, 12.74%, and 6.52%, respectively. A recent study conducted in Saudi Arabia also found that the AMA group had a significantly higher proportion of GDM (32.0% in AMA vs. 13.2% in non-

AMA, $p<.001$) (aOR: 2.6; 95% CI: 2.0–3.5) (Shams et al., 2021). The findings from these studies showed that AMA status potentially influences having GDM during pregnancy. It is crucial to know if AMA status plays a role of having GDM among women in midwifery care who are typically healthier compared to women being cared for in a hospital under physician care. Therefore, studies determining whether there is a difference in proportion of GDM between women of AMA and non-AMA in midwifery care are needed.

Neonatal Characteristics

One neonatal characteristic that appears to place the neonate at increased risk for being born by CB is macrosomia. There is also some speculation that fetal sex, or more specifically being a male fetus, may also be associated with a high-risk pregnancy resulting in CB.

Macrosomia. Macrosomia is a known risk for shoulder dystocia and also associated with CB (Araujo Júnior et al., 2017). One prospective case-control study examining the determinants and outcome of fetal macrosomia among Nigerian women found the macrosomia group had a higher CB rate compared to a control group (51.1% vs. 18.5%, $p<.001$) (Olokor et al., 2015). Additionally, a retrospective cohort study from the U.K. identified that neonates in the macrosomia (body weight >4000 grams) and severe macrosomia (body weight >4,500 grams) groups were at higher risk for a CB compared to neonates in the normal weight group (2,500-4,000 grams) (aOR: 1.45; 95% CI: 1.40-1.68) and (aOR: 2.12; 95% CI: 1.72-2.60), respectively (Beta et al., 2019). Another study conducted among Tanzanian women discovered there was no difference in the mode of delivery between the neonatal macrosomia and control groups, although macrosomia was more commonly identified as an indication for CB among neonatal macrosomia group (Said & Manji, 2016). In two Chinese studies examining the relationship between maternal age and macrosomia, they found that the risk for macrosomia increased with AMA (Li et al., 2015; S. Wang et al., 2020). The reason for this association might be that advancing age is related to having GDM during pregnancy which contributes to glucose intolerance and being macrosomia among neonates (Kc et al., 2015). However, these two studies examining macrosomia across maternal age were conducted outside the U.S., Asian continent, and neonatal birth weight varies across race/ethnicity with lowest average birth weight among Asian neonates and heaviest average birth weight among non-Hispanic white neonates (Madan et al., 2002). Therefore, it is not known if there is a difference in proportion of macrosomia between babies born in the U.S. from women of AMA and those born from women of non-AMA.

In summary, all of these studies, examining the maternal and neonatal characteristics placing women at higher risk for CB presented above, did not mention healthcare provider type (e.g., midwifery care), so the results from those studies might limit generalization to women in a midwifery care. Also, most of these studies were done outside the U.S. where their healthcare system, provider types, and/or environment differs from the U.S.; meaning that it is still unclear if the pattern of the differences in characteristics found to date are the same in the U.S. Moreover, some of these findings reveal differences in some variables (e.g., pre-pregnancy BMI, preeclampsia) and remain controversial. Therefore, in this study we address these gaps by comparing and contrasting the maternal and neonatal characteristics by AMA status, as well as Robson TGCS group, with the goal of increasing our understanding of the antecedent events and/or indicators that result in CB in women of AMA in midwifery care/settings, specifically focusing on any differences in women of AMA compared to their younger counterparts.

Robson 10-Group Classification System (TGCS)

The Robson 10-Group Classification System (TGCS) is the standardized tool used internationally to monitor and compare CB rates within/across different settings, hospitals, and countries. Before 2001, there were 27 different CB classification systems being used worldwide mentioned in a systematic review (Torloni et al., 2011). The authors of that systematic review determined that among the 27, the Robson TGCS was the most informative approach to documenting CB rates. In 2015, the WHO proposed the use of the Robson TGCS as a global standard for assessing, monitoring, and comparing CB rates within/across healthcare facilities around the world (2015).

Overview/Core variables

The Robson TGCS categorizes women based on four perinatal characteristics, including the category of the pregnancy, the previous obstetric record, the course of the labor and delivery, and the gestation of the pregnancy at the time of delivery (Table 2.1). Each woman is classified to belong in one of the 10 mutually exclusive groups (Figure 2.1) using a series of decision points in an algorithm (Figure 2.2).

Table 2.1

Perinatal Characteristics Using to Classify Women into Specific Group Following Robson (2001)

Characteristics	**Detail**
Category of the pregnancy	• Single cephalic pregnancy

Characteristics	Detail
	• Single breech pregnancy • Single oblique or transverse lie • Multiple pregnancy
Previous obstetric record	• Nulliparous • Multiparous (without a uterine scar) • Multiparous (with a uterine scar)
Course of labor and delivery	• Spontaneous labor • Induced labor • CB before labor
Gestation	• The gestational age in completed weeks at the time of delivery • The gestational age in incomplete weeks at the time of delivery

The WHO then slightly modified core variables (Table 2.2) using looking at parity, previous CB, onset of labor, number of fetuses, gestational age, and fetal lie and presentation (WHO, 2017).

Table 2.2

The Perinatal Characteristics Using to Classify Women into Specific Group Following the WHO (2017)

Characteristics	Detail
Parity; number of previous delivery(ies) (not including previous abortions/miscarriages).	• *Nullipara* - woman who has no previous delivery • *Multipara* - woman who has at least one previous delivery
Previous CB; number of previous CB(s) (not include other types of uterine scar such as myomectomy)	• *Yes* (one or more) - woman has at least one birth undergoing CB • *No* - woman has no birth undergoing CB
Onset of Labor; how labor and delivery initiated in the current pregnancy	• *Spontaneous* - experiencing labor pain before delivery • *Labor induced* - not experiencing labor pain, but labor was induced by providers before delivery • *No labor* (pre-labor CB) - not in labor at the time of admission for delivery and CB was ultimately the type of birth

Characteristics	Detail
Number of fetuses; number of fetus(es) in the current pregnancy	• *Singleton* - only one live fetus in a woman's womb. Pregnant women carry out twins with one fetal demise before 22 weeks of gestation or 500 grams should belong in a singleton. • *Multiple pregnancy* - more than one fetus in a woman's womb.
Gestational age; gestational age at the date of delivery	• *Term* - gestational age at the delivery ≥ 37 weeks. • *Preterm* - gestational age at the delivery < 37 weeks.
Fetal lie and presentation; final fetal position before delivery	• *Cephalic presentation* - fetal head is the presenting part. • *Breech presentation* - fetal buttocks/ foot/ feet are the presenting part. • *Malpresentation* (e.g., transverse, oblique) - fetal long axis is oblique in relation to the mother's long axis.

Figure 2.1

The 10 Groups of the Robson Classification

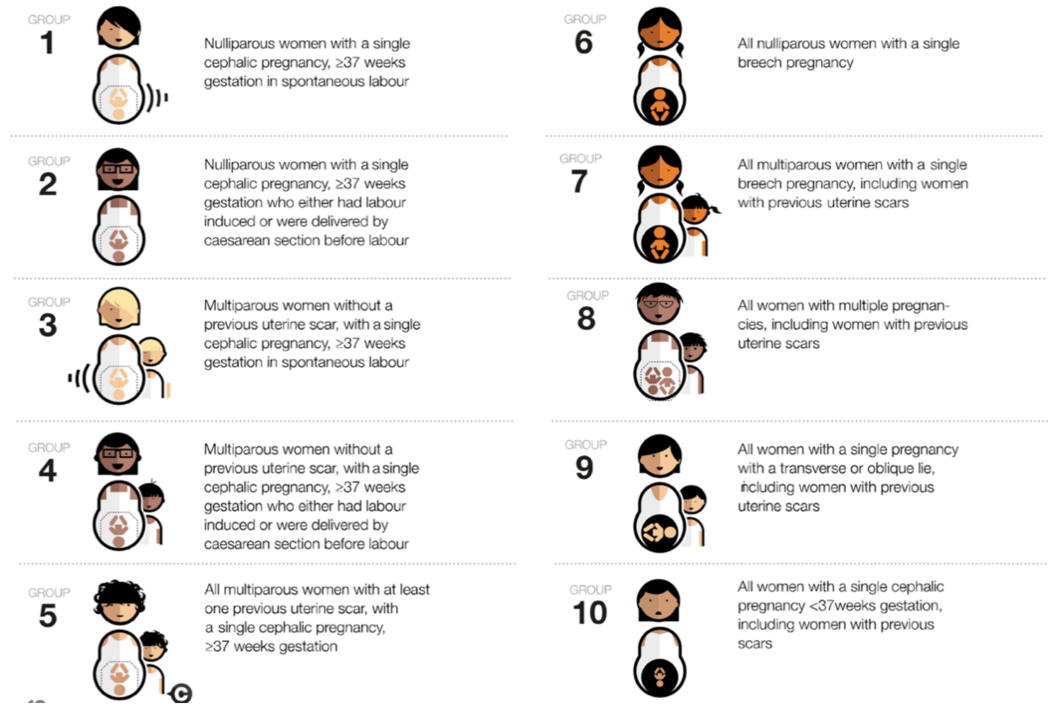
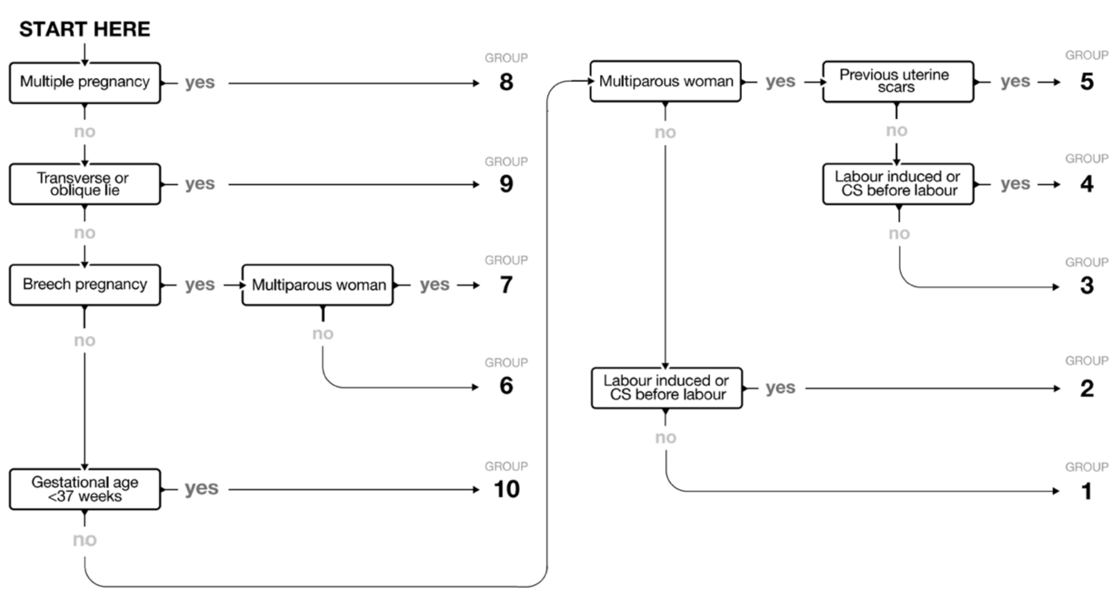


Figure 2.2

The Algorithm for the Classification of Women into Robson TGCS Groups (WHO, 2017)



Women's Reproductive Age

The typical reproductive age range for women is from 15 to 49 years old (WHO, 2022). In this age range, there are two extreme age groups: adolescent pregnancy (women <20 years old) and women of advanced maternal age (AMA) (women ≥ 35 years old). Pregnancies at the extreme ends of the reproductive age range are often considered high-risk. While considered high risk, changes in society, economy, and access to education have changed over the past few decades, resulting in an increase number of women of AMA becoming pregnant (Stack et al., 2020).

Definitions of advanced maternal age (AMA)

The American College of Obstetricians and Gynecologists (2020a) considers women of AMA as women age 35 years old and above. The Royal College of Obstetrician & Gynaecologists (2013) also uses this age definition. However, there is some confusion as to when the age is assessed, as some say the decision is made when the woman is 35 and older at the first prenatal visit, while others say the decision should be made at the birth. Further, some studies use a slightly different age range. For example, two studies examining perinatal outcomes including CB rates across women's age spectrum defined AMA as age over (but not including) 35 years old (Karabulut et al., 2013; Zgheib et al., 2017). A Lebanese study focusing on pregnancy outcomes of women of AMA, identified women over 40 years old as AMA (Seoud et al., 2002). In recent years, the most accepted definition of AMA is a woman who is age at 35 years old or older at the time at delivery (AlShami et al., 2011; El-Gilany & Hammad, 2012; Giri et al., 2012; Islam & Bakheit, 2015; Kahveci et al., 2018; Kanmaz et al., 2019; Khan et al., 2017;

Kim et al., 2020; Ogawa et al., 2017; Rashed et al., 2016; Xiaoli & Weiyuan, 2014; Xie et al., 2019; Yoshioka-Maeda et al., 2016).

Within the AMA, there are some subgroups, most typically AMA and extreme AMA. For example, one study investing pregnancy outcomes of women of extreme AMA in Thailand defined extreme AMA as women age 40 years old or older (Traisrisilp & Tongsong, 2015). However, Ritu and Mini (2020) examining the pregnancy outcomes among women of AMA defined extreme AMA as age over (not including) 40 years old. One recent study, comparing birth outcomes among women of AMA and women of extreme AMA in the urban area in the U.S., defined women of extreme AMA as women delivering at age 45 years old or over. (Smithson et al., 2022). This same age range (≥ 45 years old) was also used in a study in Israel (Yogev et al., 2010). Therefore, it is important to clarify which age ranges are being used when reviewing studies focused on women of AMA, as well as noting the timing when the age was assessed.

Trends of delayed childbearing

Many countries across the world are experiencing an increase in pregnancies in women of AMA, or delayed childbearing (The Organisation for Economic Co-operation and Development, 2021). The rising mean age at first birth of mothers in the U.S. is one example, as it was 24.9 years old in 2000, and jumped to 27.0 years old in 2019 (Mathews & Hamilton, 2016; Osterman et al., 2021). Their report also showed there was variability by state/region, with Washington D.C. and Oregon having the largest increases in the mean age as 3.4 years and 2.1 years, respectively. There was also an increase in proportion of women aged 35-39 from 45.9 per 1,000 women in 2010 to 52.8 per 1,000 women in 2019 (Osterman et al., 2021). When looking at parallel trends of delayed childbearing in European countries, such as Denmark, one report revealed that births from women aged 35-39 increased from ~11% in 1997 to ~17% in 2017, and births from women aged 40 years old and over rose from <2% in 1997 to ~5% in 2017 (Juhl & Rydahl, 2021).

Reasons for delayed childbearing

The reasons for women to delay childbearing are multifactorial and complex, including available contraception, women's expanding careers and financial stability, as well as educational opportunities, medical reasons, such as infertility, and cultural shifts about pregnancy later in life.

Contraception use. Contraception is the prevention of pregnancy, which allows women to plan for and/or delay parenthood. There are multiple methods of contraception available to women; however, one review study exploring the underlying reasons for women to take contraceptives revealed that women obtained contraceptives so they were able to remain longer in school/education, the labor market/career, and/or delay marriage and parenthood before they felt they were ready for motherhood (Mills et al., 2011).

Advances in education, career, and financial stability. Seeking to establish a stable career is one factor leading women to choose delayed motherhood. One survey study investigating the reasons for delayed childbearing, among Australian women over 35 years of age who needed assisted reproductive technology, noted that almost three-quarter (67%) of the women in their sample were professionals (Hammarberg & Clarke, 2005). In another study, Iranian women cited that they would like to have financial stability and reach a higher standard of living before they have children, so they wanted to save money and delay childbearing to ensure they could support their children if they undergo economic insecurity in the future (Behboudi-Gandevani et al., 2015). In a more recent study, exploring childbearing decisions among female medical residents across 78 U.S. programs, over a half of sample (53%) stated their reason for delayed parenthood was so they would not have extend their residency training (Stack et al., 2020). They also reported 93% of the participants reported their busy work schedule as another reason for delayed childbearing (Stack et al., 2020). Earlier, Mills and colleagues (2011) noted that delayed motherhood can be the result of labor force participation. They found that women felt they might miss the opportunity to get training and/or a promotion if they were pregnant and/or had children, as it often set up work/family conflicts.

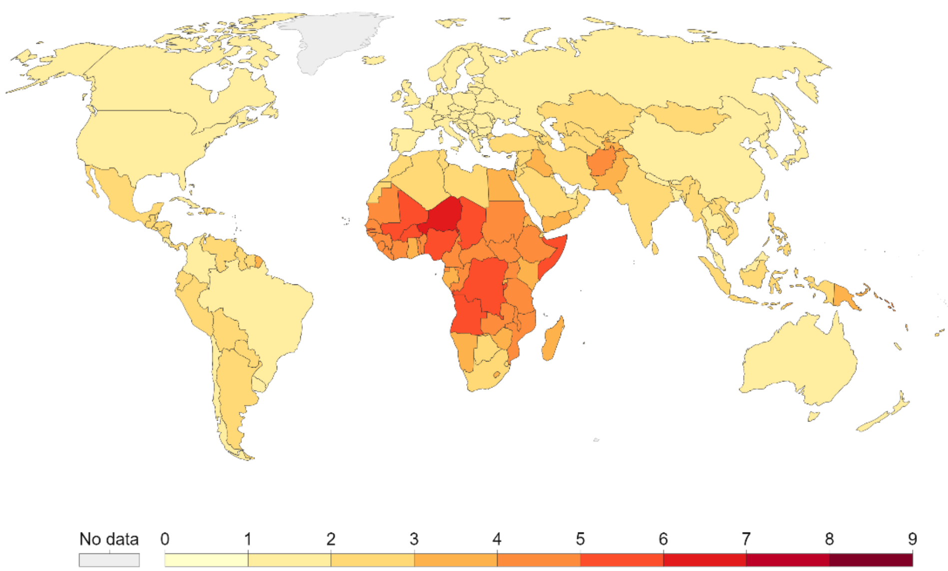
Medical reasons. While some women voluntarily delayed childbearing and motherhood, others were delayed because of medical issues. For example, one Spanish study (Molina-García et al., 2019) investigating the reason and determinants for delayed motherhood found that medical reasons, including preexisting diseases and infertility, as one of the primary reasons for delayed childbearing, especially in women of AMA, while younger women (age 30.47±0.38 years) cited personal reasons for delaying. This study also showed that 30.93% of women of AMA needed medical assistance to achieve a successful pregnancy, whereas only 2.82% of women aged 25-29 years did.

Cultural and value shifts. In the past, larger families were more typical; however, people in modern societies prefer smaller family sizes. For example, in the early 1800s, most women in the U.S. had 7 children, but that number has steadily decreased, except for during the Baby Boom (1946-1964), when the U.S. fertility rate had a momentary jump back up to 3.62. In

2018, U.S. woman had 1.7 children on average, which is similar to most other countries in the world with the exception of Africa (Figure 2.3).

Figure 2.3

Number of Children per Women in 2020 (Our World in Data, 2020)



The shift to smaller family sizes also means women can start having children later (Mills et al., 2011). Further, in a qualitative study done in the U.K. examining women's views and experiences surrounding delayed childbearing, Cooke and colleagues (2012) found that some women said they delayed motherhood because they needed to be in the right relationship first and finding a good partner was not always easy or within their control. They also found that women believed that age by itself was not a risk for poor pregnancy outcomes. One reason for this belief may be due to media portrayals. One U.K. study, examining the representation of women of AMA in newspapers, magazines, and on TV programs, found the media did not communicate challenges and/or poor outcomes related to AMA, such as infertility and perinatal loss (Mills et al., 2015). In contrast, delayed childbearing was positively represented, including sentiments such as it is never too late to get pregnant and it is not challenging to regain one's pre-pregnancy body after birth (Sauer, 2015).

The effect of AMA on pregnancy, birth, and postpartum outcomes

Although becoming pregnant at an advanced maternal age is more likely to ensure the woman has career and financial stability, there are a number of adverse pregnancy and birth outcomes in women of AMA from antenatal to postnatal period, including miscarriage (Magnus et al., 2019; Verma et al., 2016), multiple gestation (Fitzpatrick et al., 2017; Glick et al., 2021; Xiaoli & Weiyuan, 2014), as well as medical complications (Islam & Bakheit, 2015; Kahveci et al., 2018), abnormal placentation (Lean et al., 2017; Martinelli et al., 2018), labor dystocia (Waldenström & Ekéus, 2017; Wang et al., 2011), postpartum hemorrhage (Radoń-Pokracka et al., 2019; Xiaoli & Weiyuan, 2014), and postpartum depression (Muraca & Joseph, 2014). Additionally, neonates born from women of AMA are more likely to be preterm (Berger et al., 2021; Waldenström & Ekéus, 2017; Xiaoli & Weiyuan, 2014), stillbirth (Contemporary OB/GYN, 2012; Laopaiboon et al., 2014), have perinatal/birth asphyxia (Abdo et al., 2019; Bi et al., 2021), and be admitted to Neonatal Intensive Care Unit (NICU) (Kahveci et al., 2018).

Potential mediating effect of Robson TGCS group on the association between AMA and CB

AMA status can be a factor used for considering if the women should have her labor induced, at times prompting induction of labor before labor spontaneously begins (Glick et al., 2021; Howell & Blott, 2021; Spiegelman et al., 2017; Walker & Thornton, 2016). The literature also highlights that induction of labor potentially leads to CB (Vecchioli et al., 2020; Zenzmaier et al., 2017). However, it is unclear whether induction of labor or prelabor CB is on the pathway through the association between AMA status and CB or not. Additionally, we still do not know if this pathway presents in both nulliparas and multiparas. A Robson Group variable can be tested as a mediator based on which group a woman is classified following their mode of labor onset to examine the mediating effect on the association between AMA status and CB. For instance, among nulliparous women of AMA, it would be important to test whether Robson Group 2 (vs. Robson Group 1) mediates the relationship between AMA status and CB rate.

Focusing on Midwifery Care

Birth settings in the U.S. can be classified into three types, including hospitals, birth centers, and homes (Backes & Scrimshaw, 2020). Of these settings, most women birth in hospitals, with one study reporting ~98 % of births occur in a hospital (MacDorman & Declercq, 2019). Hospital births are primarily supervised by physicians, with midwives in the minority. However, when birth centers and/or homes are chosen as the setting, these births are primarily supervised by midwives. This distinction is important as the lens through which physicians and midwives view the birthing process is very different (Backes & Scrimshaw, 2020). The distinctive difference is addressed in the following sections and is important for the current study, which focuses on the care of women of AMA birthing with midwives, rather than physicians.

Definition/roles of midwife

The definition of the midwife, provided by the International Confederation of Midwives (ICM) (2017), is “a person who has successfully completed a midwifery education programme that is based on the ICM Essential Competencies for Midwifery practice and the framework of the ICM global standards for midwifery education". Midwives are typically acknowledged as persons who support, provide advice, and care for women and their newborn, as well as their family during pregnancy, labor, and the postpartum period (ICM, 2017). Most distinctive, the midwifery care model typically offers non-interventional or less intervention when they are caring women, especially during the intrapartum period (ICM, 2014; Merz et al., 2020). While there are three types of midwives, certified nurse midwives, certified midwives, and certified professional midwives, each of which have different education, training, and licensing requirements, they all have the same intention when it comes to applying this midwifery care model (Backes & Scrimshaw, 2020).

Characteristics of a Midwifery Care Settings

Midwifery care settings typically create a home-like atmosphere and emphasize physiologic birth without medical interventions interrupting birth processes when not needed (ICM, 2014; Merz et al., 2020). Women who receive care in midwife-led models are less likely to experience episiotomy (average RR: 0.84; 95% CI: 0.77-0.92), experience regional analgesia (average RR: 0.85; 95% CI: 0.78-0.92) or amniotomy (average RR: 0.80; 95% CI 0.66-0.98), and deliver by instrumental vaginal birth (average RR: 0.90; 95% CI: 0.83-0.97) compared to those who were admitted in other settings (Sandall et al., 2016).

Pregnancy and birth outcomes of women cared by midwives

There is no difference in maternal and/or neonatal mortality between women cared by midwives and women cared by obstetricians; yet, the processes of care by midwives and obstetricians differ primarily because there are typically fewer medical interventions in midwifery care (Elderhorst et al., 2019; Thiessen et al., 2016; Weisband et al., 2018; Wernham et al., 2016). There also appears to be fewer issues with postpartum hemorrhage (Hamlin et al., 2021; Weisband et al., 2018).

Decreased medical interventions, including CB.

Midwifery-led care emphasizes non-intervention or interruption in normal physiologic childbirth processes. Accordingly, the CB rate in midwifery care is typically lower than CB rate in general obstetric- or physician-led care. Women under midwifery care are significantly more likely to experience spontaneous vaginal birth comparing to women under obstetric care (Martin-Arribas et al., 2022; Raipuria et al., 2018; Souter et al., 2019; Tracy et al., 2014). One retrospective cohort study comparing midwifery and obstetrician practices and birth outcomes, in low-risk women from 11 hospitals in the U.S., found that women under midwifery care were less likely to undergo medical interventions (e.g., artificial rupture of membranes, oxytocin use, epidural use, episiotomy) and had a lower rate of CB compared to women under obstetric care (aRR: 0.68; 95% CI: 0.57-0.82) (Souter et al., 2019). Another study noted women who initiated prenatal care with midwives (vs. obstetricians) had a lower risk of CB (aRR: 0.66; 95% CI: 0.57-0.78) (Weisband et al., 2018). Additionally, another study noted that, compared with women under care by obstetricians, women under care by midwives were less likely to undergo induction or augmentation labor (aOR: 0.55; 95% CI: 0.52-0.58) and CB (aOR: 0.17; 95% CI: 0.17-0.18) (Hamlin et al., 2021). In one systematic review, midwifery care resulted in fewer CBs, instrumental vaginal deliveries (e.g., forceps, vacuum), episiotomies, and more VBACs, compared to obstetrical care (Johantgen et al., 2012). An earlier literature review focusing on reducing labor and birth intervention found that over 60% of included studies demonstrated that women under midwifery care had a lower risk for CB (Raipuria et al., 2018). This finding also holds true when comparing birth outcomes for women receiving interprofessional care which includes midwives vs. those who receive interprofessional care that does not include midwives, (26.1% vs. 33.5%, $p < .001$) (Smith et al., 2020). However, there are other studies that report no significant differences in CB rates between women whose labor was induced under midwifery vs. obstetrical care (Elderhorst et al., 2019).

Midwifery studies incorporating Robson TGCS.

There are only two studies using the Robson TGCS as a tool to investigate the CB rates between midwifery and other care settings. The first study (Smith et al., 2020), which compared the incidence of CB between the settings with and without midwives in the U.S., found that women were less likely to have CB in the settings with interprofessional care that included midwives (26.1% vs. 33.5%, $p<.001$). Further, nulliparous women with singleton, cephalic, term fetuses (Robson Group 2) were less likely to have their labor induced (11.1% vs. 23.4%, $p<.001$) and women with previous CB (Robson Group 5) had lower subsequent CB rates (73.8% vs. 85.1%, $p<.001$) in those settings that included midwives. In centers without midwives, nulliparous women with singleton, cephalic, term fetuses with induction of labor (Robson Group 2a) were less likely to have a CB compared with those in interprofessional care centers in unadjusted comparison (30.3% vs. 35.8%, $p<.001$). In the second study conducted in Ireland, 9.75% of births were CB and women in Robson Group 2 (nulliparous women with induction of labor or prelabor CB) were the primary contributor to increased CB rates; however, this study purposefully excluded women allocated to Robson Groups 5 (previous CB) and 8 (multiple gestation) (Hanahoe, 2020). Of note, is that these two studies focused on CB among all-aged women, which identifies a gap in understanding CB, by using Robson TGCS and clearly delineating women of AMA from their younger counterparts, in midwifery care.

Summary

This chapter drew attention to the current knowledge and gaps in understanding CB among women of AMA, especially in those in midwifery care. The gaps existing in current literature are: 1) studies examining CB using Robson TGCS mostly included women in all-age spectrum and were done in the hospital settings where care are mainly provided by physicians; 2) studies examining maternal and neonatal characteristics increasing risk for CB by AMA status showed inconsistent findings and none of these studies were conducted among women in midwifery care; and 3) no insight if particular Robson TGCS groups mediate the association between AMA status and CB. These gaps provide the scaffolding for the specific aims of the current study.

The overall objective of this study was to add to the body of knowledge of antecedent events and/or indicators that result in CB in women of AMA in midwifery care/settings, specifically focusing on any differences in women of AMA compared to their younger counterparts. Using the 2007-2019 Certified Nurse-Midwife (CNM) Clinical Data Repository in two U.S. states (Oregon and Michigan, we conducted a secondary data analysis to compare CB rates within and across Robson TGCS Groups in women of AMA (≥ 35 years old) and women of non-AMA (<35 years old)) as well as compare and contrast the differences in maternal and neonatal characteristics between AMA and non-AMA groups. We also examined if certain Robson Groups mediate the relationship between AMA status and CB. The long-term goal of this study is to increase safe and appropriate access to CB worldwide, while continuing to support vaginal delivery and reduce medically unnecessary CB, especially among women of AMA while highlighting midwifery care.

CHAPTER THREE

RESEARCH DESIGN & METHODS

Research Design

This study was a secondary analysis of an observational cohort datasets collected from 2007 to 2019 (Michigan) and 2012 to 2019 (Oregon) as part of a birth database. The intent of the secondary analysis was to determine cesarean birth (CB) rates among women of advanced maternal age (AMA) and examine maternal and neonatal characteristics which might be contributing factors of CB. The Robson 10-Group Classification System (TGCS) was utilized to classify women who have similar obstetric history and characteristics into the same group before determining CB rates and risks for CB. Selected Robson TGCS Groups (1-4) were tested as a mediator in the pathway between AMA status and CB.

Data Sources

The data for this study were obtained from the two existing databases previously collected to track birth data at two large academic midwifery settings located in Oregon and Michigan -*Michigan-Oregon Data collaboration*. Midwifery settings at both institutions have a similar approach to providing care to pregnant women, which supports physiologically natural birth. Both databases include approximately 190 variables across ante-, intra-, and postpartum care recorded by the nurse-midwives providing care at Oregon Health & Science University (OHSU) Hospital and University of Michigan Health Systems (UMHS) Hospital. The variables include maternal socio-demographic characteristics, personal medical history, personal obstetrical history, labor process, types of birth, and newborn information. These databases are a part of repositories used for quality assessment in the settings and for examining outcomes of midwifery care in pregnancy and birth. The Michigan database was previously sent to and maintained under the OHSU IRB, after receiving approval of Michigan IRB. This waiver of documentation of consent was granted, and the IRB at OHSU approved and signed data-use agreements. The Michigan data were merged and are monitored by the OHSU (STUDY00019828: Outcomes of Midwifery Care in Pregnancy and Birth–Michigan-Oregon Data Collaboration).

Study Sample

The de-identified birth records from two academic midwifery settings were used in these analyses. The eligible birth records for the proposed study were identified by logically screening and cleaning the OHSU Nurse Midwifery Database (2012-2019) and the University of Michigan Database (2007-2019), following the inclusion and exclusion criteria explained in the Table 3.1. The samples were divided into two groups by maternal age at birth: 1) below 35, but ≥ 18 years of age, and 2) 35 years old and over. Then, each sample group was classified into one of the 10 mutually exclusive Robson Groups. The ethical approval for the current secondary analysis of de-identified data was waved because the investigators were covered under the OHSU IRB STUDY00019828: Outcomes of Midwifery Care in Pregnancy and Birth –Michigan-Oregon Data Collaboration.

Table 3.1

Inclusion and Exclusion Criteria for the Current Study

Inclusion Criteria	Exclusion Criteria
1. All women cared by midwives at either: a. OHSU hospital b. University of Michigan hospital.	1. Age below 18 years old[1] 2. Missing information on: a. maternal age b. type of birth c. gestational age d. parity e. fetal presentation f. onset of labor 3. Women with stillbirth/ intrauterine demise/ unidentified lived birth

[1] Teenage pregnant women (age <18 years old) are more likely to have vaginal birth and less likely to have CB (Indarti et al., 2020; Mohamed et al., 2015; Torvie et al., 2015; Tyrberg et al., 2013).

Sample size

Specific Aim 1: Determine overall CB rates for women in midwifery care/settings.

The sample size for this aim was calculated by using G*power (version 3.1; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) (Faul et al., 2009) with statistical power = 0.8, Cronbach alpha = 0.05, and the proportions of CB rates between AMA and non-AMA from the previous study with 0.37 for AMA and 0.26 for non-AMA (37% in AMA vs. 26% in non-AMA) (Janoudi et al., 2015). A minimum sample of 594 (297/group) was needed for the proposed comparative analysis of CB rates between women of AMA and non-AMA. Additionally, the sample size for testing the odds of CB by maternal age groups was calculated by using G*power (version 3.1; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) (Faul et al., 2009) with statistical power=0.8, Cronbach alpha=0.05, the odds ratio=1.67 (37% in AMA vs. 26% in non-AMA), and proportion of AMA=0.23 (Janoudi et al., 2015). A minimum total sample of 773 was needed for testing the magnitude of differences in odds of CB by AMA status.

Specific Aim 2: Compare and contrast selected maternal (e.g., race/ethnicity, interpregnancy interval (IPI), pre-pregnancy BMI, total weight gain (TWG) during pregnancy, preeclampsia, gestational diabetes mellitus (GDM)), and neonatal (e.g., macrosomia) characteristics for women in midwifery care/settings.

The sample size for this aim was calculated by using G*power (version 3.1; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) (Faul et al., 2009) with statistical power=0.8, Cronbach alpha=0.05, and the proportions of preeclampsia between AMA and non-AMA retrieved from the previous study comparing this incidence with 0.18 for AMA and 0.06

for non-AMA (17.6% in AMA vs. 5.6% in non-AMA) (Mehari et al., 2020). Using this approach, the minimum sample for addressing this aim was 250 (125/group). The sample size was also calculated with statistical power=0.8, Cronbach alpha=0.05, and an anticipated effect size=0.22 retrieved from the study comparing maternal characteristics, including mean BMI, between AMA and non-AMA (26.8±6.6 kg/m^2 in AMA vs. 25.4±6.3 kg/m^2) (Dunn et al., 2017). The minimum sample using this approach was 670 (335/group). We decided to seek at least 670 records for the comparative analysis of maternal and neonatal characteristics between AMA and non-AMA, because the larger sample size allows for a more accurate estimation of differences between two groups.

Specific Aim 3: Explore the role of each Robson TGCS Group (1-4) as a mediator between AMA status and CB for women in midwifery care.

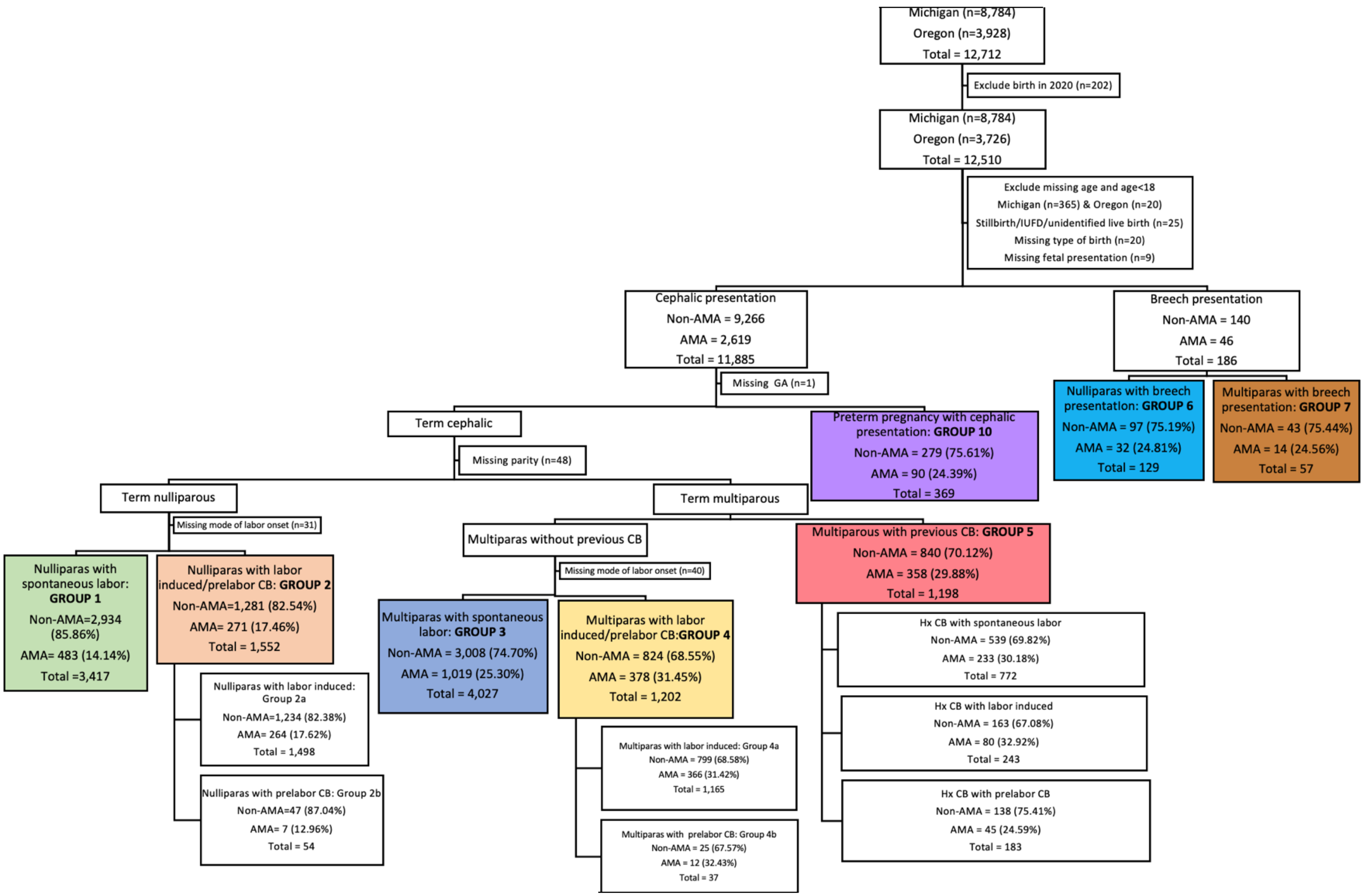
The sample size for this aim was not able to be calculated by statistical parameters retrieved from prior studies because there was none testing the role of Robson TGCS Group as a mediator, so we planned to include the entire analytic sample to address this aim. According to the relative sizes of Robson TGCS Group 1-4 from the study of Kanjanakaew and Erickson (2022) showing the relative sizes of Robson TGCS Group 1-4 being 31.58%, 13.59%, 29.94%, and 10.65%, respectively, we estimated that the number of women in Robson TGCS Group 1-4 would be approximately 3,500, 1,500, 3,300, and 1,200 people. These numbers would provide adequate statistical power (0.8) across a majority of situations (Fritz & MacKinnon, 2007).

As the OHSU database contains 3,928 women and the Michigan database contains 8,784 women (total = 12,712 women), we anticipated having sufficient numbers to address all aims. After logically checking and cleaning the data, the number of eligible women was 11,951 (Figure

3.1). Even though the final number was smaller [NOTE: We lost 5.99% of the original sample during the analysis], we had sufficient statistical power to address all aims with an estimated sample size of over 11,000 participants.

Figure 3.1

Sample Flow Chart



Data Collection Instruments

Primary outcome (dependent) variable

The primary outcome of this study was cesarean birth (CB) vs. vaginal birth (VB). This variable is categorical: Yes (CB) or No (VB).

Main predictors (independent) variables

Table 3.2

Independent Variables

Variables	Category
Maternal age	• AMA (≥35 years old) • Non-AMA (18-34 years old)
Race/ethnicity	• White • Black • Hispanic/Latina • Asian • Native American/ Alaska Native • Native Hawaiian or Pacific Islander • Middle Eastern • Identified by two or more/ other
Interpregnancy interval (for multiparous women only)	• Short (<18 months) • Optimal (≥18 months)

Variables	Category
Pre-pregnancy BMI[2]	• Underweight (BMI <18.5 kg/m^2) • Normal weight (BMI 18.5 – 24.9 kg/m^2) • Overweight (BMI 25-29.9 kg/m^2) • Obese (BMI ≥ 30 kg/m^2)
Total weight gain during pregnancy (TWG)[3,4]	• Insufficient • Optimal • Excessive
Preeclampsia	• Yes • No
Gestational diabetes mellitus (GDM)	• Yes • No
Neonatal macrosomia	• Yes (birth weight ≥ 4,000 grams) • No (birth weight <4,000 grams)

[2] Pre-pregnancy BMI was also compared by using mean of BMI of each group
[3] TWG was also compared by using mean of TWG of each group
[4] Recommended total weight gain during pregnancy based on pre-pregnancy BMI by IOM (Institute of Medicine) (Rasmussen et al., 2009)

Pre-pregnancy BMI	Total weight gain		
	Insufficient weight gain (in pounds)	Optimal weight gain (in pounds)	Excessive weight gain (in pounds)
Underweight (<18.5 kg/m^2)	<28	28-40	>40
Normal weight (18.5-24.9 kg/m^2)	<25	25-35	>35
Overweight (25-29.9 kg/m^2)	<15	15-25	>25
Obese (≥30 kg/m^2)	<11	11-20	>20

Variables	Category
Robson TGCS Groups	• Robson Group 1 (nulliparous women with spontaneous labor) • Robson Group 2 (nulliparous women with labor induced or prelabor CB) • Robson Group 3 (nulliparous women with spontaneous labor) • Robson Group 4 (multiparous women with labor induced or prelabor CB)

Method

In this section, each study aim is presented, followed by the statistical analysis(es):

Specific Aim 1: Determine overall CB rates for women in midwifery care/settings:

a. By AMA status (e.g., AMA [≥ 35 years old] vs. non-AMA [<35 years old])

b. Across Robson TGCS Groups, and

c. Between AMA and non-AMA status within Robson TGCS Groups

Analysis

1.a) Chi-square was used to examine the difference in CB rate between the two maternal age groups (by AMA status).

1.a) Logistic regression was also used to estimate the difference in odds of CB by AMA status by considering odds ratio (OR), 95% confidence intervals (CI), and p-value. Also, multiple logistic regression models will be adjusted for the following variables based on previous literature: gestational age, pre-pregnancy BMI, preeclampsia, and practice site (Araujo Júnior et al., 2017; Boriboonhirunsarn & Waiyanikorn, 2016; Chen et al., 2020; Dude et al., 2021; Gorgal et al., 2012; Hedderson et al., 2021; Ishaque et al., 2019; Kominiarek & Peaceman, 2017; Munim & Maheen, 2012; Pacher et al., 2014; Rietveld et al., 2017; Shen et al., 2017) and the interaction effect between AMA and parity, which is good to know if there were differences in risk for CB between AMA status by parity.

1.b) and 1.c) Standard descriptive statistics, frequencies, and percentages were used to describe Robson's Groups, including relative size, CB rates, absolute contribution, and relative contribution. The explanation of how to interpret each measure is provided in the Table 3.3.

Table 3.3

Robson's Measures

Robson's Measures	**Interpretation**
Relative size	# women in each group/total birth
CB rate	# women experiencing CB in each group/ # women in each group
Absolute contributor	# women experiencing CB in each group/ total birth
Relative contributor	# women experiencing CB in each group/ total # women with CB

Specific Aim 2: Compare and contrast selected maternal (e.g., race/ethnicity, IPI, pre-pregnancy BMI, TWG during pregnancy, preeclampsia, GDM) and neonatal (e.g., macrosomia) characteristics for women in midwifery care/settings:

a. Between AMA and non-AMA status across the analytic sample

b. Across Robson TGCS Group 1-5, and

c. Between AMA and non-AMA status within Robson TGCS Groups

Analysis

2.a) All variables (e.g., race/ethnicity, IPI, pre-pregnancy BMI status, TWG during pregnancy, preeclampsia, GDM, and macrosomia) are categorical, therefore, chi-square was used to examine differences in maternal and neonatal characteristics between the two maternal age groups.

2.b) Chi-square was used to examine the differences in the maternal and neonatal characteristics (e.g., race/ethnicity, IPI[5], pre-pregnancy BMI status, TWG during pregnancy, preeclampsia, gestational diabetes mellitus, macrosomia) across the Robson Group 1-5.

2.c) Chi-square was used to examine the differences in the maternal and neonatal characteristics between the two maternal age groups in specific Robson Groups (e.g., groups 1, 2, and5).

Pre-pregnancy BMI and TWG were continuous variables. The difference in means of pre-pregnancy BMI and TWG between AMA vs. non-AMA group and across Robson Groups 1-5. Pre-pregnancy BMI was not normally distributed, so we used Mann-Whitney U to test

[5] Interpregnancy interval (IPI) was measured for only multiparous women

differences in mean of pre-pregnancy BMI between AMA and non-AMA in the whole analytic sample and (2.a) between AMA and non-AMA within a Robson Group (2.c). For differences in means of pre-pregnancy BMI across Robson Group 1-5 (2.b), non-parametric one-way analysis of variance (ANOVA) was used.

TWG was normally distributed, so we used t-test to analyze the differences in means of TWG between AMA and non-AMA groups in the whole analytic sample (2.a) and within a Robson Group. Also, for the differences in means of TWG across Robson Group 1-5 (2.b), one-way ANOVA was used.

Specific Aim 3: Explore the role of each Robson TGCS Group (1-4) as a mediator between AMA status and CB for women in midwifery care/settings:

a. Among nulliparous women: Robson Group (1 & 2), and

b. Among multiparous women: Robson Group (3 & 4).

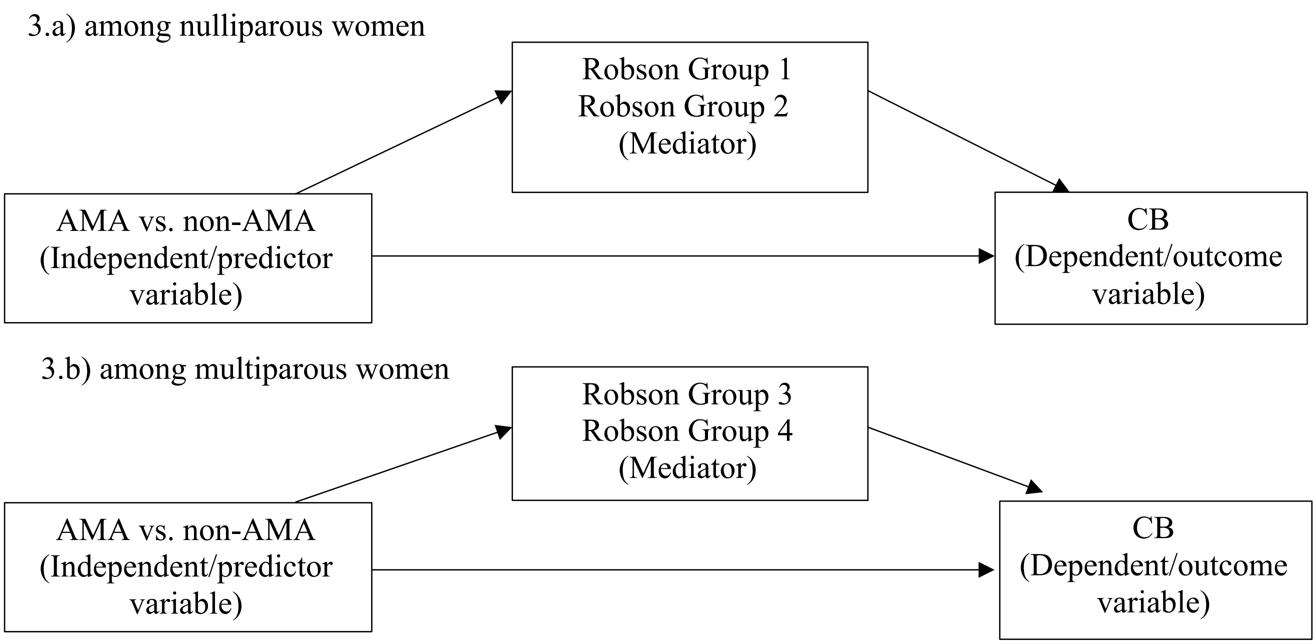
Analysis

The mediation analyses in this study were done within subgroups, including nulliparous women and multiparous women, and all mediation analyses were conducted using the Baron and Kenny (1986) method. Each subgroup was tested if AMA status, the independent/predictor variable (IV) to determine if it was significantly associated with the Robson group (mediator). The next process was testing if AMA status (IV) was also significantly associated with CB rate, the dependent/outcome variable (DV). Then, the mediating effect of Robson Group(s) was tested to see if it was significantly related to the DV variable when simultaneously entering both the IV and mediator in the testing model. If the direct relationship between AMA status and CB rates was reduced, a mediating effect is present (Figure 3.2). We also did the Sobel's test to know the indirect effect of the mediator (Robson Group).

In the adjusted models for each subgroup, we also controlled for the variables related to CB, including pre-pregnancy BMI, gestational age, preeclampsia, and site.

Figure 3.2

Analytic Plan for Testing a Mediating Effect of Robson Group on the Association between AMA Status and CB



Dealing with missing data

According to the nature of secondary data analysis, there is typically missing data needs to be addressed. The pattern of 'missingness' for this study was completely at random (MCAR).

Accordingly, missing data were handled using the listwise deletion method in both comparison (Aim 2) and regression models (Aims 1&3).

Sensitivity analysis

The sensitivity analysis was conducted to determine the robustness of the findings by running the multiple logistic regression with or without site variable which would show significant differences in CB rates to assess the difference between these models (e.g., odds of CB by AMA status and its statistical significance, coefficient of Robson Group when testing the mediation effect, and the interaction between AMA status and parity on CB and its statistical significance). All analyses were processed by using STATA version 17.0 (STATA Corp, College Station TX, 2021). Statistical significance will be determined at the level of $p < .05$.

Potential risks

This study collected the participants' data by reviewing and analyzing the databases which had been de-identified. Further, no date of birth for mothers or newborns was recorded in the databases. The potential risk of loss of confidentiality to human subjects in this study was minimal. Also, there were no potential both physical and psychological risks to participants, as the data have already been collected and the investigators did not directly contact participants.

Protection against risk

The following strategies were implemented to diminish risk. First, all investigators were trained for the protection of human subjects and protection of confidentiality required by the OHSU IRB. Next, when we accessed the databases, we established that all birth records were de-identified and did not provide date of birth or any other personal identification/information.

During reviewing and analyzing data, the databases were secured in the primary investigator's computer, which is password-protected. Any/all results were collectively reported in presentations and publications.

Potential study benefits

The participants in this study will not directly benefit from this study. However, the findings of this study will potentially provide healthcare providers and researchers insight into the antecedent events and contributors to CB for women receiving midwifery care, especially women of AMA, as well as differences in maternal and neonatal characteristics increasing risk for CB. Moreover, this study will inform whether particular Robson group(s) mediate the association between AMA status and CB. Lastly, the findings from this study may also be used to inform ongoing efforts to develop interventions to reduce unnecessary CB (e.g., programs to educate and support women to have optimal BMI, TWG, or IPI) among women of AMA.

CHAPTER FOUR

RESULTS

This chapter begins with a description of the sample and exploratory data analysis. These initial sections are followed by a detailed presentation of data which is organized by specific aim. The discussion of the findings is found in Chapter five.

Sample

The women included in the sample were from two data bases - Oregon Health & Science University (OHSU) Hospital and University of Michigan Health Systems (UMHS) Hospital – that extended over a 10-year period (2009-2019). The number of women who met the inclusion criteria in the merged database was 12,712. We excluded women birthing in 2020 (*n*=202), women with stillbirth/ intrauterine demise/ unidentified lived birth (*n*=25), and women with missing age or age below 18 years old (*n*=385). Cases with missing data for modes of birth (*n*=20), and missing data for Robson's criteria including gestational age (*n*=129) were also excluded. Therefore, the final number of eligible women were 11,951 (Figure 3.1). Of the 11,951, 3,667 (30.68%) women were admitted in the OHSU hospital and 8,284 (69.32%) women to UMHS hospital.

Preliminary Analysis

Exploratory data analysis was conducted before running analyses addressing each specific aim. Managing missing data is also a critical step in preparing data. It works together with exploratory data analysis to understand the origins and impact of missing values and establish the best strategy to overcome them. Since the amount of missing data was relatively small (5.99%), we used the list-wise deletion approach, meaning that individuals with missing data for our main interest variables were deleted. Additionally, we explored missing data for other related variables investigated in this study. Missing data were quantified as follows: race/ethnicity (0.97%), interpregnancy interval (0.94%), pre-pregnancy BMI (10.41%), total weight gain during pregnancy (TWG) (8.32%), preeclampsia (0.11%), gestational diabetes mellitus (GDM) (1.55%), macrosomia (0.96%), and practice site (0.00%).

The distribution of two continuous variables with larger proportions of missing data (pre-pregnancy BMI; TWG) were explored. TWG data were normally distributed; however, pre-pregnancy BMI data were not. Therefore, we used non-parametric tests when comparing pre-pregnancy BMI between women of AMA and women of non-AMA.

Before running logistic regression, the predictors for which we controlled (i.e., AMA status, Robson Groups, pre-pregnancy BMI, gestational age, practice site, and preeclampsia/eclampsia) were tested if there were multicollinearity. The results showed that none of correlation coefficients among predictors equal to/greater than 0.8, which indicate the absence of multicollinearity among the predictors.

Findings

The specific characteristics of the women are organized by type of birth (i.e., vaginal vs. cesarean birth [CB]) and presented in Table 4.1. Additional findings, along with related tables and figures, are presented by specific aim. Key findings are highlighted after each table/ figure and summarized.

Table 4.1

Characteristics between Women with Vaginal Birth and Women with Cesarean Birth (CB)

Variables	Total	Vaginal birth	Cesarean birth	*p*-value
Sample size	11,951	10,062 (84.19%)	1,889 (15.81%)	
Sites				<0.001

Variables	Total	Vaginal birth	Cesarean birth	*p*-value
- Oregon	3,667 (30.68%)	3,161 (86.20%)	506 (13.80%)	
- Michigan	8,284 (69.32%)	6,901 (83.31%)	1,383 (16.69%)	
Advanced Maternal Age (AMA)				0.001
- AMA	2,645 (22.13%)	2,161 (21.48%)	484 (25.62%)	
- Non-AMA	9,306 (77.87%)	7,901 (78.52%)	1,405 (74.38%)	
Age *M* ± *SD* (years)				
- Total sample	30.28±5.37	30.23±5.31	30.68±5.63	<0.001
- AMA	37.32±2.26	37.24±2.19	37.70±2.51	<0.001
- Non-AMA	28.28±4.17	28.28±4.17	28.26±4.20	0.8762
Gestational age *M* ± *SD* (weeks)	39.86± 1.43	39.82 ± 1.39	40.05 ± 1.62	<0.001
Race/Ethnicity				0.286
- White	8,934 (75.49%)	7,506 (75.27%)	1,428 (76.65%)	
- Black	1,024 (8.65%)	854 (8.56%)	170 (9.13%)	
- Asian	533 (4.50%)	450 (4.51%)	83 (4.46%)	
- Latino	954 (8.06%)	825 (8.27%)	129 (6.92%)	
- Native American & American Indian	35 (0.30%)	31 (0.31%)	4 (0.21%)	
- Middle Eastern	259 (2.19%)	227 (2.28%)	32 (1.72%)	
	26 (0.22%)	23 (0.23%)	3 (0.16%)	

Variables	Total	Vaginal birth	Cesarean birth	*p*-value
- Hawaiian & Pacific Islanders				
- Identified by two or more/others	70 (0.59%)	56 (0.56%)	14 (0.75%)	
Interpregnancy Interval				0.030
- Normal/Optimal	5,750 (86.96%)	5,160 (86.66%)	590 (89.67%)	
- Short	862 (13.04%)	794 (13.34%)	68 (10.33%)	
Pre-pregnancy BMI				
$M \pm SD$ (kg/m^2)	26.03 ± 5.74	25.76 ± 5.58	27.53 ± 6.36	<0.001
- Underweight	235 (2.19%)	216 (2.39%)	19 (1.14%)	<0.001
- Normal weight	5,377 (50.22%)	4,537 (51.95%)	683 (40.85%)	
- Overweight	2,888 (26.97%)	2,408 (26.65%)	480 (28.71%)	
- Obese	2,207 (20.61)	1,717 (19.00%)	490 (29.31%)	
TWG				
$M \pm SD$ (lbs)	32.01 ± 13.52	31.62 ± 13.24	34.27 ± 14.84	<0.001
- Insufficient	1,521 (15.33%)	13.65 (16.10%)	156 (10.80%)	<0.001
- Optimal	3,244 (32.70%)	2,874 (33.90%)	370 (25.62%)	
- Excessive	5,156 (51.97%)	4,238 (49.99%)	918 (63.57%)	
Preeclampsia				<0.001
- No	11,472 (96.10%)	9,733 (96.82%)	1,739 (92.25%)	
- Yes	466 (3.90%)	320 (3.18%)	146 (7.75%)	

Variables	Total	Vaginal birth	Cesarean birth	*p*-value
GDM				0.187
- No	11,271 (95.79%)	9,537 (95.50%)	1,734 (95.22%)	
- Yes	495 (4.21%)	408 (4.10%)	87 (4.78%)	
Macrosomia				<0.001
- No	10,160 (85.84%)	8,679 (86.99%)	1,481 (79.67%)	
- Yes	1,676 (14.23%)	1,298 (13.01%)	378 (20.33%)	

Note. BMI = body mass index; *M* = mean; *SD* = standard deviation; AMA = advanced maternal age; TWG = total weight gain during pregnancy; GDM = gestational diabetes mellitus

There were several differences between women in the CB vs. vaginal birth groups. First, the percent of women of AMA was significantly higher in CB group compared to vaginal birth group (25.62% vs 21.48%, $p<0.001$). The mean gestational age of the CB group was higher than the vaginal birth group (40.05±1.62 vs. 39.82±1.39, $p<0.001$). Additionally, women in CB group had higher mean pre-pregnancy BMI and were more often overweight (28.71% for CB vs. 26.65% for vaginal birth) or obese (29.31% for CB vs. 19.00% for vaginal birth). In addition, CB occurred more commonly when women had excessive weight gain during pregnancy (according to the Institute of Medicine recommendations by pre-pregnancy BMI [(Rasmussen et al., 2009)]) (63.57% for CB vs. 49.99% for vaginal birth). Finally, CB occurred more frequently among women who had preeclampsia (7.75% for CB vs. 3.18% for vaginal birth, $p<0.001$), and when the infant was macrosomic (20.33% for CB vs. 13.01% for vaginal birth, $p<0.001$).

In contrast, a short pregnancy interval was more common among women who had a vaginal birth compared to women in CB group with 13.34% vs. 10.33%, $p=0.030$.

Specific Aim 1: Determine overall CB rates for women in midwifery care/settings:

In this specific aim, the rate of CB was determined across the entire sample as well as within each Robson group and Chi-square (χ^2) tests were used to compare CB rates between women of AMA and women of non-AMA.

a. By AMA status (e.g., AMA [≥ 35 years old] vs non-AMA [<35 years old])

Table 4.2

Cesarean Birth Rates among Women of non-AMA and Women of AMA

Type of birth	Sample: *N* (%)	Non-AMA: *n* (%)	AMA: *n* (%)	*p*-value
Vaginal	10,062 (84.19%)	7,901 (84.90%)	2,161 (81.70%)	<0.001
Cesarean	1,889 (15.81%)	1,405 (15.10%)	484 (18.30%)	

Note. AMA= advanced maternal age

The overall CB rate was 15.81%; and it was significantly higher among women of AMA (18.30% for women of AMA vs. 15.10% for non-AMA, *p*<0.001).

b. Across Robson TGCS Groups

Table 4.3

Robson's Measures across Analytic Sample

Robson groups	All sample: *N* (%)		
	# women in Robson Group (Relative size)	Cesarean (CB) rate (#CB in Robson group/#women in Robson Group)	Relative contribution (#CB in Robson group/1,889 (total CB)
Group 1: Nullipara with spontaneous labor	3,417 (28.59%)	538 (15.74%)	28.48%

Robson groups	All sample: *N* (%)		
	# women in Robson Group (Relative size)	Cesarean (CB) rate (#CB in Robson group/#women in Robson Group)	Relative contribution (#CB in Robson group/1,889 (total CB)
Group 2: Nullipara with labor induced/prelabor CB	1,552 (12.99%)	539 (34.73%)	28.53%
- 2a: labor induced	1,498 (12.53%)	485 (32.38%)	25.67%
- 2b: prelabor CB	54 (0.45%)	54 (100%)	2.86%
Group 3: Multipara with spontaneous labor	4,027 (33.70%)	81 (2.01%)	4.29%
Group 4: Multipara with labor induced/prelabor CB	1,202 (10.06%)	90 (7.49%)	4.76%
- 4a: labor induced	1,165 (9.75%)	53 (4.55%)	2.81%
- 4b: prelabor CB	37 (0.31%)	37 (100%)	1.96%
Group 5: Multipara with previous CB	1,198 (10.02%)	420 (35.06%)	22.23%
Group 6: Nullipara with breech presentation	129 (1.08%)	119 (92.25%)	6.30%
Group 7: Multipara with breech presentation	57 (0.48%)	53 (92.98%)	2.81%

Robson groups	All sample: *N* (%)		
	# women in Robson Group (Relative size)	Cesarean (CB) rate (#CB in Robson group/#women in Robson Group)	Relative contribution (#CB in Robson group/1,889 (total CB)
Group 10: Preterm birth	369 (3.09%)	49 (13.28%)	2.59%

Note. No cases were reported for Groups 8 and 9.

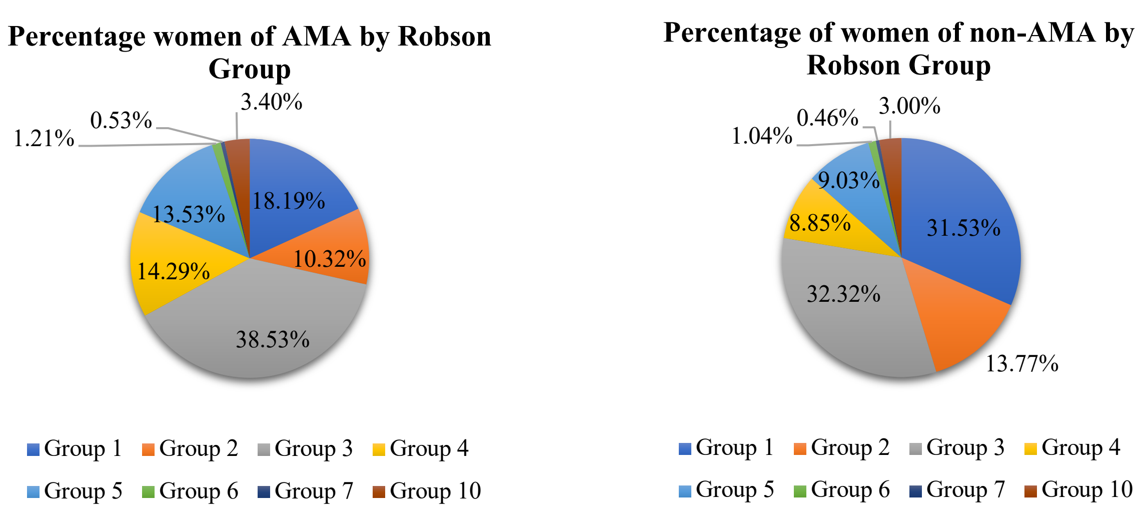
CB rates were the highest (92.98%) among multiparous women with fetal breech presentation (Group 7) and (92.25%) for nulliparous women with breech presentation (Group 6), followed by (35.06%) multiparous women with previous CB (Group 5). When looking at relative contribution to the overall CB rate, the largest contributors were nulliparous women with labor induced/prelabor CB (Group 2) at 28.53%, nulliparous women with spontaneous labor (Group 1) at 28.48%, and multiparous women with previous CB (Group 5) at 22.23%.

d. Between AMA and non-AMA status within TGCS Groups

Figure 4.1

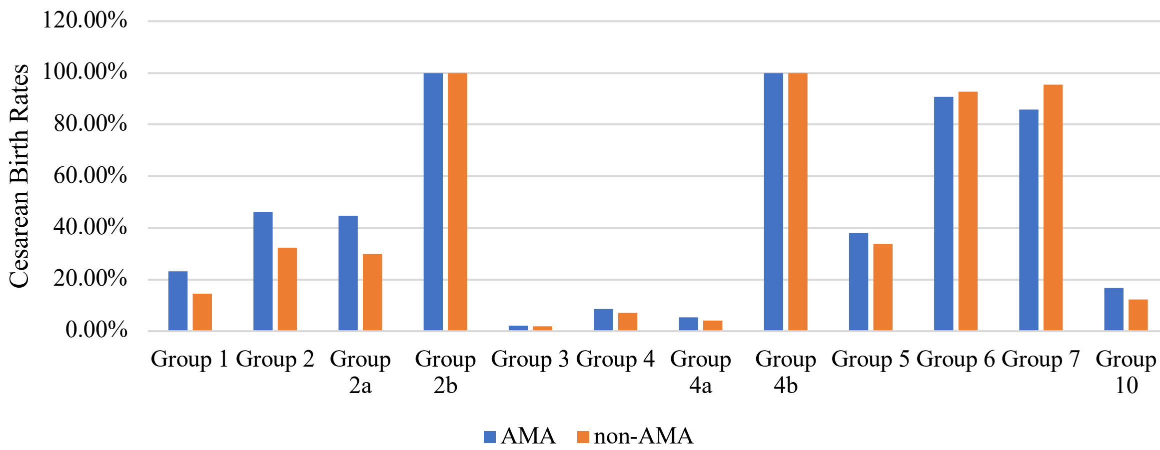
Robson's Measures between Women of AMA and Women of non-AMA

a. Relative size[6]

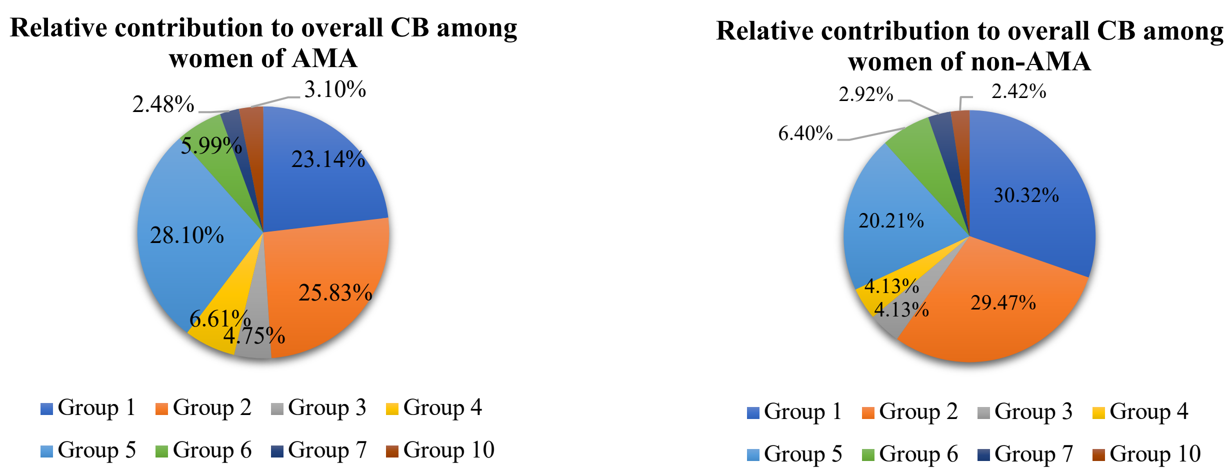


[6] Relative size=#women in a Robson Group/total women

b. CB rates[7]



c. Relative contribution[8]



Across all Robson Groups, women of AMA had higher CB rates except for women with breech presentation (90.62% vs. 92.78% for Group 6 and 85.71% vs. 95.35% for Group 7) compared to women of non-AMA (Figure 4.1b). The three largest contributors to CB for both women of AMA and non-AMA were similar: Robson Group 1 (nulliparous women with spontaneous labor), Robson Group 2 (nulliparous women with labor induced or prelabor CB),

[7] CB rate= #CB in Robson Group/#women in a Robson Group
[8] Relative contribution = #CB in a Robson Group/total CB

and Robson Group 5 (multiparous women with previous CB) (Figure 4.1c); However, the order of the largest contributors was different. The largest contributors to overall CB rate among women of AMA were Robson Group 5 (28.10%) followed by Robson Group 2 (25.83%), and Robson Group 1 (23.14%). In contrast, the largest contributors to overall CB rate among women of non-AMA were Robson Group 1 (30.32%), Robson Group 2 (29.47%), and Robson Group 5 (20.21%).

Specific Aim 2: Compare and contrast selected maternal (e.g., race/ethnicity, Interpregnancy interval, pre-pregnancy BMI, TWG during pregnancy, preeclampsia, GDM), and neonatal (e.g., macrosomia) characteristics for women in midwifery care/settings:

In this specific aim, Chi-square (χ^2), t-test, Mann Whitney-U, and parametric and non-parametric one-way analysis of variance (ANOVA) statistics were used to compare and contrast the differences of characteristics among women in midwifery care. The characteristics of interest were race/ethnicity, interpregnancy interval, pre-pregnancy BMI, TWG, preeclampsia, GDM, and neonatal macrosomia.

a. Between AMA and non-AMA status across the analytic sample

Table 4.4

Characteristics among Women of AMA and Women of non-AMA

Variables	AMA	Non-AMA	*p*-value
Race/Ethnicity			<0.001
- White	2,119 (80.60%)	6,815 (74.03%)	
- Black	105 (3.99%)	919 (9.98%)	

Variables	AMA	Non-AMA	*p*-value
- Asian	142 (5.40%)	391 (4.25%)	
- Latino	180 (6.85%)	774 (8.41%)	
- Native American & American Indian	7 (0.27%)	28 (0.30%)	
- Middle Eastern	51 (1.94%)	208 (2.26%)	
- Hawaiian & Pacific Islanders	7 (0.27%)	19 (0.21%)	
- Identified by two or more/others	18 (0.68%)	52 (0.56%)	
Interpregnancy Interval			0.053
- Normal/Optimal	1,662 (88.26%)	4,148 (86.47%)	
- Short	213 (11.74%)	649 (13.53%)	
Pre-pregnancy BMI			
M ± *SD* (kg/m^2)	25.98 ± 5.39	26.05 ± 5.84	0.352
- Underweight	43 (1.81%)	192 (2.31%)	0.179
- Normal weight	1,199 (50.36%)	4,178 (50.18%)	
- Overweight	670 (28.14%)	2,218 (26.64%)	
- Obese	469 (19.70%)	1,738 (20.87%)	
TWG[9]			

[9]Total weight gain during pregnancy recommended by the Institute of Medicine (Rasmussen et al., 2009)

Pre-pregnancy BMI	Total weight gain		
	Insufficient weight gain (in lbs)	Optimal weight gain (in lbs)	Excessive weight gain (in lbs)
Underweight (<18.5 kg/m^2)	<28	28-40	>40

Variables	**AMA**	**Non-AMA**	***p*-value**
$M \pm SD$ (lbs)	30.58±12.06)	32.41±13.87	<0.001
- Insufficient	364 (16.46%)	1,557 (15.01%)	0.002
- Optimal	773 (34.95%)	2,471 (32.05%)	
- Excessive	1,075 (48.60%)	4,081 (52.94%)	
Preeclampsia			0.751
- No	2,538 (95.99%)	8,983 (96.13%)	
- Yes	106 (4.01%)	360 (3.87%)	
GDM			<0.001
- No	2,425 (93.16%)	8,846 (96.54%)	
- Yes	178 (6.84%)	317 (3.46%)	
Macrosomia			0.001
- No	2,197 (83.82%)	7,963 (86.41%)	
- Yes	424 (16.18%)	1,252 (13.59%)	

Note. BMI = body mass index; *M* = mean; *SD* = standard deviation; AMA = advanced maternal age; TWG = total weight gain during pregnancy; GDM = gestational diabetes mellitus

Across the analytic sample, race/ethnicity differed by AMA status ($p<0.001$). Non-Hispanic White women were more common among women of AMA (80.60% for women of AMA vs. 74.03% for non-AMA), while non-Hispanic Black women were more common among

Normal weight (18.5-24.9 kg/m^2)	<25	25-35	>35
Overweight (25-29.9 kg/m^2)	<15	15-25	>25
Obese (≥30 kg/m^2)	<11	11-20	>20

women of non-AMA (3.99% for women of AMA vs. 9.98% for non-AMA). The mean TWG was higher among women of non-AMA compared to women of AMA (32.41 vs. 30.58, $p<0.001$), and TWG differed by AMA status ($p=0.002$). GDM was more common among women of AMA (women of AMA 6.84% vs. women of non-AMA 3.46%, $p<0.001$). Also, macrosomic newborns were more common among women of AMA (women of AMA 16.18% vs. non-AMA 13.59%, $p=0.001$).

In addressing Specific Aim 2.b, Groups 1-5 were selected because the majority (95.36%) of the total sample were from in these groups, and of these groups, Groups 1, 2, and 5 were the largest contributors to CB. Also, there were no cases in Robson Groups 8 and 9 reported. Thus, the following Tables 4.5 and 4.6 only include Robson TGCS Groups 1-5.

b. *Across* Robson TGCS Group 1-5

Table 4.5

Characteristics among Women across Robson Groups 1-5

Variables	Group 1	Group 2	Group 3	Group 4	Group 5	*p*-value
Race/Ethnicity						<0.001
- White	2,627	1,197	2,942	865	867	
	(77.58%)	(77.78%)	(73.88%)	(72.51%)	(73.04%)	
- Black	279	150	329	131	98	
	(8.24%)	(9.75%)	(8.26%)	(10.98%)	(8.26%)	
- Asian	181	64	175	41	38	
	(5.35%)	(4.16%)	(4.36%)	(3.44%)	(3.20%)	
- Latino	191	78	386	117	151	

Variables	Group 1	Group 2	Group 3	Group 4	Group 5	*p*-value
	(5.67%)	(5.07%)	(9.69%)	(9.81%)	(12.72%)	
- Native American & American Indian	11 (0.32%)	7 (0.45%)	9 (0.23%)	3 (0.25%)	4 (0.34%)	
- Middle eastern	71 (2.10%)	27 (1.75%)	108 (2.71%)	24 (2.01%)	24 (2.02%)	
- Hawaiian & Pacific Islanders	8 (0.24%)	3 (0.19%)	11 (0.28%)	4 (0.34%)	0	
- Identified by two or more/others	18 (0.53%)	13 (0.84%)	22 (0.55%)	8 (0.67%)	5 (0.42%)	
Interpregnancy Interval						0.006
- Normal/Optimal	-	-	3,496 (87.66%)	1,000 (84.10%)	1,033 (86.81%)	
- Short	-	-	492 (12.34%)	189 (15.90%)	157 (13.19%)	
Pre-pregnancy BMI						
$M \pm SD$ (kg/m^2)	24.91 ± 4.99	26.94 ± 6.27	25.62 ± 5.46	27.74 ± 6.47	27.72 ± 6.21	<0.001
- Underweight	78 (2.53%)	32 (2.27%)	88 (2.47%)	15 (1.39%)	8 (0.74%)	<0.001
- Normal weight	1,813 (58.77%)	618 (43.77%)	1,884 (52.85%)	403 (37.38%)	424 (39.33%)	

Variables	Group 1	Group 2	Group 3	Group 4	Group 5	*p*-value
- Overweight	777 (25.19%)	386 (27.34%)	940 (26.37%)	332 (30.80%)	313 (29.04%)	
- Obese	417 (13.52%)	376 (26.63%)	653 (18.32%)	328 (30.43%)	333 (30.89%)	
TWG						
M ± *SD* (lbs)	34.00 ± 12.96	35.03 ± 14.67	30.44 ± 12.79	30.08 ± 13.93	30.55 ± 13.83	<0.001
- Insufficient	426 (14.45%)	136 (10.35%)	576 (17.33%)	150 (15.09%)	135 (14.26%)	<0.001
- Optimal	931 (31.58%)	350 (26.64%)	1,189 (35.78%)	332 (33.40%)	313 (33.05%)	
- Excessive	1,591 (53.97%)	828 (63.01%)	1,558 (46.89%)	512 (51.51%)	499 (52.69%)	
Preeclampsia						<0.001
- No	3,311 (96.90%)	1,373 (88.52%)	3,982 (99.01%)	1,147 (95.50%)	1,147 (96.06%)	
- Yes	106 (3.10%)	178 (11.48%)	40 (0.99%)	54 (4.50%)	47 (3.94%)	
GDM						0.017
- No	3,270 (96.40%)	1,458 (95.67%)	3,834 (96.14%)	1,121 (94.76%)	1,092 (94.55%)	
- Yes	122	66	154	62	63	

Variables	Group 1	Group 2	Group 3	Group 4	Group 5	*p*-value
	(3.60%)	(4.33%)	(3.86%)	(5.24%)	(5.45%)	
Macrosomia						<0.001
- No	3,052 (89.92%)	1,307 (85.15%)	3,373 (84.45%)	981 (82.23%)	932 (79.12%)	
- Yes	342 (10.08%)	228 (14.85%)	621 (15.55%)	212 (17.77%)	246 (20.88%)	

Note. BMI = body mass index; *M*=mean; *SD* = standard deviation; AMA = advanced maternal age; TWG = total weight gain during pregnancy; GDM = gestational diabetes mellitus

The majority (>70%) of women in each group were non-Hispanic White. Latino women were more common in Robson Group 5 (12.72%) and non-Hispanic Black women were more common in Robson Group 4 (10.98%). Additionally, short IPI was more common in Robson Group 4 (15.90%). Women in Robson Group 1 had lowest pre-pregnancy BMI (24.91 ± 4.99), while women in Robson Groups 4 and 5 had highest (27.74 ± 6.47 and 27.72 ± 6.21). Women in Robson Group 5 had the highest prevalence of GDM and macrosomic newborns (5.45% and 20.88%, respectively), while women in Robson Group 1 had lowest (3.60% and 10.08%, respectively). However, preeclampsia/eclampsia was more common in Robson Group 2 (11.48%) than any other Robson group.

c. ***Between*** AMA and non-AMA status within Robson TGCS Groups

Table 4.6 *Characteristics between Women of AMA and Women of AMA within Robson Groups (1-5)*

Variables	Group 1		Group 2		Group 3		Group 4		Group 5	
	AMA	Non-AMA	AMA	Non-AMA	AMA	Non-AMA	AMA	Non-AMA	AMA	Non-AMA
Race/Ethnicity**										
- White	414	2,213	226	971	791	2,151	297	568	282	585
	(86.43%)	(76.13%)	(84.01%)	(76.46%)	(78.01%)	(72.47%)	(78.99%)	(69.52%)	(79.21%)	(70.40%)
- Black	8	271	7	143	54	275	21	110	11	87
	(1.67%)	(9.32%)	(2.60%)	(11.26%)	(5.33%)	(9.27%)	(5.99%)	(13.46%)	(3.09%)	(10.47%)
- Asian	26	155	16	48	62	113	12	29	16	22
	(5.43%)	(4.25%)	(5.95%)	(3.78%)	(6.11%)	(3.81%)	(3.19%)	(3.55%)	(4.49%)	(2.65%)
- Latino	20	171	10	68	74	312	31	86	37	114
	(4.18%)	(5.88%)	(3.72%)	(5.35%)	(7.30%)	(10.51%)	(8.24%)	(10.53%)	(10.39%)	(13.72%)
- Native American &	1	10	2	5	2	7	2	1	-	4
American Indian	(0.21%)	(0.34%)	(0.74%)	(0.39%)	(0.20%)	(0.24%)	(0.53%)	(0.12%)		(0.48%)
- Middle Eastern	8	63	4	23	20	88	7	17	9	15
	(1.67%)	(2.17%)	(1.49%)	(1.81%)	(1.97%)	(2.96%)	(1.86%)	(2.08%)	(2.53%)	(1.81%)

Variables	Group 1		Group 2		Group 3		Group 4		Group 5	
	AMA	**Non-AMA**	**AMA**	**Non-AMA**	**AMA**	**Non-AMA**	**AMA**	**Non-AMA**	**AMA**	**Non-AMA**
- Hawaiian & Pacific Islanders	-	8 (0.28%)	-	3 (0.24%)	4 (0.39%)	7 (0.24%)	3 (0.80%)	1 (0.12%)	-	-
- Identified by two or more/others	2 (0.42%)	16 (0.55%)	4 (1.49%)	9 (0.71%)	7 (0.69%)	15 (0.51%)	3 (0.80%)	5 (0.61%)	1 (0.28%)	4 (0.48%)
Interpregnancy Interval										
- Normal/Optimal	-		-		903 (89.76%)	2,593 (86.96%)	316 (84.04%)	684 (84.13%)	312 (87.89%)	721 (86.35%)
- Short	-		-		103 (10.24%)*	389 (13.04%)*	60 (15.96%)	129 (15.87%)	43 (12.11%)	114 (13.65%)
Pre-pregnancy BMI										
M ± *SD* (kg/m^2)	24.93± 4.49)	24.91± 5.06	26.81± 5.77	26.97± 6.37	29.97± 11.79	30.60± 13.11	27.08± 6.15*	28.04± 6.59*	26.63± 5.38*	28.20± 6.48*
- Underweight	10 (2.29%)	68 (2.57%)	2 (0.80%)	30 (2.58%)	21 (2.32%)	67 (2.52%)	4 (1.17%)*	11 (1.49%)*	3 (0.91%)*	5 (0.67%)*
- Normal weight	254 (58.26%)	1,559 (58.85%)	119 (47.79%)	499 (42.91%)	474 (52.32%)	1,410 (53.03%)	142 (41.52%)*	261 (35.46%)*	155 (47.11%)*	269 (35.91%)*

Variables	Group 1		Group 2		Group 3		Group 4		Group 5	
	AMA	**Non-AMA**	**AMA**	**Non-AMA**	**AMA**	**Non-AMA**	**AMA**	**Non-AMA**	**AMA**	**Non-AMA**
- Overweight	116 (26.61%)	661 (24.95%)	64 (25.70%)	322 (27.69%)	256 (28.26%)	684 (25.72%)	112 (32.75%)*	220 (29.89%)*	87 (26.44%)*	226 (30.17%)*
- Obese	56 (12.84%)	361 (13.63%)	64 (25.70%)	312 (26.83%)	155 (17.11%)	498 (18.73%)	84 (24.56%)*	244 (33.15%)*	84 (25.58%)*	249 (33.24%)*
TWG										
M ± *SD* (lbs)	32.95± 11.55	34.17± 13.17	33.24± 12.65*	35.40± 15.04*	29.97± 11.79	30.60± 13.11	29.22 ±12.61	30.47± 14.50	29.72± 11.62	30.92± 14.68
- Insufficient	61 (14.63%)	365 (14.42%)	28 (12.02%)	108 (9.99%)	152 (17.88%)	425 (17.15%)	52 (16.20%)	98 (14.56%)	39 (13.27%)	96 (14.70%)
- Optimal	133 (31.89%)	798 (31.53%)	71 (30.47%)	279 (25.81%)	313 (36.82%)	876 (35.42%)	119 (37.07%)	213 (31.65%)	109 (37.07%)	204 (31.24%)
- Excessive	223 (53.48%)	1,368 (54.05%)	134 (57.51%)	694 (64.20%)	385 (45.29%)	1,173 (47.43%)	150 (46.73%)	362 (53.79%)	146 (49.66%)	353 (54.06%)
Preeclampsia										
- No	460 (95.24%)	2,851 (97.17%)	238 (87.82%)	1,135 (88.67%)	1,008 (99.02%)	2,974 (99.00%)	356 (94.18%)	791 (96.11%)	349 (97.49%)	798 (95.45%)

Variables	Group 1		Group 2		Group 3		Group 4		Group 5	
	AMA	Non-AMA	AMA	Non-AMA	AMA	Non-AMA	AMA	Non-AMA	AMA	Non-AMA
- Yes	23 (4.76%)*	83 (2.83%)*	33 (12.18%)	145 (11.33%)	10 (0.98%)	30 (1.00%)	22 (5.82%)	32 (3.89%)	9 (2.51%)	38 (4.55%)
GDM										
- No	446 (92.92%)	2,824 (96.98%)	244 (91.39%)	1,214 (96.58%)	953 (94.54%)	2,881 (96.68%)	340 (91.40%)	781 (96.30%)	324 (93.10%)	768 (95.17%)
- Yes	34 (7.08%)**	88 (3.02%)**	23 (8.61%)**	43 (3.42%)**	55 (5.46%)*	99 (3.32%)*	32 (8.60%)*	30 (3.70%)*	24 (6.90%)	39 (4.83%)
Macrosomia										
- No	421 (88.08%)	2,631 (90.23%)	233 (86.94%)	1,074 (84.77%)	834 (82.57%)	2,539 (85.09%)	304 (81.07%)	677 (82.76%)	277 (78.25%)	655 (79.49%)
- Yes	57 (11.92%)	285 (9.77%)	35 (13.06%)	193 (15.23%)	176 (17.43%)	445 (14.91%)	71 (18.93%)	141 (17.24%)	77 (21.75%)	169 (20.51%)

Note. BMI = body mass index; *M* = mean; *SD* = standard deviation; AMA = advanced maternal age; TWG = total weight gain during pregnancy; GDM = gestational diabetes mellitus

$^{**}p<0.001$

$^{*}p<0.05$

Race/ethnicity was consistently different between women of AMA and non-AMA within each of the Robson Groups (1-5), whereas macrosomia was not different between women of AMA and women of non-AMA within each of the Robson Groups 1-5. IPI, mean TWG, and preeclampsia were only significantly different between the two maternal age groups in Robson Groups 3, 2, and 1, respectively. Pre-pregnancy BMI was significantly different by AMA status among women in Robson Groups 4 and 5. GDM was also significantly different by AMA status within each of the Robson Groups 1-4 (Table 4.6).

Specific Aim 3: Explore the role of each Robson TGCS Group (1-4) as a mediator between AMA status and CB for women in midwifery care/settings:

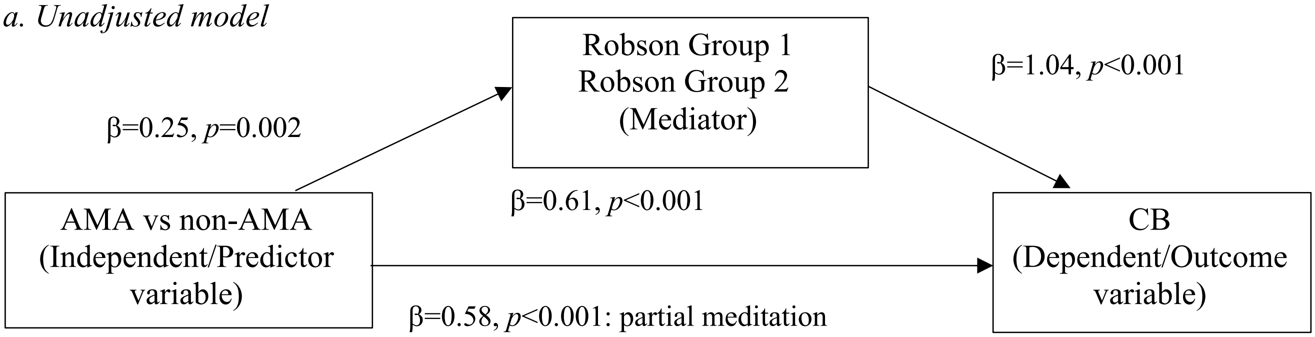
In this specific aim, multiple logistic regression, using the method defined by Baron and Kenny (1986), was used to find the mediation effect. Also, Sobel's test was used to understand the indirect effect of the mediator.

a. Among nulliparous women: Robson Group (1 & 2) as a mediator

Figure 4.2

Mediation Effect of Robson Group (1 vs. 2[10]) on the Association between AMA status and CB among Nulliparas

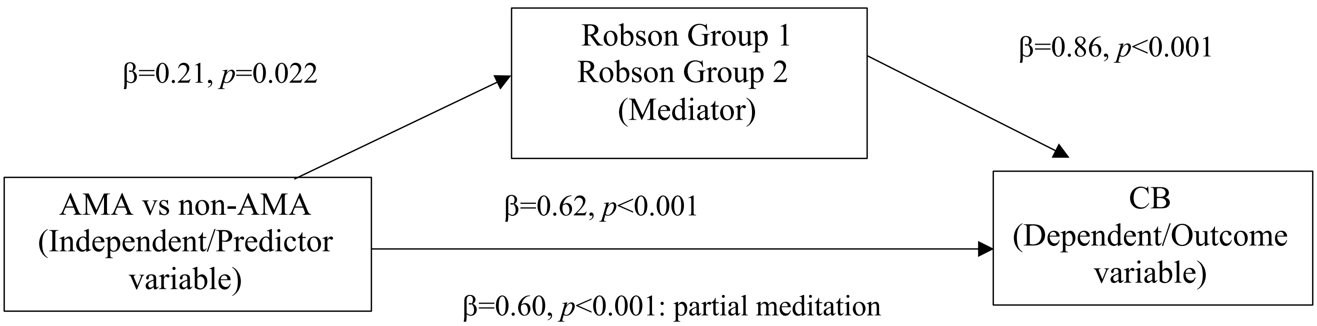
a. Unadjusted model



[10] group 2a: nulliparous women with labor induced and group 2b: nulliparous women with prelabor CB

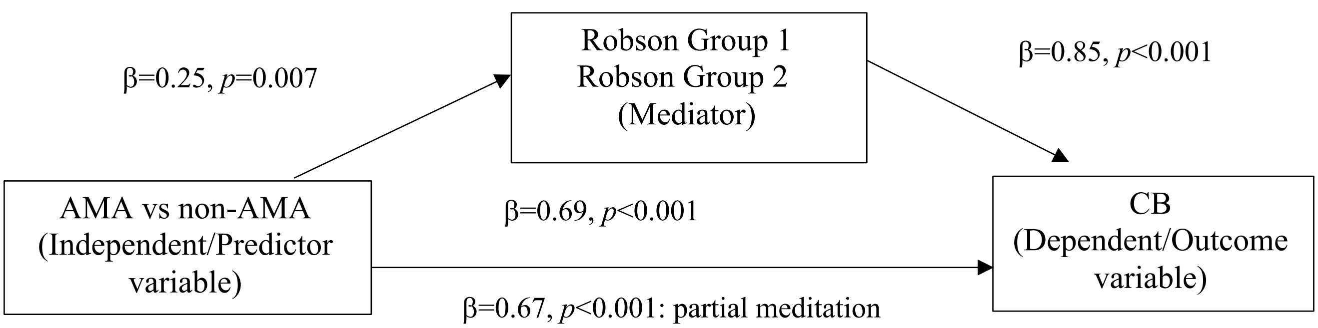
Proportion of total effect that is mediated: 0.09

b. Controlling for pre-pregnancy BMI, gestational age, and preeclampsia/eclampsia



Proportion of total effect that is mediated: 0.06

c. Controlling for pre-pregnancy BMI, gestational age, preeclampsia/eclampsia, and site



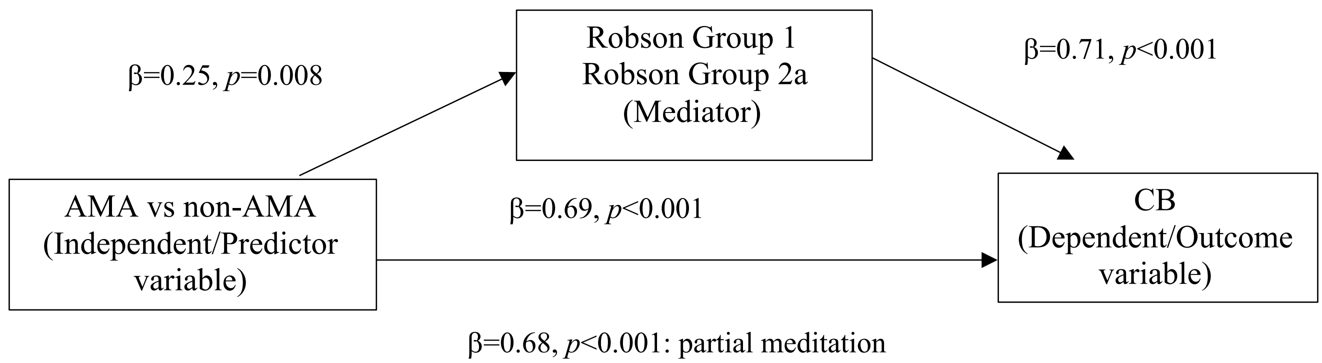
Proportion of total effect that is mediated: 0.06

Both unadjusted and adjusted models (Figures 4.2a; 4.2b) showed that Robson Group 2 mediated the association between AMA and CB. After controlling for pre-pregnancy BMI, gestational age, preeclampsia/eclampsia, and the practice site, both the total effect (AMA→CB) and direct effect (AMA→CB mediated by Robson Group) were statistically significant (Figure 4.2c). When Robson Group (1 vs. 2) variable was included in the model, the coefficient of AMA status on CB was reduced (*from* 0.69, 95% CI: 0.496-0.876 *to* 0.67, 95% CI: 0.475-0.861). The odds of indirect effect were 1.02 (95% CI: 1.015-1.021). This means that being nulliparous women of AMA compared to women of non-AMA, the odds of CB increase by a factor of 1.02 through Robson Group 2.

Figure 4.3

Mediation Effect of Robson Group (1 vs.2a[11]) on the Association between AMA and CB among Nulliparas

Controlling for pre-pregnancy BMI, gestational age, preeclampsia/eclampsia, and site



Proportion of total effect that is mediated: 0.05

The adjusted model was repeated comparing Robson Group 1 to Robson Group 2 excluding the prelabor CB (only nulliparous women with labor induced, 2a), and the results showing partial mediation through labor induction was replicated (Figure 4.3).

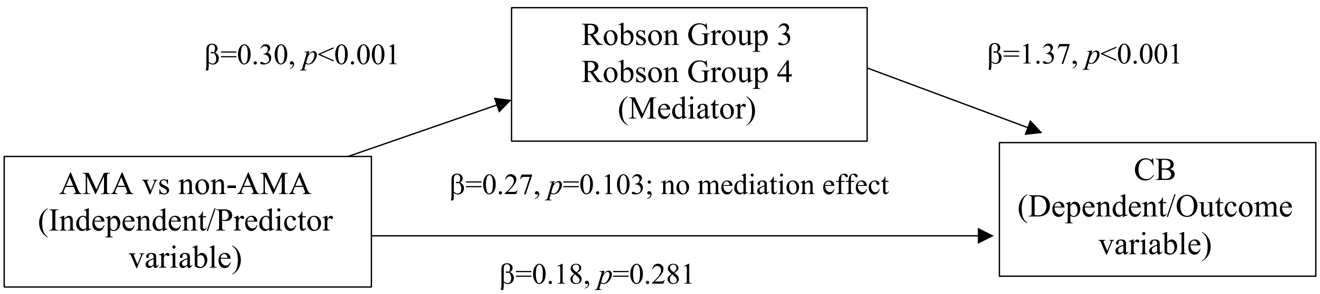
[11] Exclude nulliparous women with prelabor CB

b. Among multiparous women: Robson Group (3 & 4) as a mediator

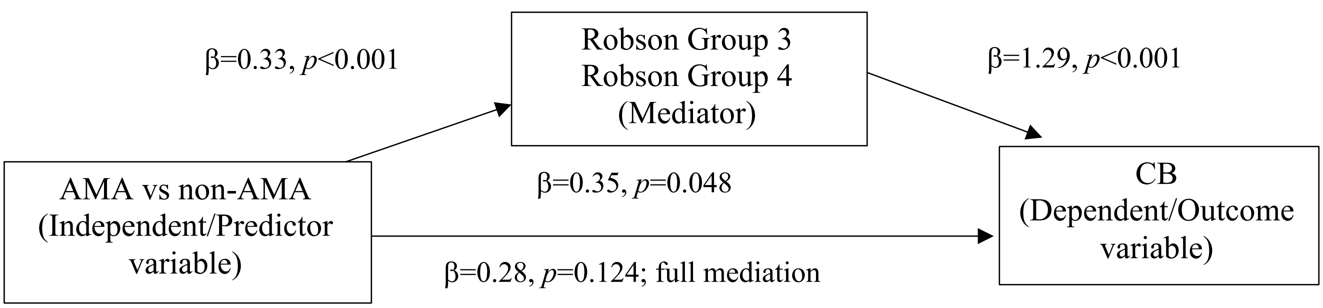
Figure 4.4

Mediation Effect of Robson Group (3 vs. 4[12]) on the Association between AMA and CB among Multiparas

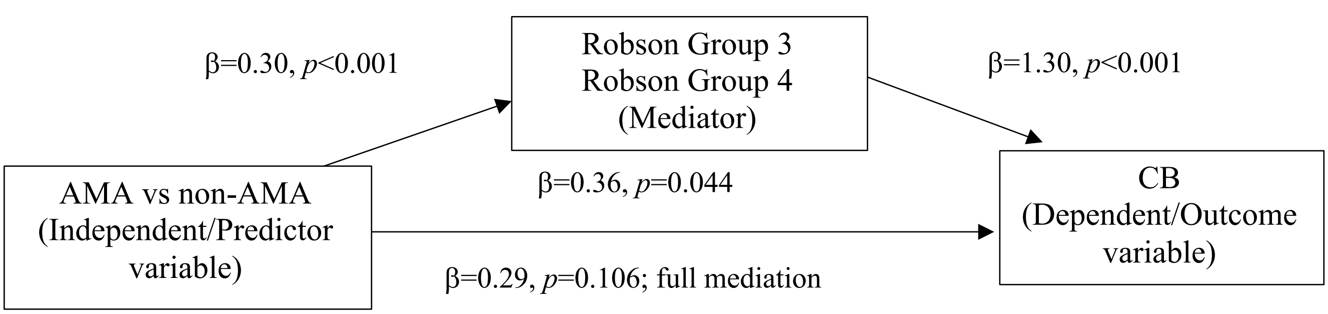
a. Unadjusted model



b. Controlling for pre-pregnancy BMI, gestational age, and preeclampsia/eclampsia



c. Controlling for pre-pregnancy BMI, gestational age, preeclampsia/eclampsia, and site



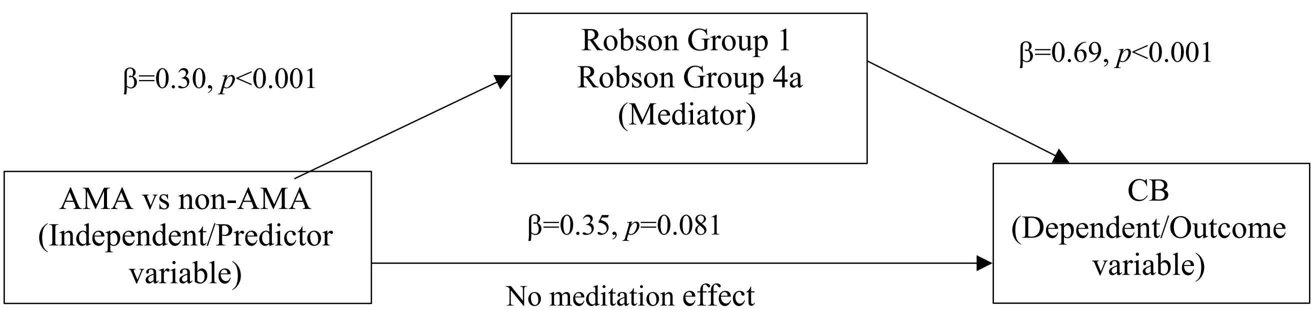
[12] Both 4a: multiparous women with labor induced and 4b: multiparous women with prelabor CB

In the unadjusted model (Figure 4.4 a), there was no mediation effect of Robson Group (3 vs. 4) presented through the association between AMA status and CB among multiparous women. After controlling for pre-pregnancy BMI, gestational age, preeclampsia/eclampsia, and the data collection/ practice site, total effect (AMA→CB) was significant with coefficient 0.361 (95% CI: 0.010-0.713). After adding Robson Group (3 vs. 4) variable, there was no longer a significant direct effect (AMA→CB controlling for Robson Group) with coefficient 0.293 (95% CI: -0.062 - 0.649). So, there was a full mediation effect presented. Therefore, being multiparous women of AMA compared to women of non-AMA, the odds of CB increase through Robson Group 4.

Figure 4.5

Mediation Effect of Robson Group (3 vs.4a[13]) on the Association between AMA and CB among Multiparas

Controlling for pre-pregnancy BMI, gestational age, preeclampsia/eclampsia, and site



The adjusted model was repeated comparing Robson Group 3 to Robson Group 4 excluding the prelabor CB (only 4a, multiparous women with labor induced), and the results showed no mediation effect through only labor induction among multiparas (Figure 4.5). This

[13] Exclude multiparous women with prelabor CB

result indicates that prelabor CB might serve a significant role as a mediator for the multiparous group.

The sensitivity analysis was conducted with or without the site variable in the adjusted models of both nulliparas (Figure 4.2) and multiparas (Figure 4.4) as there were differences in CB rates between two sites (Table 4.1). With or without site, there were slight differences in coefficients, but the mediation effect was still present in both models reported in Figure 4.2 for nulliparous women and Figure 4.4 for multiparous women.

CHAPTER FIVE

DISCUSSION

The overall objective of this study was to increase our understanding of the antecedents to CB in women of advanced maternal age (AMA) in midwifery care, including the identification of any differences between women of AMA and their younger counterparts. This final chapter highlights and discusses key findings from this study (Figure 5.1), and discuss how these findings confirm and/or shift current thinking of CB among women of AMA and how using the Robson 10-Groups Classification (TGCS) system contributes to deeper understanding of identifying antecedents and contributors to CB.

The chapter begins by reviewing general characteristics of women included in the study whose pregnancies resulted in a vaginal vs. cesarean birth (CB) and is followed by the significant key findings of the study. Then, the discussion is presented by a closer look at CB among women of AMA and further insight into the characteristics of this group of women. At the end of the chapter, the strengths and limitations of the study are presented. The chapter concludes with research and clinical implications and recommendations for further research, with a particular focus on how findings from this study inform our long-term goal to increase safe and appropriate access to CB worldwide, while continuing to support vaginal delivery and reduce medically unnecessary CB, especially among women of AMA.

Figure 5.1

Key findings

Characteristics of Women by Type of Birth

In this study, most women (~84%) gave birth vaginally, with only a small number (~16%) of women having a CB. This finding was not surprising since women receiving prenatal care from midwives are typically committed to vaginal delivery and have fewer medical risk factors and complications. In their 2014 series, the Lancet, reported that midwifery had the potential to reverse high morbidity and mortality of mothers and infants. Their analyses also found more spontaneous onset of labor and greater numbers of unassisted vaginal births when women were under the care of a midwife (Renfrew et al., 2014). These findings are consistent with a recent study examining the rate of CB in women in midwifery care in Ireland, which showed the CB rate was only 9.75% (Hanahoe, 2020). In the U.S., while Alabama has been one of the top nine states having the highest CB rates (~34-35%), Alaska has been one of top two states having the lowest CB rates since 2014 CB rate (~22-24%) (CDC, 2022), both of which are significantly higher than the Ireland rate; however, the U.S. statistics are not specific to midwifery-led care. It is interesting to note that ~27% of births in 2013 in Alaska were attended by midwives vs. only ~2 % in Alabama (The American College of Nurse-Midwives [ACNM], 2015). Although the CB rate of our sample was lower than other studies reporting CB rates in the U.S., it is important to note which characteristics in CB group differed from those of women in vaginal birth group, as it can increase our understanding of the antecedents to CB in women in midwifery care.

We examined women in our study whose pregnancies resulted in a vaginal vs. CB and found the following important differences.

Maternal Age

The mean age ± standard deviation of the total sample was 30.28 ± 5.37 years; however, more women of AMA (i.e., 35+ years of age) were found in the CB (25.62%) vs. the vaginal birth (21.48%) group. This finding is consistent with evidence from previous studies that similarly revealed that women of AMA had a higher rate of CB compared to their younger counterparts (Bayrampour & Heaman, 2010; Liabsuetrakul et al., 2019; Pinheiro et al., 2019;

Pukale et al., 2016; Rydahl et al., 2019; Sydsjö et al., 2019b; Verma et al., 2016; Walker & Thornton, 2020). Possible reasons for higher rate of CB among women of AMA include: poor cervical progression, longer duration of labor, labor dystocia, deterioration of myometrial contractility by advancing age, or even high use of cesarean on maternal request particularly for women of AMA (Pinheiro et al., 2019).

Site

This study recruited the participants from two geographically different states in the U.S. - Michigan and Oregon. The women in Michigan had higher rate of CB (16.96%) compared to 13.08% in Oregon. This finding parallels data for all provider types (e.g., physicians, midwives) from the Centers for Disease Control and Prevention (CDC, 2021), which identified the statewide rate of CB was higher in Michigan (32.5%) than in Oregon (28.8%). The reason for this difference is not well-understood, since both sites were university-based, metropolitan centers and the only major demographic difference between the two states is overall population, with Michigan having ~2.4 times higher statewide population, which should not be relevant. When considering maternal and neonatal characteristics contributing to CB among these settings (Table A1 in Appendix), we found that the sample from Michigan had higher portion of being overweight, obese, gaining weight excessively, and having a macrosomic baby. These characteristics were found to be the influences of CB in the current study. Moreover, the practice of nurse-midwives in Michigan requires a collaborative agreement with a physician, while the practice of nurse-midwives in Oregon is independent, which can fully support vaginal birth (ACNM, 2015).

Gestational Age (GA)

In this study, women with CB had slightly longer pregnancies (40.05 ± 1.62 for CB vs. 39.82 ± 1.39 for vaginal births). This is an interesting clinical finding in that longer GA is correlated with higher infant weight, which can pose difficulties for successful vaginal birth. It may also reflect larger practice guidelines, such as the statement from the American College of Obstetricians and Gynecologists (ACOG) that non-medically indicated delivery, including CB (as well as inductions of labor and cervical ripening), should not occur before *full* term (39 weeks and 0 days gestation) and neonatal morbidity/mortality rates are higher among neonates born during the *early* term (before 39 weeks of gestation) compared to those born during the full term (ACOG, 2013).

Interpregnancy interval (IPI)

Examination of interpregnancy interval (IPI) is an additional variable to explore within the subsample of *multiparous* women as it may be a potentially modifiable risk factor. For this study, we examined short vs. recommended (or optimal) IPI intervals. The literature suggests there is an increased risk of adverse outcomes with intervals less than 18 months, with risk increasing with intervals less than 6 months. There are some studies showing that long IPI (e.g., greater than 5 years) potentially influenced higher CB; however, our databases did not include this variable. In our study, we found that more women in vaginal birth group had shorter IPIs (13.34%) than those in the CB group (10.33%). This finding is novel, in that this variable is typically not explored in terms of vaginal vs CB outcomes; however, it may not be clinically helpful. We found only one study (Bassey & Johnson, 2019), which reported women with short IPI were about 1.4 times higher in their CB group vs. women within the recommended or optimal IPI range, but the difference was not statistically significant. Instead, the literature focuses more on the types of adverse outcomes associated with *prior* rather than current vaginal vs CB. For example, one of the consequences of a short IPI in women with a prior CB is an increased risk for uterine rupture. Further, women who have a prior stillbirth or abortion, for example, might want to conceive again with minimal delay, as may women of AMA, who feel their reproductive years are waning. While IPI is seen as a potentially modifiable variable, there are clearly a variety of contributing factors for clinicians to consider when weighing risks/benefits of the optimal IPI.

Pre-pregnancy Body Mass Index (BMI)

Obesity is considered a risk factor for CB (Porreco & Sheen, 2022) as the risk for developing complications during the childbearing period (i.e., pre-eclampsia, GDM, and pulmonary embolism). Importantly, these complications increase with increasing severity of obesity. It has been suggested that the increase in CB rates appear to parallel with the 'obesity epidemic'(Lim et al., 2022). It was therefore not surprising we found that there were more women with a pre-pregnancy BMI in the overweight or obese category in the CB group than in the vaginal delivery group. This finding is also consistent with other recent studies (e.g., Chen et al., 2020; Munim & Maheen, 2012). While some of the pregnancy-related complications for obese women (e.g., hypertension, gestational diabetes, blood clots) often lead to a risk for CB, there is also evidence that a higher pre-pregnancy BMI is associated with slower labor progress (Carlson, 2019). Pre-pregnancy BMI continues to be an important variable as evidence continues to emerge, including a recent study that identified the incidences of macrosomia, postpartum hemorrhage, dystocia, CB, and gestational diabetes increased significantly with the increase of pre-pregnancy BMI (Zhang et al., 2023).

Total weight gain (TWG)

Besides a higher pre-pregnancy BMI, increased total weight gain (TWG) is also a known predictor of CB (Dude et al., 2021; Goldstein et al., 2017; Kominiarek et al., 2018). It was not surprising, therefore, that we also found that there were more women with excessive TWG in CB group (63.57%) than in the vaginal birth group (49.99%). One potential reason for an increase in CB in this group might be related to increase in fetal weight (i.e., LGA; macrosomia), which often impacts mode of birth. However, fetal size does not always parallel TWG, meaning there are other considerations, including studies examining the timing of the weight gain (e.g., during 2nd trimester vs. 3rd trimester vs. across entire pregnancy) as better predictors (Feng et al., 2019; Zhang et. al., 2023). TWG is also seen as a potentially modifiable variable that can reverse some of these risks (Zhang et al., 2023), making it clinically relevant.

Preeclampsia/Eclampsia

When preeclampsia/eclampsia occur, both mother and fetus are monitored closely. If either deteriorates, the decision if made to deliver, which often results in an emergency/unplanned CB (Pacher et al., 2014; Shen et al., 2017). Therefore, we expected to find more women in CB group having preeclampsia/eclampsia (7.75%) when compared to the vaginal birth group (3.18%). This finding is also consistent with the current literature, as delivery prevents maternal mortality/morbidity from preeclampsia/eclampsia. Our findings, in terms of percentages, are consistent with the recent March of Dimes (2023) report that preeclampsia affects between 5-8% of pregnancies in the U.S. Preeclampsia and eclampsia are part of the spectrum of hypertensive disorders that can occur during pregnancy (HDP). At the mild end of the spectrum is gestational hypertension, which was not tracked in the data bases used for our study. Going forward, databases need to include the entire spectrum of HDP, not only because

HDP continues to increase in the U.S., but also because the highest prevalence of HDP appears to be in women of AMA (Boulet et al., 2020; CDC, 2022b), which may be an important antecedent to identify.

Macrosomia

Our study looked at macrosomia based on newborn weight at delivery, rather than fetal weight estimates (from prenatal ultrasound), which are less precise. Our findings showed that newborn macrosomia was more common in CB group (20.33%) compared to the vaginal birth group (13.01%). This finding supports similar evidence from previous studies (Beta et al., 2019; Olokor et al., 2015; Said & Manji, 2016). The rationale for this association is that newborns with macrosomia are at higher risk for shoulder dystocia, which can increase the decision for prophylactic CB (Araujo Júnior et al., 2017). Macrosomia has also been associated with a prolonged first/second stage of labor or arrest of descent, which can also be an indication for CB. AMA is considered as an important risk factor for macrosomia (Dai et al., 2019). It is probably because women of AMA are typically more likely to have GDM which is associate with having a macrosomic baby (Kc et al., 2015).

Cesarean Birth among Women of Advanced Maternal Age (AMA)

The overall CB rate for the total sample was 15.81%, which was lower than published CB rates in Oregon (28.8%) and Michigan (32.5%) (CDC, 2022); the lower CB rate was expected since our data were collected in midwifery care setting. Women of AMA had significantly higher CB rate compared to women of non-AMA (18.30% for women of AMA vs. 15.10% non-AMA, $p<0.001$). This finding is aligned with evidence from previous studies (Bayrampour & Heaman, 2010; Liabsuetrakul et al., 2019; Pinheiro et al., 2019; Pukale et al., 2016; Rydahl et al., 2019; Sydsjö et al., 2019b; Verma et al., 2016; Walker & Thornton, 2020).

To take a closer look at CB in our data, we first subdivided the sample using the Robson 10-Group Classification System to see which groups were the main contributors to CB among both women of AMA and women of non-AMA.

Main Contributors to CB among Women of AMA

When examining the total sample, we found that Robson Group 2 (nulliparous women with either labor induced or prelabor CB) was the largest contributor to CB. This finding is consistent with a recent study investigating CB in midwifery care in Ireland (Hanahoe, 2020). A potential reason for this association might be induction of labor is the intervention that midwives can independently perform which was mentioned as an increase in risk for CB in prior studies (Vecchioli et al., 2020; Zenzmaier et al., 2017). It is increasingly apparent that exploring the variables leading to the induction of labor may provide further insights.

When looking specifically at women of AMA, we found that Robson Group 5 (multiparous women with previous CB) was the main contributor to CB among women of AMA, while the second and third largest contributors were Robson Groups 2 and 1, respectively. This finding also aligns with an earlier study examining CB among women of AMA in a Canadian hospital (Janoudi et al., 2015). As noted earlier, women of AMA had a higher CB rate compared to their younger counterparts in our study. One rationale for this specific finding is that vaginal birth after cesarean (VBAC) requires a trial of labor after cesarean (TOLAC), which is an accepted and generally safe practice; however, it also has serious potential complications (e.g., uterine rupture or uterine dehiscence and associated maternal, neonatal morbidity) that women of AMA may not want to risk.

While Robson Group 5 was the largest contributor to CB among women of AMA, it is interesting to know that Robson Group 1 (nulliparous women with spontaneous labor) was the largest contributor to CB among women of non-AMA. When looking at non-AMA samples, women in Robson Group 1 were the majority (31.53%) of overall non-AMA sample, and women in this group generally have more difficulty achieving vaginal birth compared to multiparous women due to slower cervical progression in active phase (Ashwal et al., 2020). In addition, induction of labor in nulliparous women - typically having a rigid and nearly closed cervix - can potentially contribute to CB due to unfavorable/unripen cervix (Sutter Health, 2023). This may be potential explanation for higher CB among women of non-AMA in Robson Groups 1 and 2.

CB, AMA status, and Parity

We also examined if there was an interaction effect of AMA status and parity to understand differences in risk for CB between AMA status by parity. After controlling for prenatal predictors linked to CB (gestational age, pre-pregnancy BMI, fetal presentation, preeclampsia, and geographic site) the interaction effect between AMA and parity on CB was significant. Among multiparous women, there was very little difference in CB rates between women of AMA and non-AMA. However, among nulliparous women, there was a significant difference in CB rates between AMA and non-AMA. This finding is consistent with the evidence from a Danish study which also found a greater risk for CB by AMA status among nulliparous women compared to those of multiparous women (Rydahl et al., 2019). In our study, *nulliparous* women (aged 35-39 years) had twice higher risk for CB (aOR: 2.18; 95%CI: 2.11–2.26) and women aged ≥40 years had triple the risk (aOR 3.64; 95%CI: 3.41–3.90) compared to women aged <30 years. For *multiparous* women, women aged 35-39 years had 1.56 higher risk for CB (aOR: 1.56; 95%CI:1.53-1.60), and for those aged ≥ 40 years had twice higher risk for CB compared to women aged <30 years (aOR: 2.02; 95%CI:1.92–2.09).

One possible reason for the interaction effect between age, parity, and CB is that multiparous women (without a prior CB) typically have a shorter duration of labor at every stage resulting in less difficulty of vaginal birth due their prior birth experience compared to nulliparous women, which can eliminate the need for CB due to prolonged labor, cervical arrest, etc. Other reasons may be the specific characteristics of women of AMA influencing CB, which are discussed in the following paragraphs.

Characteristics of Women of Advanced Maternal Age (AMA) Influencing Cesarean Birth (CB)

Of the seven characteristics influencing CB tested in our study, four were significantly different by AMA status. The first two - gestational diabetes mellitus (GDM) and newborn macrosomia – were found more often in women of AMA, which is consistent with the literature. In contrast, race/ethnicity and excessive TWG findings differed. Each is discussed below.

Race/ethnicity

Across entire sample, non-Hispanic White women were more common among women of AMA (80.60% AMA vs. 74.03% non-AMA). In contrast, non-Hispanic Black women were more commonly non-AMA (3.99% AMA vs. 9.98% non-AMA). This may imply that non-Hispanic White women are more likely to delay childbearing compared to non-Hispanic Black, which is also supported by the national vital statistics report for 2019 that illustrated that mean age of mothers at first birth among non-Hispanic White was older than mean age of mothers at first birth among non-Hispanic Black (27.8 years for non-Hispanic White vs. 25.2 years for non-Hispanic Black) (Osterman et al., 2021). The potential reasons might be non-Hispanic White women opt for highly-effective methods of contraception and/or have a planned pregnancy compared to non-Hispanic Black (Sweeney & Raley, 2014), but that is speculative. Although the previous studies showed non-Hispanic Black had the highest CB rates compared to others (Stark et al., 2021; Valdes, 2020), our study found that there was no difference in CB rates by race/ethnicity. We speculate that this finding might be because all births of our sample were attended by midwives where they fully respect an individual woman through the highest quality care as well as being in a crucial role to connect with multidisciplinary teamwork and community settings to provide an optimal care to women (The Lancet, 2014) regardless of patients' race/ethnicity (LoGiudice, 2022).

Total weight gain during pregnancy (TWG)

The Institute of Medicine has published recommendations on optimal TWG according to a woman's pre-pregnancy BMI. Abnormal TWG (either insufficient or excessive) is related to adverse birth outcomes. Our findings showed that the average TWG of women of AMA was significantly lower than average TWG of women of non-AMA, and TWG differed by AMA status which women of AMA were less common in excessive TWG group compared to women of non-AMA. This finding supports the evidence from previous study comparing TWG by maternal age, which found that women aged 20-29 years were significantly more likely to gain over 16 kgs (≈35 lbs) during pregnancy compared to women of AMA (Bayrampour & Heaman, 2010). Additionally, this finding is similar to that of Lewandowska et al. (2020) who found women aged less than 35 years old significantly gain more weight compared to women aged ≥ 35 year. This can reflect that excessive TWG might not be a characteristic that influences women of AMA to have higher CB, even though TWG itself has a potential to increase a chance of CB.

Gestational Diabetes Mellitus (GDM)

Our study found that women of AMA developed GDM more frequently (6.81% for women of AMA vs. 3.46% for women of non-AMA, $p<0.001$). This finding is consistent with previous studies and meta-analysis, which revealed that women of AMA more likely to develop GDM during pregnancy (Li et al., 2020; Mehari et al., 2020; Shams et al., 2021). Further, this finding is not surprising given the increased risk for metabolic syndrome in later adulthood which is a cluster of condition including high blood pressure, high triglyceride/cholesterol, elevate fat, and high blood sugar related to insulin intolerance (National Heart, Lung, and Blood Institue, 2022). Prior studies have also reported that GDM increased the odds of CB (Boriboonhirunsarn & Waiyanikorn, 2016; Gorgal et al., 2012); however, while we found a higher proportion of GDM in the CB group, it was not statistically significant in the overall sample.

Macrosomia

Our study showed that newborn macrosomia was also more prevalent among women of AMA (16.18% for women of AMA vs. 13.59% for non-AMA. This finding supports the evidence from previous studies, which found that risk of having a macrosomic infant increased with maternal age or AMA status (Li et al., 2015; S. Wang et al., 2020). Advancing age is also associated with having GDM, which is commonly linked to newborn macrosomia as well (Kc et al., 2015).

Differences in characteristics between women of AMA and women of non-AMA within a Robson Groups 1-5

Even though race/ethnicity, TWG, GDM, and rates of macrosomia differed by AMA status across entire sample, not all of these characteristics differed by AMA status once the women were examined by Robson Group. When controlling for parity, mode of labor onset, or history of CB, the differences in IPI, pre-pregnancy BMI, TWG, preeclampsia/eclampsia, GDM, and macrosomia by AMA status changed, with only race/ethnicity was still significantly different between maternal age groups within same Robson Group, while macrosomia was not different by AMA status within same Robson Group. And, IPI, pre-pregnancy, mean of TWG, preeclampsia/eclampsia, and GDM were significantly different by AMA status in some Robson Groups.

The Mediation Effect of Robson Group on the Relationship Between Advanced Maternal Age (AMA) Status and Cesarean Birth (CB)

This study found that Robson Groups 2 and 4 (women with labor induced or prelabor CB) mediated the relationship between AMA status and CB among nulliparas and multiparas, respectively. This means that induction of labor or prelabor CB is an intervention through the relationship between AMA status and CB in both nulliparous and multiparous women. It illustrates that women of AMA are more often recommended to have either labor induced or prelabor CB which more often leads to CB. As previous studies mentioned, maternal age may prompt recommendations to have labor induced or women of AMA might experience greater complication(s) during pregnancy leading to induction of labor/CB before their labor spontaneously begins (Glick et al., 2021; Howell & Blott, 2021; Spiegelman et al., 2017; Walker & Thornton, 2020). And, the induction of labor potentially leads women to CB (Vecchioli et al., 2020; Zenzmaier et al., 2017).

However, when we excluded prelabor CB group and tested if only induction of labor was a mediator between AMA status and CB, we found that induction of labor was a mediator sitting between the relationship between AMA and CB only among nulliparous women. It was not found in multiparous group. This finding indicated that prelabor CB plays more mediating role between AMA status and CB among multiparous women and it may reflect that having pregnancy complications prompting CB before labor among multiparous women of AMA more put them to give birth by CB compared with having labor induced.

Study Strengths and Limitations

The primary strength of this study is that we examined the antecedents to CB in women of advanced maternal age (AMA) in *midwifery-led* care. Those receiving care from midwives are typically committed to vaginal birth and minimal or non-intervention during birth, meaning that CB is performed only when medically needed. To our knowledge, this is the first study that examined antecedents to CB by Robson Groups, which provided nuanced understanding as well as highlighting that the type of provider affects CB rates. Another strength was that we were able to collect the data from two different states - Oregon and Michigan - which make our sample more diverse in that midwifery practice guidelines differ in these states, but the midwives have a similar approach to care and criteria/indication for CB. Finally, we were fortunate to have a very large sample size, which was sufficient to conduct the robust statistical analyses needed for addressing our aims.

However, this study had some limitations. We did not have a sample in Robson Group 8 (multiple gestation) and Robson Group 9 (women with fetal transverse lie), which we did not expect to see in Midwifery care. Nevertheless, we could not see the distribution of women AMA in these two groups. This study was based on data from women in large university hospitals (generally serving urban and suburban populations), which might not be generalizable to women receiving care from other types of hospitals. Additionally, there is the potential for errors in data recording and missing data especially for pre-pregnancy BMI. Lastly, the IPI variable has only two categories which are normal/optimal and short IPI. There was no long IPI category, so we could not explore if multiparous women with long IPI are more likely to end up with a vaginal or CB.

Clinical Implications

Implement Greater Use of Trial of Labor after Cesarean (TOLAC)

To reduce high CB rate from women in Robson Group 5, one approach is implementation of TOLAC (trial of labor for women with prior CB), especially for women of AMA, with the goal of vaginal birth after cesarean (VBAC). Although there is a possible risk during/after VBAC of uterine rupture, the incidence of uterine rupture is less than 1% and the successful VBAC is over 70% (Center for Women's Health, OHSU, n.d.). Therefore, TOLAC should receive considered attention for multiparous women with history of CB.

Reduce Primary Cesarean Births

Given that Robson Group 5 was the primary contributor to CB among women of AMA and nulliparous women of AMA are more likely than their multiparous counterparts to have a CB, attention to primary Cesarean prevention is warranted. The American College of Obstetricians and Gynecologists and Society for Maternal-Fetal Medicine consensus statement suggested safe reduction of primary CB, including: a) revisiting the definition of labor dystocia, b) standardizing interpretation of fetal heart rate, c) supporting non-medical intervention during labor, d) external cephalic version among women with fetal breech presentation, and e) trial of labor for twin pregnancy when the first twin is in the cephalic presentation (Caughey et al., 2014).

Delayed Admission until Active Labor

When giving birth vaginally, women normally go through labor stages 1 – 4. The initial stage includes latent and active phases depended on cervical progression. The latent phase normally takes longer time than the active phase, and the study showed that women admitted during the latent phase had higher CB rate compared to those admitted during the active phase (Tilden et al., 2015). To reduce primary CB especially among nulliparous women, they should be admitted during the active phase.

Prevent GDM

Although GDM occurs during pregnancy period and usually resolves after birth, having GDM leads to several adverse birth outcomes, especially macrosomic newborns. We found that GDM was more common in women of AMA and that Robson Group 5 had the highest proportion of women with GDM (5.45%) (Table 4.5). To prevent GDM, providers need to emphasize exercise and diet, especially in women of AMA who are overweight/obese at the pre-pregnancy period, beginning of their pregnancies and/or those with a family history of diabetes or a prior history of GDM (National Center for Biotechnology Information, 2020).

Perform Induction of Labor only if Medically Needed

According to the findings that we found both Robson Group 2 and Robson Group 4 were the mediators between AMA status and CB among nulliparas and multiparas, respectively. Although induction of labor can be implemented to prevent stillbirth among women of AMA, the trade-off is an increased risk for CB and women of AMA should be counseled around this point through a process of shared decision making. Therefore, induction of labor or prelabor CB should be utilized if needed or almost post term. Expectant management which is a management decision should be considered as an alternative to labor induction in cases of low-risk pregnancy. And, when providers are waiting for a woman to have spontaneous labor, they need to monitor fetal health and maternal health often.

Apply Robson 10-Group Classification System (TGCS)

Interpretation of rising CB rates in the U.S. and worldwide would benefit from including Group designations. For example, specifically examining the characteristics of women in each Robson Group may be especially helpful in clinical settings/quality assessment in the development of targeted and tailored interventions for all women, but especially for women of AMA.

Recommendations for Further Research

Recommendations for further research based on the findings of the study include: 1) examine factors influencing successful VBAC among women of AMA in Robson Group 5; 2) compare CB rates between nulliparous women of AMA with labor induced and those with expectant management in midwifery care; and 3) examine indicators for CB among multiparous women of AMA with prelabor CB (groups 2b and 4b) in order to know either maternal request or any complications prompting them to CB.

Recommendations for further research based on the limitations of the study include: 1) recruit sample from non-university hospitals; 2) focus on under-represented racial/ethnic minorities; 3) observe and compare weight between women of AMA and women of non-AMA within/across trimesters; 4) classify IPI of multiparous women into three categories which are short IPI, normal/optimal IPI, and long IPI; 5) examine IPI and modes of birth among nulliparous women who have prior pregnancy loss (e.g., miscarriage); and 6) examine other factors (besides GDM) which predispose macrosomia among women of AMA.

Recommendations for further research for advancing science include: 1) test the mediator effect of onset of labor on the relationship between AMA status and CB among women in Robson Group 5; 2) investigate social economic status and/or other social determinants of health and emerging variables (e.g., fetal sex); and 3) specifically focus on CB rate of women of AMA during the COVID-19 pandemic.

Conclusion

This secondary data analysis was to add to the body of knowledge of antecedent events and/or indicators that result in CB in women of AMA in nurse-midwifery care specifically focusing on any differences in women of AMA compared to their younger counterparts by using Robson TGCS. The findings of this study indicate that the largest contributor/antecedent to CB of each maternal age group was different, and Robson Groups 5 and 1 were the largest contributor to CB among women of AMA and non-AMA, respectively. CB rates of both AMA and non-AMA groups were significant different with higher among women of AMA. The relationship between AMA status and CB was mediated by induction of labor/prelabor CB. Moreover, when comparing and contrasting the differences in maternal and neonatal characteristics between AMA status, the characteristics potentially leading women of AMA to have CB were GDM and macrosomia. These insights from the study can provide the understanding of rising CB rates in women of AMA and facilitate development of targeted and tailored interventions.

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APPENDIX

Appendix A: Overall Sample

Table A1

Sample Characteristics

Variables	Total	Oregon	Michigan	*p*-value
Sample size	11,951	3,667 (30.68%)	8,284 (69.32%)	
Advanced Maternal Age (AMA)				0.001
- AMA	2,645 (22.13%)	2,161 (21.48%)	484 (25.62%)	
- Non-AMA	9,306 (77.87%)	7,901 (78.52%)	1,405 (74.38%)	
Age (years)				
M ± *SD* (year)				
- Whole sample	30.28±5.37	31.52±5.11	29.73±5.39	<0.001
- AMA	37.32±2.26	37.36±2.22	37.30±2.28	0.508
- Non-AMA	28.28±4.17	29.16±3.88	27.95±4.24	<0.001
Gestational age *M* ± *SD* (weeks)	39.86±1.43	40.02±1.32	39.78±1.47	<0.001
Race/Ethnicity				<0.001
- White	8,934 (75.49%)	2,674 (72.94%)	6,260 (76.63%)	
- Black	1,024 (8.65%)	96 (2.62%)	928 (11.36%)	
- Asian	533 (4.50%)	199 (5.43%)	334 (4.09%)	
- Latino	954 (8.06%)	597 (16.28%)	357 (4.37%)	

Variables	**Total**	**Oregon**	**Michigan**	***p*-value**
- Native American & American Indian	35 (0.30%)	19 (0.52%)	16 (0.20%)	
- Middle Eastern	259 (2.19%)	-	259 (3.17%)	
- Hawaiian & Pacific Islanders	26 (0.22%)	26 (0.71%)	-	
- Identified by two or more/others	70 (0.59%)	55 (1.50%)	15 (0.18%)	
Interpregnancy Interval				<0.001
- Normal/Optimal	5,750 (86.96%)	1,276 (67.80%)	4,474 (94.59%)	
- Short	862 (13.04%)	606 (32.20%)	256 (5.41%)	
Pre-pregnancy BMI				
$M \pm SD$ (kg/m^2)	26.03 (5.74)	25.98 (5.62)	26.06 (5.74)	0.715
- Underweight	235 (2.19%)	50 (1.41%)	185 (2.59%)	<0.001
- Normal weight	5,377 (50.22%)	1,873 (52.67%)	3,504 (49.00%)	
- Overweight	2,888 (26.97%)	922 (25.93%)	1,966 (27.49%)	
- Obese	2,207 (20.61%)	711 (19.99%)	1,496 (20.92%)	
TWG				
$M \pm SD$ (lbs)	32.01±13.52	30.62±12.53	32.67±13.92	<0.001
- Insufficient	1,521 (15.33%)	584 (16.66%)	937 (14.60%)	<0.001
- Optimal	3,244 (32.70%)	1,216 (34.69%)	2,028 (31.61%)	
- Excessive	5,156 (51.97%)	1,705 (48.64%)	3,451 (53.79%)	

Variables	Total	Oregon	Michigan	*p*-value
Preeclampsia				0.053
- No	11,472 (96.10%)	3,505 (95.58%)	7,967 (96.32%)	
- Yes	466 (3.90%)	162 (4.42%)	304 (3.68%)	
GDM				<0.001
- No	11,271 (95.79%)	3,404 (92.83%)	7,867 (97.14%)	
- Yes	495 (4.21%)	263 (7.17%)	232 (2.86%)	
Macrosomia				0.023
- No	10,160 (85.84%)	3,167 (86.93%)	6,993 (85.35%)	
- Yes	1,676 (14.23%)	476 (13.07%)	1,200 (14.65%)	
Type of birth				<0.001
- Vaginal birth	10,062(84.19%)	3,161 (86.20%)	6,901 (83.31%)	
- Cesarean birth	1,889 (15.81%)	506 (13.80%)	1,383 (16.69%)	

Note. BMI = body mass index; *M* = mean; *SD* = standard deviation; AMA = advanced maternal age; TWG = total weight gain during pregnancy; GDM = gestational diabetes mellitus

CB rate among women in Michigan (MI) setting was higher than CB rate among women in Oregon (OR) (16.69% for MI vs. 13.80% for OR, $p<0.001$). Non-Hispanic black women were more represented in MI sample (11.36% for MI vs. 2.62% for OR). In addition, women in the MI sample more frequently found to have abnormal (lower/higher) pre-pregnancy BMI (underweight: 2.59% for MI vs. 1.41% for OR; overweight: 27.49% for MI vs. 25.93% for OR; obese: 20.92% for OR vs. 19.99% for MI) (48.41% for MI vs. 45.92% for OR, $p<0.001$), excessive weight gain during pregnancy (53.79% for MI vs. 48.64% for OR), or had a macrosomic newborn (14.65% for MI vs. 13.07% for OR, $p=0.023$) compared to women in OR.

However, mean age and proportion of women of AMA in OR were higher than mean age and proportion of women of AMA in Michigan (Mean age of women in OR was 31.52±5.11 vs. Mean age of women in MI was 27.95±4.24, p<0.001, and the proportion of women of AMA in OR was 29.15% vs. proportion of women of AMA in MI was 19.02%, p<0.001). Moreover, mean of gestational age of women in OR was higher than gestational age of women in MI (40.02±1.32 for OR vs. 39.78±2.28 for MI, p<0.001). Additionally, women in OR had higher prevalence of GDM comparing to women in MI (7.17% for women in OR vs. 2.86% for women in MI, p<0.001).

Appendix B: Tables and Figure related Aim 1

Table B1

Multivariable Logistic Regression Analyses of Factors associated with CB

Variables	**Unadjusted Odds Ratio (95% CI)**	**Adjusted Odds Ratio*** (95% CI)**	**Adjusted Odds Ratio**** (95% CI)**
AMA status	1.26** (1.12-1.41)	1.69** (1.48-1.93)	1.95** (1.62-2.34)
Parity (multiparous vs. nulliparous)	0.37** (0.33-0.40)	0.34** (0.32-0.38)	0.36** (0.31-0.42)
AMA##Parity	0.70* (0.55-0.88)	-	0.75* (0.56-0.95)
Gestational age (wks)	1.13** (1.09-1.18)	1.19 ** (1.14-1.25)	1.19** (1.14-1.25)
Pre-pregnancy BMI	1.05** (1.04-1.06)	1.06** (1.05-1.07)	1.06** (1.05-1.07)
Site (Michigan vs. Oregon)	1.26** (1,12-1,40)	1.37** (1.21-1.54)	1.38** (1.22-1.56)

Variables	Unadjusted Odds Ratio (95% CI)	Adjusted Odds Ratio***(95% CI)	Adjusted Odds Ratio**** (95% CI)
Fetal presentation (non-cephalic vs. cephalic)	71.90** (41.60-124.26)	81.56** (45.42-146.82)	80.69** (44.91-144.96)
Preeclampsia/eclampsia	2.55** (2.09-3.13)	2.23** (1.77-2.81)	2.23** (1.77-2.80)

Note. AMA=Advanced maternal age; BMI= body mass index; CI=Confidence Interval
***p<0.05, **p<0.001**
*****Adjusted for parity, gestational age, pre-pregnancy BMI, site, fetal presentation, preeclampsia**
****** Adjusted for gestational age, pre-pregnancy BMI, site, fetal presentation, preeclampsia, and the interaction between AMA and parity**

Figure B1

Interaction between AMA status and Parity on CB

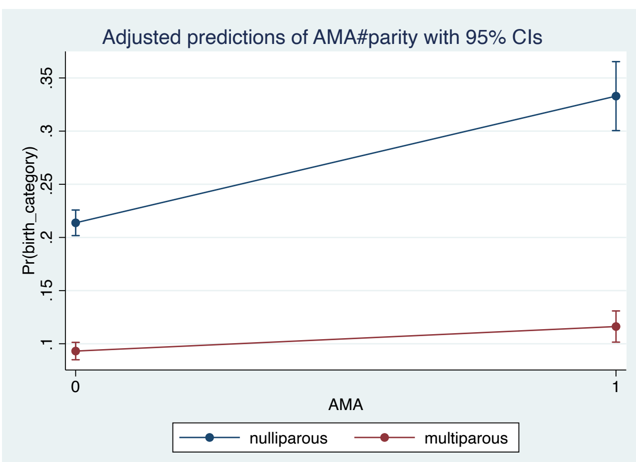


Table B2

The Adjusted Logistic Regression Analyses of Factors associated with CB

Variables	Adjusted Odds Ratio*** (95% CI)	Adjusted Odds Ratio**** (95% CI)
AMA status	1.60** (1.41-1.83)	1.82** (1.51-2.18)

Variables	Adjusted Odds Ratio*** (95% CI)	Adjusted Odds Ratio**** (95% CI)
Parity	0.35** (0.31-0.39)	0.37** (0.33-0.43)
AMA##Parity	-	0.77 (0.56-1.00)
Gestational age	1.18** (1.13-1.24)	1.18** (1.13-1.23)
Pre-pregnancy BMI	1.06** (1.05-1.07))	1.06** (1.05-1.07)
Fetal presentation	84.05** (46.83-150.89)	83.26** (46.41-149.36)
Preeclampsia/eclampsia	2.18** (1.73-2.75)	2.17** (1.72-2.74)

Note. AMA=Advanced maternal age; BMI= body mass index
***p<0.05, **p<0.001**
*****Adjusted for parity, gestational age, pre-pregnancy BMI, fetal presentation, preeclampsia**
****** Adjusted for gestational age, pre-pregnancy BMI, fetal presentation, preeclampsia, and the interaction between AMA and parity**

In unadjusted model, women of AMA were 1.26 times higher in CB rates comparing to CB (OR:1.26; 95% CI: 1.12-1.41). In adjusted model, we controlled for variables related to CB which are known as predictors including parity, gestational age, pre-pregnancy BMI, fetal presentation, preeclampsia, sites, and the interaction between AMA and parity. We found that women of AMA were about two times higher in CB rates comparing to women of non-AMA (aOR:1.95; 95%CI: 1.62-2.34) (Table B1). The interaction effect between AMA and parity on CB was presented in this model. Among multiparous women, there was very little difference in

CB rates between women of AMA and women of non-AMA. However, among nulliparous women, there was a big difference in CB rates women of AMA and women of non-AMA, meaning that nulliparous women of AMA were more likely to give birth by CB comparing to nulliparous women of non-AMA.

The sensitivity analysis was also done by running another model without site variable which showed significant differences in CB rates (Table B2). Of particular note, women of AMA remained twice as likely to have a CB compared to women of non-AMA (aOR:1.82; 95% CI: 1.51-2.18). However, the interaction between AMA and parity were no longer presented (p=0.056). Meaning that women of AMA had evenly higher CB rate than women of non-AMA both in nulliparous and multiparous women.

Table B3

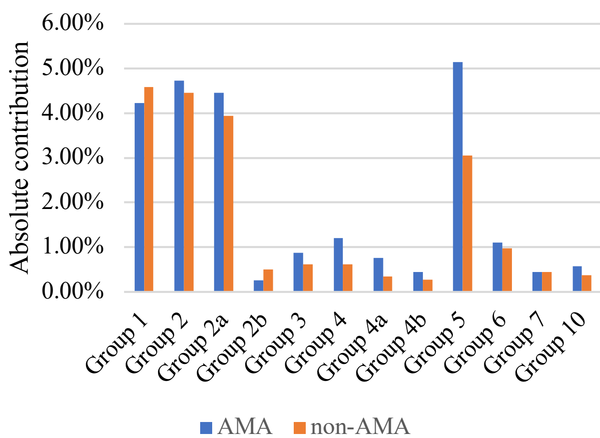
Absolute Contribution of all Analytic Sample

Robson Group	**Absolute contribution** (#CB in a group)/11,951(#total sample)
Group 1: Nullipara with spontaneous labor	4.50%
Group 2: Nullipara with:	4.51%
- 2a: labor induced	4.06%
- 2b: prelabor CB	0.45%
Group 3: Multipara with spontaneous labor	0.68%
Group 4: Multipara with:	0.75%
- 4a: labor induced	0.44%
- 4b: prelabor CB	0.31%
Group 5: Multipara with previous CB	3.51%

Robson Group	Absolute contribution (#CB in a group)/11,951(#total sample)
Group 6: Nullipara with breech presentation	1.00%
Group 7: Multipara with breech presentation	0.44%
Group 10: Preterm birth	0.41%

Figure B2

Absolute Contribution to CB of Women of AMA and Women of non-AMA



The major contribution to CB among all analytic samples was Robson Group 2 (nulliparous women with labor induced/prelabor CB) (Table B3). When looking specifically at women of AMA (Figure B2), the major contribution to CB among women of AMA was Robson Group 5 (multiparous women with previous CB). In contrast, the major contribution to CB among women of non-AMA was Robson Group 1 (nulliparous women with spontaneous labor).