A Scoping Review on Gestational Diabetes in Hawai'i: A "Window of Opportunity" to Address Intergenerational Risk for Type 2 Diabetes Mellitus

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Abstract

The health of women over the entire span of their reproductive years is crucial — beginning in adolescence and extending through the postpartum period. This paper provides a scoping review of the relevant literature on risk factors for gestational diabetes mellitus (GDM) and progression from GDM to type 2 diabetes mellitus (T2DM), particularly among women of Native Hawaiian and Pacific Islander (NHPI) and Asian racial/ethnic backgrounds in Hawai'i, using the PubMed database (July 2010 to July 2020). NHPI and Asian populations have a greater likelihood of developing GDM compared to their White counterparts. Risk factors such as advanced maternal age, high maternal body mass index, and lack of education about GDM have varying levels of impact on GDM diagnosis between ethnic populations. Mothers who have a history of GDM are also at higher risk of developing T2DM. Common risk factors include greater increase in postpartum body mass index and use of diabetes medications during pregnancy. However, few studies investigate the progression from GDM to T2DM in Hawai'i's Asian and NHPI populations, and no studies present upstream preconception care programs to prevent an initial GDM diagnosis among Hawai'i's women. Thus, updated reports are necessary for optimal early interventions to prevent the onset of GDM and break the intergenerational cycle of increased susceptibility to T2DM and GDM in both mother and child. Further attention to the development of culturally sensitive interventions may reduce disparities in GDM and improve the health for all affected by this condition.

Keywords

gestational diabetes mellitus, Native Hawaiian or Pacific Islander, Asian, minority populations, health disparities, intergenerational prevention, scoping review

Acronyms

BMI = body mass index
GDM = gestational diabetes mellitus
NH = Native Hawaiian
NHPI = Native Hawaiian and Pacific Islander
PI = Pacific Islander
T2DM = Type 2 Diabetes Mellitus

Introduction

Gestational diabetes mellitus (GDM) refers to "any degree of glucose intolerance with onset or first recognition during pregnancy"[1] and increases the risk of adverse pregnancy outcomes for both mother (ie, preeclampsia, cesarean delivery, preterm delivery) and neonate (ie, shoulder dystocia, macrosomia, neonatal hypoglycemia, and birth trauma).[2–4] These issues are of increasing importance as GDM affects 5% to 9% of pregnancies in the United States (US), with the prevalence steadily increas-ing over the last 20 years.[5,6] As GDM incidence and prevalence increase, the racial/ethnic disparities gap continues to widen between Whites and non-White minority women diagnosed with GDM. Previous studies have shown that American Indians, Native Hawaiians (NH), Hispanics, Asians and African Americans experience higher rates of GDM compared to White women.[7]

GDM is also of particular concern because it is associated with an increased risk of developing type 2 diabetes mellitus (T2DM), obesity, and other adverse metabolic effects on metabolism later in a mother's lifetime.[8–10] T2DM is a major health concern in the US, especially among racial/ethnic groups such as Native Hawaiians and Pacific Islanders (NHPI) and Asians. In Hawai'i, 27% of the population self-identifies as NHPI and 24.2% as multiracial. Among Asians in Hawai'i, 37.6% self-identify as Asian only, although the state reports 56.4% of its 1.4 million residents are of diverse Asian backgrounds.[11] From 2017 to 2019, 14.4% of NH, 18.5% of Pacific Islander (PI), and 8.4%-13.0% of adults from various Asian races in Hawai'i reported a diagnosis of T2DM, and this prevalence has continued to increase.[12]

Furthermore, ample epidemiologic and experimental evidence supports the phenomenon of "fetal programming," in which the intrauterine environment predisposes the fetus to adult onset cardiometabolic conditions later in life.[13-16] Infants born to mothers with GDM are themselves at increased risk for T2DM as adults, in part due to epigenetic changes induced by the diabetic intrauterine environment.[13–16] Thus, existing health disparities in GDM in the current generation may exacerbate T2DM disparities in future generations. This lends urgency and importance to the prevention of GDM in today's women of reproductive age.

Given the increasing risk of both GDM and T2DM among racial/ethnic minority populations as well as the increased risk for T2DM in the offspring of pregnancies complicated by GDM, the need to understand how best to stop the intergenerational risk for developing GDM, and hence T2DM, is imperative to break this cycle (Figure 1). Thus, the purpose of this paper was to conduct a scoping review to evaluate the current literature relevant to Hawai'i's multi-ethnic women and adolescent females of NHPI and Asian (Chinese, Japanese, Korean, Vietnamese, Filipino) ethnic groups who are at highest risk of developing GDM and subsequent T2DM.

Methods

Database searches were performed in PubMed for the time period between July 1, 2010 and July 1, 2020 for English language publications. Two authors independently reviewed all articles' abstracts and discussed the selection until consensus was reached,

The search was conducted with two primary areas of focus. The first search aimed to include literature on GDM risk and risk factors among Asian and NHPI women. The search terms used included *gestational diabetes* combined with the following terms using an AND function: *Hawai'i, Pacific Islander,* and *Asian.* Articles were excluded if they (1) were reviews of previous literature, (2) did not distinguish between pre-gestational and gestational diabetes, (3) were limited either to neonatal outcomes/populations other than Asians and/or NHPIs, or (4) included a population exclusively outside of the US. After review of all retrieved articles and application of exclusion criteria, a final selection of 15 peer-reviewed papers were included (Figure 2a).

The second portion of the search included literature on the progression of GDM to T2DM. The following search terms were used: *gestational diabetes, type 2 diabetes, progression, Hawai'i, Pacific Islander,* and *Asian* (Figure 2b). Articles were excluded if they (1) were reviews of previous literature, (2) did not address the progression between GDM and T2DM, or (3) included a population exclusively outside of the US. All retrieved articles were reviewed and exclusion criteria were applied, yielding a selection of 14 papers. Thus, a total of 29 articles were included in this scoping review.

Results

Studies on Risk for Developing GDM and Characteristics of GDM Pregnancies (Table 1A)

The 15 studies highlighted racial disparities in GDM as well as differing associations between GDM and risk factors among Asian and NHPI women compared to other racial groups. Key findings include the following:

Epidemiology and Racial/Ethnic Disparities (Table 1.A.1)

Multiple studies from varying cohorts within the US demonstrated increased risk of GDM among Asian women.[17–21] For example, one study found that GDM prevalence was higher in Asian American subgroups (Filipino: 19.0%, Asian Indian: 19.3%, Chinese: 15.3%, Korean: 12.9%, Vietnamese: 18.8%) compared with non-Hispanic Whites (7.0%).[20] Similar findings of increased rates of GDM among Asian women were present in a Los Angeles cohort.[17] Also, Hunsberger et al found that Asian women had a 16.4% prevalence of GDM while PI women had an 11.7% prevalence, both of which were increased compared to White women (6.0%).[21] However, it is important to note that such comparisons may be affected by different diagnostic criteria used to diagnose GDM and/or variable access to care.

Among women in Hawai'i in 2013, Tsai et al found the highest GDM prevalence to be among Filipino women (13.1%) and NHPI women (12.1%), with lowest prevalence in White women (7.4%). Overall, Asian and PI women had a 50% increased odds of developing GDM compared to their White counterparts.[22] In 2015, Chang et al looked at PI subpopulations and found that NHs (9.3%), Micronesians (8.5%), Samoans (11.8%), and other PIs (13.7%) had higher rates of GDM compared to Whites (5.8%).[3] Such findings also demonstrate the heterogeneity even within Asian and PI populations and speak to the need to disaggregate ethnic groups from larger racial classifications, especially if there are substantial differences within racial classifications that can inform interventions targeted to specific cultures.

Clinical, Lifestyle, Nutrition, and Environmental Factors (Table 1.A.2-3)

Several studies identified common risk factors for developing GDM, including advanced maternal age, high pre-pregnancy body mass index (BMI), a history of a GDM pregnancy, and non-White race.[17,21–25]

Despite the commonality among GDM risk factors, differences between and within racial/ethnic groups were observed. For example, Pu et al found the effects of advanced maternal age to be more significant for non-Hispanic Whites and Hispanics compared to Asian Americans, suggesting that the pathophysiology of GDM might differ by racial/ethnic group.[20] Similarly, BMI was less predictive for GDM among Asians,[19] and overweight/obese BMI contributed less to GDM risk in Asian and PI women compared to other racial groups.[23–25] Conversely, an inverse association between maternal height and GDM risk was strongest in Asian women.[26] Another study found that individuals of Asian or PI ancestry have a higher susceptibility to pancreatic beta cell dysfunction when exposed to volatile organic compounds.[27]

Associations between immigration and acculturation and GDM risk have been investigated with conflicting results.[17,20,28–30] Pu et al found that Chinese and Filipino women born outside the US had a higher risk of developing GDM compared to their US-born counterparts,[20] and Chen et al also found increased GDM among Asian women with less acculturation.[17] Likewise, in a California cohort, Pacific Islander, Filipina, and Chinese women born outside the US had higher rates of GDM compared to those born in the US. However, in that same cohort, Japanese and Korean women born outside of the US had decreased risks of GDM compared to those who were born in the US.[28] Other cohorts have not found GDM rates to change with country of birth or markers of acculturation.[29,30] These inconsistencies highlight the complexity of the relationships between immigration, acculturation, and GDM. Immigration from various Asian and Pacific Island locations to Hawai'i, both historical and current, highlights the need for careful ongoing evaluation of GDM disparities.[20]

Studies on Risk for Developing T2DM following GDM Pregnancy (Table 1B)

Women with a history of GDM pregnancy are at an increased risk of developing T2DM later in life. A clear limitation of those findings is the unknown rates of T2DM among those who do not receive postpartum testing. Key findings from the 14 reviewed articles include the following:

Clinical, Lifestyle, and Metabolic Signatures (Table 1.B.1-3)

Risk factors for the subsequent diagnosis of T2DM after GDM include low intensity and short duration of lactation, earlier gestational age at GDM diagnosis, use of insulin or oral diabetes medications during pregnancy, higher pre-pregnancy BMI (>25 kg/m^2), advanced age, lower physical activity, higher dietary consumption of animal fat, greater intakes of total iron, lack of healthy lifestyle behaviors, adverse newborn outcomes, and greater postpartum BMI increase.[31–37] For example, the Diabetes and Women's Health cohort study found that women who gained greater than 5 kg (11 lbs) after a GDM pregnancy had a 43-times higher risk of developing T2DM compared to those gaining less than 5 kg (11 lbs).[6] Other risk factors included lipid dysmetabolism and the presence of metabolic signatures such as certain amino acids, medium-chain acylcarnitines, and reduced levels of sphingolipid metabolism.[38–41]

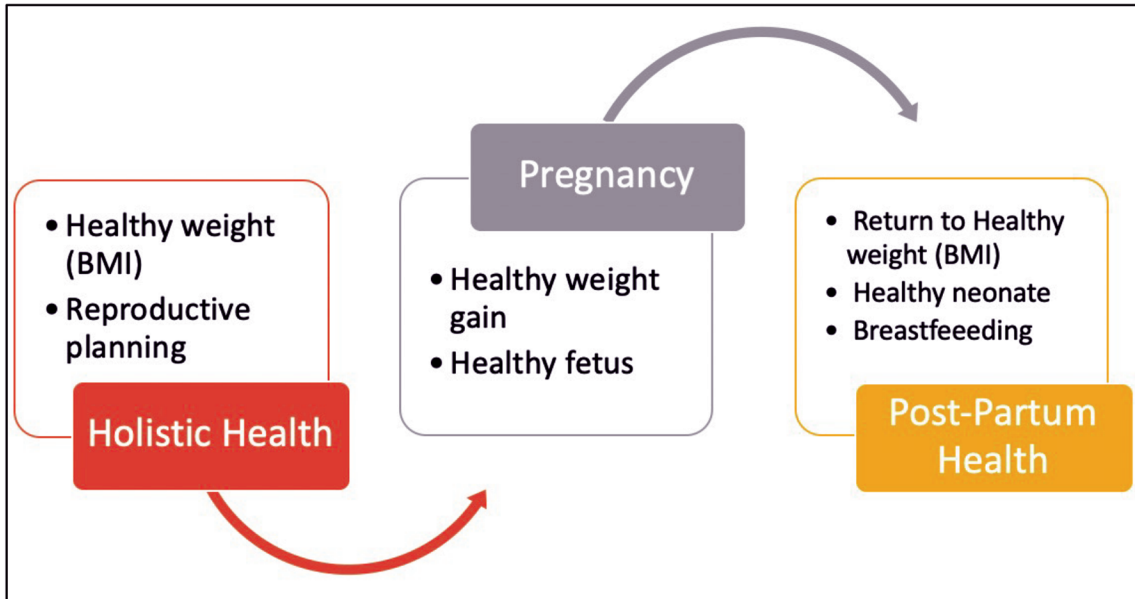*Racial/Ethnic Disparities (Table 1.B.4)*

Racial/ethnic disparities have been observed in the development of T2DM after GDM. Gunderson et al reported that Hispanic (41%) and Asian (32%) women were at a higher risk for developing T2DM after a GDM pregnancy compared to non-Hispanic Whites (15%).[31] However, recent investigations regarding the progression from GDM to T2DM among Hawai'i's Asian and NHPI women were lacking.

Prevention Interventions and Postpartum Follow-up Care (Table 1.B.5)

GDM represents a strong risk factor for later development of T2DM. Despite the importance of screening, suboptimal follow-up prevents many women from obtaining T2DM screening and education.[42] Reasons for not obtaining postpartum T2DM screening include missed appointments, false assumptions about the low risk for T2DM, inconvenient or unpleasant tests, fear of a T2DM diagnosis, time constraints, and lack of physician awareness and communication.[38]

For those who do receive follow-up care, it was found that postpartum intervention implementation reduces the progression to T2DM. One study reported that diets consisting of fruits, vegetables, and low-fat dairy products, were associated with a 15-35% reduction in incidence of T2DM after GDM.[6] Other studies also found that intensive lifestyle interventions and metformin were highly effective in delaying and preventing subsequent T2DM.[10]

a) Holistic Health and Reproduction

Pregnancy
- Healthy weight gain
- Healthy fetus

- Healthy weight (BMI)
- Reproductive planning

Holistic Health

- Return to Healthy weight (BMI)
- Healthy neonate
- Breastfeeeding

Post-Partum Health

b) Intergenerational risk of Gestational Diabetes Mellitus and Type 2 Diabetes Mellitus

- Overweight/Obese
- No reproductive counseling
- Racial/ethnic minority

Increased Risk for Developing GDM

GDM Pregnancy

Complications:
- Maternal (preeclampsia, cesarean, etc)
- Neonatal (macrosomia, hypoglycemia, etc)

Maternal:
- Risk for GDM in future pregnancies
- Risk for future T2DM

Post-GDM Pregnancy
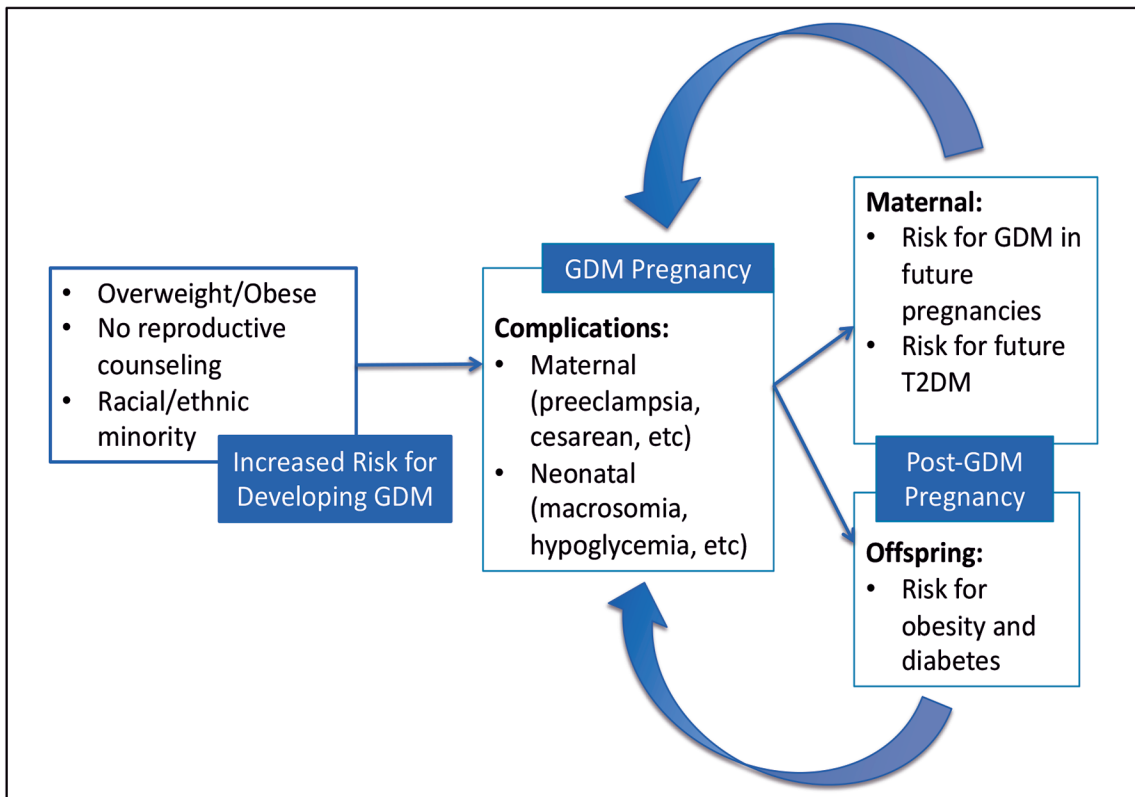
Offspring:
- Risk for obesity and diabetes

Figure 1. Proposed Concept of Holistic Health and Reproduction compared with Intergenerational Risk of Gestational Diabetes Mellitus for At-risk Women
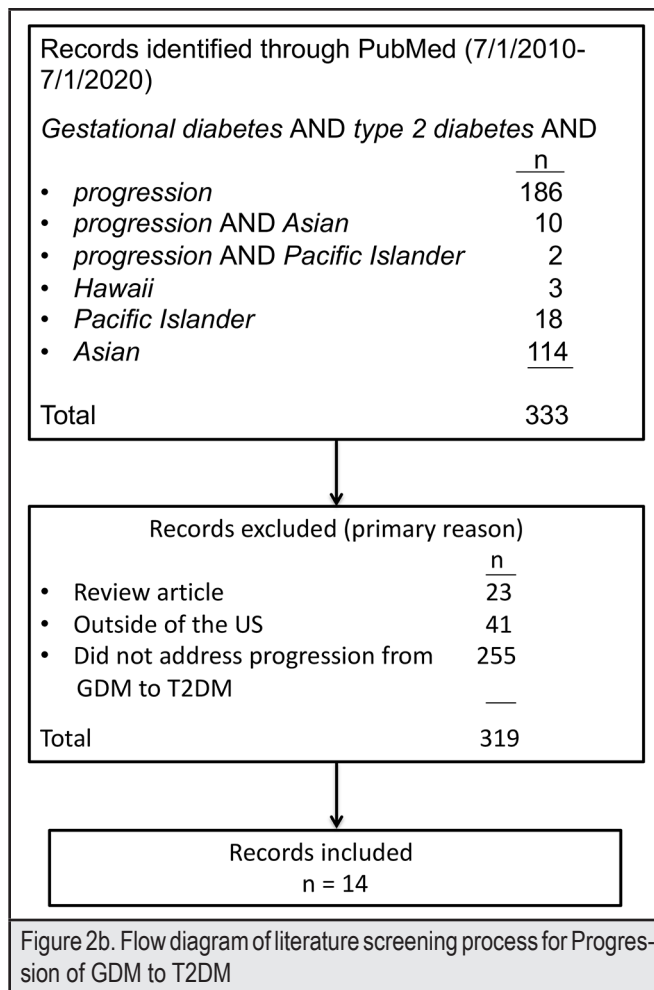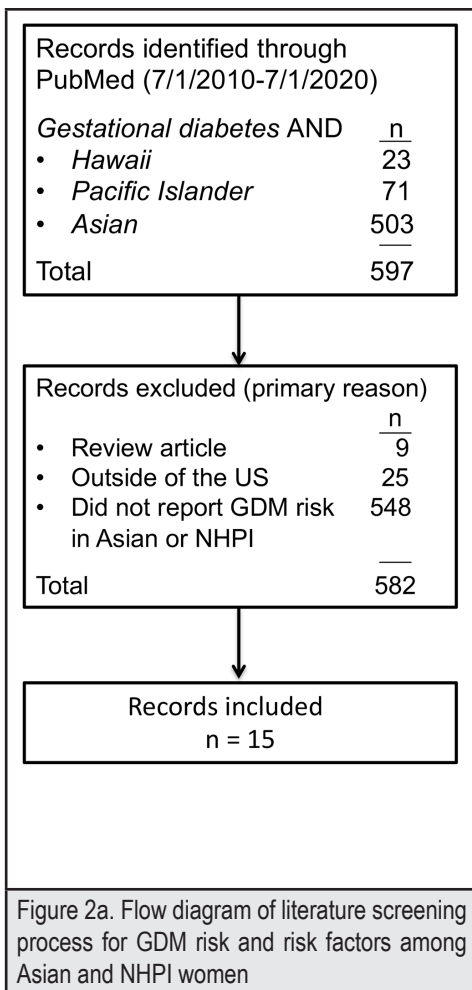
Records identified through
PubMed (7/1/2010-7/1/2020)

Gestational diabetes AND   n
- *Hawaii*   23
- *Pacific Islander*   71
- *Asian*   503

Total   597

↓

Records excluded (primary reason)
                           n
- Review article   9
- Outside of the US   25
- Did not report GDM risk   548
  in Asian or NHPI

Total   582

↓

Records included
n = 15

Figure 2a. Flow diagram of literature screening process for GDM risk and risk factors among Asian and NHPI women

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Records identified through PubMed (7/1/2010-7/1/2020)

Gestational diabetes AND *type 2 diabetes* AND
                             n
- *progression*   186
- *progression* AND *Asian*   10
- *progression* AND *Pacific Islander*   2
- *Hawaii*   3
- *Pacific Islander*   18
- *Asian*   114

Total   333

↓

Records excluded (primary reason)
                           n
- Review article   23
- Outside of the US   41
- Did not address progression from   255
  GDM to T2DM

Total   319

↓

Records included
n = 14

Figure 2b. Flow diagram of literature screening process for Progression of GDM to T2DM

Table 1. Summary of Scoping Review on Risk Associated with Developing Gestational Diabetes Mellitus and Subsequent Type 2 Diabetes Mellitus							
Study Categories	**Studies**	**Number of Participants**	**Study Time Period**	**Location**	**Purpose of Study**	**Methods**	**Key Findings Relevant to Hawai'i's Multi-ethnic Population**
A) Studies on Risk for Developing GDM and Characteristics of GDM Pregnancies (n=15)							
1) Epidemiology and Racial/Ethnic Disparities	**Chang et al. (2015)**	n = 5,510 (Native Hawaiian=6,662, Micronesian=1,548, Samoan=897, Other Pacific Islanders=539)	2010-2011	Hawai'i	Quantify obstetric outcomes of Pacific Islander subgroups in Hawai'i	Retrospective cohort study	Outcome differences were observed between Pacific Islander subpopulations and when compared to White women. Of Pacific Islander subgroups, Micronesians had the highest risk of cesarean sections and Native Hawaiians had the highest risk of low-birthweight infants Samoans had a higher risk of macrosomia compared to Whites, while Native Hawaiians and Micronesians were significantly less likely to have an infant with macrosomia compared to Whites
	Chen et al. (2019)	n = 5,562	2007	Los Angeles, California	Assess GDM prevalence among Asian Americans and association with acculturation	Cross-sectional study	Compared to non-Hispanic White women, Asian women had a higher risk of GDM (OR 2.44 [95%CI 1.81-3.29]) Acculturation negatively associated with GDM
	Hunsberger et al. (2010)	n = 3,883 (API=617)	2004-2005	Oregon	Explore racial/ethnic disparities in the prevalence of GDM	Retrospective cohort study	Asian/Pacific Islander women (both normal and high BMI) had the highest prevalence of GDM (14.8%) among all women studied Asian women were more likely to have GDM compared to Pacific Islander women
	Liu et al. (2020)	16,258 (Asian n=620)	2010-2015	Detroit, Michigan	Investigate relationships between maternal race/ethnicity and age with GDM	Retrospective cohort study	Asian women had a significantly higher GDM risk compared to White women (OR 2.53 [95%CI 2.10-3.10]) Older maternal age increased GDM risk and affected risk interactively with race/ethnicity (smaller effect of age among African American compared to non-African American women)
	Pu et al. (2015)	n = 24,195 (Chinese=3,218), Filipino=1,088, Japanese=677, Korean=460, Vietnamese=460)	2007-2012	California	Assess racial/ethnic differences in risk factors for GDM	Retrospective cohort study	GDM was most prevalent among Asian American subgroups: Asian Indian (19.3%), Chinese (15.3%), Filipino (19.0%), Korean (12.9%) and Vietnamese (18.8%) Family history and foreign-born status were important risk factors for Asian subgroups Risk attributed to advanced maternal age was modified by race/ethnicity
	Tsai et al. (2013)	n = 4,735 (Native Hawaiian/Pacific Islander=20,851, Filipina=9,922, Other Asian=9,225)	2009-2011	Hawai'i	Examine the relationship between ethnicity, GDM, and macrosomia in Hawai'i	Retrospective cohort study	Overall prevalence of GDM in Hawai'i was 10.9% The highest prevalence of GDM was in Filipina (13.1%) and Native Hawaiian/Pacific Islander (12.1%) women, while the lowest prevalence was in White women (7.4%) Asian/Pacific Islander women had a 50% increased odds of having GDM compared to White women

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Study Categories	**Studies**	**Number of Participants**	**Study Time Period**	**Location**	**Purpose of Study**	**Methods**	**Key Findings Relevant to Hawai'i's Multi-ethnic Population**
2) Clinical Risk Factors	**Brite et al. (2014)**	n=135,861 (Asian=4,190)	2002-2008	Consortium on Safe Labor study (11 states and District of Columbia)	Evaluate associations between maternal height and GDM across racial/ethnic groups	Retrospective cohort study	Maternal height was inversely correlated to GDM risk, with the strongest association among Asians
	Hedderson et al. (2012)	n=123,040 (Asian=18,497, Filipina=9,636)	1995-2006	Northern California	Examine associations between GDM and BMI by racial/ethnic groups	Retrospective cohort study	Asian and Filipina women had an increased risk of GDM at a lower BMI compared to non-Hispanic White and African American women
	Kim et al. (2012)	n=656,925 (API=16,799)	2004-2007	Florida	Evaluate percentages of GDM attributable to overweight and obesity across racial/ethnic groups	Cross-sectional study	API women had a higher GDM prevalence (9.9% vs 4.0% for Black women). API women had the lowest percentage of GDM attributable to overweight and obesity compared to other racial groups
	Kim et al. (2013)	n=1,228,265 (API=168,933)	2007-2009	California	Evaluate percentages of GDM attributable to overweight and obesity across racial/ethnic groups	Cross-sectional study	API women had a higher GDM prevalence (11.9% vs 5.4% for White women). API women had the lowest percentage of GDM attributable to overweight and obesity compared to other racial groups
	Shah et al. (2011)	24,325 (Asian n=7,404)	1988-2001	San Francisco, California	Examine body mass index as a screening tool for GDM among racial/ethnic groups	Retrospective cohort study	Asian women had increased risk of GDM compared to White women regardless of body mass index Body mass index had the poorest sensitivity for GDM among Asian women compared to other racial groups

Table 1. Summary of Scoping Review on Risk Associated with Developing Gestational Diabetes Mellitus and Subsequent Type 2 Diabetes Mellitus							
Study Categories	Studies	Number of Participants	Study Time Period	Location	Purpose of Study	Methods	Key Findings Relevant to Hawai'i's Multi-ethnic Population
3) Lifestyle, Nutrition, and Environmental Factors	Hedderson et al. (2010)	n=216,089	1995-2004	Northern California	Compare GDM risk by country of birth (US or non-US) among racial/ethnic groups	Retrospective cohort study	Being born outside of the US associated with increased risk of GDM among Filipina, Chinese, and Pacific Islander women, but a decreased risk of GDM in Japanese and Korean women
	Janevic et al. (2014)	n=89,703 (Chinese=10,603)	2001-2002	New York City	Evaluate associations between living in an ethnic enclave and risk for GDM	Cross-sectional study	Among Chinese women, no association between living in an ethnic enclave and GDM risk
	Ramadhani et al. (2011)	n=6,463 (API=198)	1997-2005	National Birth Defects Prevention Study (10 states in the US)	Examine differences in pregnancy-related risk factors among US versus non-US born women across racial/ethnic groups	Retrospective cohort study	No difference in GDM between US and non-US born API women
	Williams et al. (2019)	n=220,065 (API=9,068)	2002-2008	Consortium on Safe Labor study (11 states and District of Columbia)	Understand racial/ethnic disparities in GDM by looking at exposure to volatile organic compounds (VOCs)	Retrospective cohort study	Exposure to high VOCs was associated with increased odds of GDM among whites and Asian/Pacific Islanders GDM risk was significantly higher for Asian/Pacific Islanders compared to whites for most compounds
B) Studies on Risk for Developing T2DM following GDM pregnancy (n=14)							
1) Clinical Factors	Bao et al. (2015)	n=1,695	1991-2001	Nurse's Health Study II cohort (14 states in US)	Examine how adiposity and weight change influences the long-term risk of developing T2DM after GDM	Prospective cohort study	Baseline BMI, most recent BMI, and weight gain after GDM pregnancy were significantly and positively associated with risk of progression from GDM to T2DM
	Gunderson et al. (2014)	n=1,007 (Asian=362)	2008-2011	SWIFT cohort; Northern California: Asian, Non-Hispanic White, Non-Hispanic Black, Hispanic, Other	Investigate whether higher lactation intensity is related to more favorable blood lipids, lipoproteins, and adipokines after a GDM pregnancy	Prospective cohort study	Higher lactation intensity was associated with more favorable biomarkers for T2DM except for lower plasma adiponectin after GDM delivery
	Zhang et al. (2019)	n=7,759	2012-2016	Denmark and US	Investigate the genetic and environmental factors that are implicated in the progression from GDM to T2DM	Hybrid Prospective cohort study combined with existing data	Progression from GDM to T2DM ranged from 23.1% to 27.2% of the study population Women with a history of GDM have a greater risk of hypertension and cardiovascular disease A healthful diet, lifestyle factors, and weight control correlated with a lower risk of T2DM, hypertension, and cardiovascular disease

Table 1. Summary of Scoping Review on Risk Associated with Developing Gestational Diabetes Mellitus and Subsequent Type 2 Diabetes Mellitus							
Study Categories	**Studies**	**Number of Participants**	**Study Time Period**	**Location**	**Purpose of Study**	**Methods**	**Key Findings Relevant to Hawaiʻi's Multi-ethnic Population**
2) Lifestyle Factors	**Allalou et al. (2016)**	n=1,035 (Asian=340)	2008-2011	Non-Hispanic White, Non-Hispanic Black, Hispanic, Asian, Other	Identify early diagnostic biomarkers to predict risk and etiology of developing T2DM following GDM	Prospective cohort study	Several amino acids and all hexose sugars play important roles in T2DM development and impaired fasting glucose levels Women who developed T2DM had a more T2DM-like metabolite profile within 6-9 weeks postpartum and were more likely to have been treated with insulin or oral medication during pregnancy
	Bao et al. (2014)	n=4,554	1991-2007	Nurse's Health Study II cohort (14 states in US)	Examine the role of physical activity and sedentary behaviors in the progression from GDM to T2DM	Prospective cohort study	Increased physical activity may lower the risk of progression from GDM to T2DM
	Bao, Chavarro et al. (2016)	n=3976	1991-2009	Nurse's Health Study II cohort (14 states in US)	Examine the association of habitual iron intake with long-term risk of T2DM among women with previous GDM	Prospective cohort study	Greater intakes of total iron, dietary heme iron, dietary heme iron and supplemental iron were associated with increased risk for T2DM among women with a history of GDM
	Bao, Li et al. (2016)	n=4,502	1991-2011	Nurse's Health Study II cohort (14 states in US)	Examine the long-term effects of a low-carbohydrate diet on GDM to T2DM progression	Prospective Cohort Study	Low-carbohydrate diet with high protein and fat intake from animal-source foods is associated with higher risk of T2DM, while a low-carbohydrate diet with high protein and fat intake from plant-source foods is not significantly associated with risk of T2DM
	Brown et al. (2016)	n=1,463 (Chinese=168, Filipina=165, South Asian=144, Other Asian=153)	2011-2013	Northern California (Black, Latina, Non-Hispanic white, Chinese, Filipina, South Asian, Other Asian)	Examine whether strength of attachment to one's ethnic group could account for variation in lifestyle behaviors in women with previous GDM who are at high risk for T2DM	Cross-sectional study	Ethnic group attachment is associated with certain lifestyle behaviors that may promote behaviors associated with risk of developing T2DM

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Study Categories	Studies	Number of Participants	Study Time Period	Location	Purpose of Study	Methods	Key Findings Relevant to Hawaiʻi's Multi-ethnic Population
3) Metabolic Signatures	Batchuluun et al. (2018)	n=24	Not specified	SWIFT cohort; Northern California: Asian, Non-Hispanic White, Non-Hispanic Black, Hispanic, Other	Investigate the link between acylC species and ß-cell dysfunction / onset of diabetes after GDM	Prospective cohort study	Serum medium-chain (M)-acylCs are associated with GDM and early TD2M onset, which directly impairs ß-cell function
	Khan et al. (2019)	n=1,035 (Asian=362)	2008-2011	SWIFT cohort; Northern California: Asian, Non-Hispanic White, Non-Hispanic Black, Hispanic, Other	Identify a predictive signature and early-stage pathophysiology of the transition from GDM to TD2M	Prospective cohort study	Predictive signature of reduced sphingolipids is associated with the pathophysiology of transition from GDM to T2DM
	Lai et al. (2020)	n=658 (Asian=196)	2008-2011	California: White, Black, Asian, Hispanic	Further the understanding of the pathology underlying the transition from GDM to T2DM	Nested case-control study	Amino acid and lipid dysmetabolism among women with a history of GDM can serve as a metabolic signature to predict the transition from GDM to T2DM in the early postpartum period
4) Racial/Ethnic Disparities	Gunderson et al. (2015)	n=1,035 (Asian=362)	2008-2011	SWIFT cohort; Northern California: Asian, Non-Hispanic White, Non-Hispanic Black, Hispanic, Other	Evaluate lactation and 2-year incidence of T2DM after GDM pregnancy	Prospective observational cohort study	Lower lactation intensity and shorter duration; Hispanic/Asian ethnicity, adverse newborn outcomes, use of insulin or oral medications during pregnancy, and higher dietary consumption of animal fat were associated with higher 2-year incidences of T2DM following a GDM pregnancy
5) Prevention Interventions and Postpartum Follow-up Care	Aroda et al. (2015)	n=350 (GDM) n=1,416 (no GDM)	1996-2009	Caucasian, African American, Hispanic, American Indian, and Asian American (n=47)	Evaluate the impacts of Intensive Lifestyle (ILS) and metformin interventions in women with and without a history of GDM using Diabetes Prevention Program (DPP) cohort	Randomized controlled clinical trial with observational follow-up	Among women with a history of GDM, both lifestyle and metformin interventions were effective in reducing the progression to diabetes over a 10-year period Among women without a history of GDM, lifestyle interventions only reduced the progression to T2DM
	Bernstein et al. (2019)	n=12,622 (Asian=123/1,091 women who conceived within 3 years of index pregnancy)	2006-2012	United States; Asian, Black, Hispanic, White	Assess the impact of GDM recurrence and/or delivery interval on follow-up care and T2DM onset	Secondary analysis	GDM severity in the index pregnancy was a strong predictor of subsequent T2DM onset Regardless of interval between deliveries, GDM reoccurs in 50% of subsequent pregnancies A short interval (<1 year, compared to >2 years) between the initial GDM delivery and subsequent pregnancy increased the likelihood of early onset T2DM, suggesting the importance of contraceptive counseling after a GDM pregnancy

Discussion

This scoping review confirms the disproportionate burden of risk factors leading to GDM or subsequent development of T2DM in NHPIs and Asians. These findings are supported by other studies in the literature, which demonstrate that GDM disproportionately affects Asian, African American, and Hispanic women compared to White women, and that the risk for developing GDM is 3-fold higher for Asian women: a trend that increases exponentially with increasing BMI.[4,43–45]

In addition to the 2 studies in this review that investigated GDM prevalence among Asian and NHPI populations in Hawaiʻi,[3,22] the most recent PRAMS data reported that 14.4% of new mothers in Hawaiʻi self-reported a GDM diagnosis in 2015, including 27.1% of Samoan and 20.2% of Filipino mothers, compared to 6.6% of White mothers. This review demonstrates the growing number of pregnancies complicated by GDM in Hawaiʻi, which is up from 4.8% in 1995. Work done prior to this scoping review found similar racial/ethnic disparities in GDM prevalence.[45] This further highlights the longstanding disparities in GDM prevalence that are still present today.

The time before and during pregnancy is an important time in a woman's life to prevent an initial GDM diagnosis, or to mitigate the risk of a future T2DM diagnosis for both herself and her offspring.[16,46] A substantial number of women, especially those of high-risk racial/ethnic groups, are unaware of the risk factors that could lead to the development of GDM and subsequent T2DM. For example, one study showed that 42% of a cohort of Samoan women were either unsure or not aware that diabetes could first occur during pregnancy. Furthermore, only 25% of participants identified pre-pregnancy obesity as a risk factor for GDM, which was the most widely identified risk factor in the study.[46] Another study interviewed American Indian and Alaska Native women who stated they wished they had been aware of the risk factors for GDM prior to pregnancy. Participants also voiced that intervention programs should be cognizant of cultural preferences when encouraging diet and lifestyle modifications.[47]

Therefore, culturally appropriate preconception planning programs are important to provide education counseling to women of reproductive age who may face language barriers when seeking reproductive health guidance.[5,8,9,47] Populations that may benefit from such programs include immigrants to higher-income countries, who are traditionally underweight or of normal weight, yet have higher rates of obesity and thus are at increased risk of developing GDM.[20,43,48,49] For example, a program for a disadvantaged Mexican-American cohort partnered coaches with diabetic patients based on language and ethnicity. These coaches helped to promote patient engagement during medical appointments.[9] Other studies proposed and implemented programs that educated women about GDM, GDM-associated risk factors, reproductive health, nutrition label interpretation, and how to include diabetes care amidst family and social situations.[8,9,28]

Prior work has reported success in preventative interventions for GDM during pregnancy. One study of high-risk Finnish women in early pregnancy using a lifestyle intervention was shown to reduce the development of GDM by 39%.[50] In addition, 2 meta-analyses found physical activity programs in pregnancy reduce the development of GDM.[51,52] While not all preventative interventions demonstrated such positive results,[16] these encouraging data suggest that modifiable risk factors can be effectively addressed to reduce GDM. Thus, based on our review findings highlighting disparities and challenges regarding GDM particular to NHPI and Asian women, preventative interventions targeted to these high-risk groups are warranted.

Because a recent meta-analysis found that women with previous GDM have a 10-fold increased risk of developing T2DM compared to women without a history of GDM,[53] and the prevalence of T2DM following GDM ranged from 26% to 36% with the risk of T2DM increasing linearly by 10% every 10 years in other cohorts, the necessity to manage care after an initial GDM diagnosis is critical to avoid long-term health complications.[54,55] A common theme across other reviews shows that early and consistent postpartum screening for T2DM plays an essential role in delaying and preventing the onset of T2DM after GDM.[56] However, similar to the reviewed literature, other sources cite inadequate GDM screening resources and inadequate training for staff, difficulty scheduling appointments or tests, and family-related practicalities as reasons why patients are unable to receive proper follow-up screening.[43,57]

While various risk factors have been established for the progression of GDM to T2DM, few studies focus on Asian and NHPI women, particularly in Hawaiʻi. As previous studies showed that PIs had the highest need for insulin to treat GDM, and the use of insulin, as a marker of greater hyperglycemia, is associated with a 3.5 times higher risk for postpartum T2DM. Similar investigation of disparities in other risk factors would offer the opportunity to develop a tailored-approach to preventative care for high-risk populations.[49]

Study Limitations

There were several common limitations that posed difficulties in reviewing and interpreting the published literature. First, inconsistent criteria used to clinically diagnose GDM hindered comparisons between, and possibly even within, cohorts.[17–21] GDM risk factors may also vary depending on the criteria used to diagnose the condition.

In addition, due to the large number of multiracial women in Hawaiʻi, classifying individuals into a single racial/ethnic group is challenging. Aggregating racial/ethnic groups and subgroups

may assist in classification, however, heterogeneity within racial/ethnic groups may obscure important differences between ethnic groups that are clinically relevant.[3,20–22]

Finally, many of the studies relied on retrospective data, such as birth certificate data, that may underestimate GDM prevalence and lack important variables.[3] On the other hand, GDM diagnoses in women prior to 20 weeks' gestation suggest the presence of pre-existing undiagnosed diabetes that was only identified when tested during pregnancy, thereby overestimating true GDM prevalence.[3] Other studies also used self-report data for variables such as GDM, BMI, and ethnicity, which may also be subject to bias.[22]

Conclusion

This review shows that there is a paucity of recent literature on the ethnic disparities in GDM and subsequent development of T2DM, particularly for Hawaiʻi's Asian and NHPI populations, despite these populations' known increased risk for GDM. Given the relationships between GDM, subsequent T2DM, and increased adult-onset metabolic disease in offspring exposed to in-utero GDM/T2DM, these disparities are likely to worsen without intervention. Periodic reviews of present disparities and the healthcare system's response to the increase of GDM and T2DM are necessary to help design upstream ethnic-specific intervention and education programs in order to stop the perpetual intergenerational cycle of GDM and T2DM in Asian and NHPI populations. Identifying high-risk women prior to and early in pregnancy offers unique advantages during a "window of opportunity" in women's reproductive lifecycles to implement interventions and educational programs aimed at healthy lifestyle behaviors that may reduce the risk of GDM and subsequent T2DM.

Future studies should also look at individuals who identify with a particular mix of races/ethnicities that independently are at increased risk for GDM or subsequent T2DM. This would provide a more accurate representation of Hawaiʻi's multi-ethnic population and could inform the development of ethnic-specific approaches to dietary preferences and cultural-based physical activities. In addition, it is critical to establish consistent screening with standard diagnostic criteria to better detect and compare the development of GDM in vulnerable populations.[5]

Lastly, several risk factors for GDM were shown to vary by race/ethnicity, such as high BMI and maternal age. Future studies should continue to investigate other modifiable and health system risk factors, such as follow-up screening and post-partum care of GDM pregnant mothers aimed at reducing the progression from GDM to T2DM that may vary between populations.

Conflict of Interest

None of the authors identify a conflict of interest.

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