

BREASTFEEDING DURATION, INTENSITY, AND ITS ASSOCIATION WITH POSTNATAL DIABETES AMONG WOMEN WITH PRIOR GESTATIONAL DIABETES MELLITUS: A SCOPING REVIEW

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Abstract: Infants who are breastfed enjoy numerous health advantages. Nevertheless, its benefits for women with a history of gestational diabetes mellitus (GDM) are frequently disregarded. There are currently few guidelines for GDM to advocate breastfeeding because there is scant scientific data that does so. This review aims to explore breastfeeding duration and intensity among women with prior GDM over the past decade, explicitly observing its association with postnatal glycaemic control and diabetes incidence. A systematic search on lactation and GDM studies published in the Cochrane Library, Medline, Science Direct, and Scopus databases between 2010 and 2021 was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We included English publications relevant to GDM and breastfeeding and the incidence of postnatal diabetes. Nine articles were included in the final data set. Women with GDM seemed to have a shorter breastfeeding duration but had a higher breastfeeding rate during the early postnatal period. Breastfeeding duration and intensity among women with prior GDM did have a protective effect against the risk of getting postnatal diabetes. The association is more pronounced with higher breastfeeding intensity and longer breastfeeding duration. These findings would assist the healthcare team in developing suitable breastfeeding interventions for optimal prevention among women with prior GDM to reduce the risk of postnatal diabetes.

Keywords: Gestational diabetes mellitus, breastfeeding intensity, breastfeeding duration, postnatal diabetes, scoping review.

Introduction

Gestational diabetes mellitus (GDM) is defined as any degree of glucose intolerance with the first onset during pregnancy and ceases after delivery (Chiefari *et al.*, 2017). It is often associated with substantial maternal complications later in life. Women with a past medical history of GDM will eventually develop type 2 diabetes mellitus (T2DM) during the first ten years after delivery. This is because insulin secretion degenerates to chronic insulin resistance, progressive high blood glucose, and predominantly T2DM (Metzger *et al.*, 2007).

Globally, GDM affects an estimated 15% of pregnant women; of that percentage, and the majority were in low- and middle-income countries (Ogurtsova *et al.*, 2017). Data from a

systematic review reported that the prevalence of GDM worldwide, with the highest number of statistics of GDM cases, was among the Middle East and North Africa, followed by Southeast Asia and Western Pacific regions. In contrast, it is the lowest in Europe (Zhu *et al.*, 2016).

Recent studies have shown that diabetes can be prevented or delayed through intensive lifestyle changes in these high-risk women. Most of the current evidence supports that breastfeeding provides protective effects towards developing co-morbidities in maternal health, including T2DM and metabolic syndrome (Vandyousefi *et al.*, 2019; Ley *et al.*, 2020). The rate of insulin resistance in women who exclusively breastfeed (EBF) their child was lesser than in women who did not exclusively

breastfeed their child. Besides, women with GDM who EBF their child is associated with reduced fasting blood glucose (FBG) (Shub *et al.*, 2019). Remarkably, the results' trend demonstrated that the risk of T2DM and glucose biomarkers reduces with longer breastfeeding duration (Ley *et al.*, 2020).

During breastfeeding, the mother's body will produce a milk-secreting hormone called prolactin that promotes milk production and stimulates insulin secretion from pancreatic beta cells to regulate the blood glucose in the body. Research conducted in Korea shows that pancreatic beta cells also produce serotonin during breastfeeding. This hormone acts as an antioxidant and helps to reduce oxidative stress, making the mother's beta-pancreatic cells healthier. It has been documented that serotonin induces the proliferation of beta-pancreatic cells, increasing beta-cell mass and helping maintain appropriate blood glucose levels. Lactation improves beta-pancreatic cells function and blood glucose regulation at a mean of 3.6 years postpartum among lactated mothers compared to non-lactated mothers. (Kim, 2020).

Nonetheless, it is essential to note that the breastfeeding rate globally remains far below the international target, especially in most high-income countries (Victora *et al.*, 2016). Only 20% of these countries breastfed their child until 12 months and had shorter lactation duration than low-income and middle-income countries (Victora *et al.*, 2016). Available evidence showed that women with a past medical history of GDM were less likely to breastfeed their children than women with no previous history of GDM (Kim *et al.*, 2018).

Undeniably, women with a history of GDM face many challenges in breastfeeding their babies. This is because they have delayed lactogenesis and breastfeeding initiation, which increases the probability of introducing formula milk and reducing the breastfeeding rate (Kim *et al.*, 2010; Much *et al.*, 2014). Furthermore, women with a history of GDM are prone to have many adverse pregnancy outcomes like caesarean section, premature delivery, macrosomia, and

neonatal hypoglycaemia, which also affect the initiation and determination of breastfeeding (Salahudeen *et al.*, 2013).

Many findings reported that breastfeeding offers vast health benefits for infants. Nevertheless, its benefits on maternal health with a history of GDM were often overlooked. With little evidence, few GDM recommendations advise breastfeeding to reduce the risk of developing T2DM. This was supported by previous studies (Farhanah *et al.*, 2014; Farhanah *et al.*, 2017) that documented the focus and management of women with GDM are more on dietary and lifestyle modification with less emphasis on breastfeeding practices. These approaches may identify mothers with a previous history of GDM needing intensive breastfeeding support to achieve their breastfeeding goals.

In addition, the association between breastfeeding duration and intensity influence on postnatal abnormal glucose intolerance among women with GDM remains unclear. Thus, this review aims to explore the breastfeeding duration and intensity among women with prior GDM and its association with improved postnatal glycaemic control and diabetes risk.

Methodology

This scoping review used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). This scoping review involves studies related to lactation and GDM published between 2010 to 2021 in the Cochrane Library, Medline, Science Direct, and Scopus databases. The methodology of this study was: (i) Identification of the research question, (ii) Developing searching strategies, (iii) Data screening, (iv) Summarising data for analysis.

Identifying the Research Questions

In this phase, this scoping review aimed to investigate breastfeeding practices among women with a medical history of GDM after delivering a baby. The research questions were: (i) What are the breastfeeding intensity and duration among women with prior GDM? and

(ii) Can breastfeeding reduce the risk of postnatal prediabetes among women with GDM?

Developing Searching Strategies

In the next phase, comprehensive searching was conducted to find all the relevant articles needed to fulfil the aim of this review. The search considered all relevant articles written in English and published between 2010 to 2021. The investigation was restricted to human samples only. Two authors independently assessed the articles' eligibility to answer the research questions using keywords (“breastfeeding” OR “breastfeeding” OR “lactation” OR “nursing”) AND (“GDM” OR “gestational diabetes” OR “gestational diabetes mellitus” OR “diabetes in pregnancy”).

Data Screening

The study is targeted to observe the breastfeeding duration and intensity among women with prior GDM. Breastfeeding duration and intensity of a mother are associated with the risk of getting postnatal T2DM. Hence, the next phase was the eligibility process. The material selection for this review was based on the following inclusion criteria: (i) relevant to GDM and breastfeeding, (ii) outcome measures of breastfeeding duration and intensity, glucose profile and development of postnatal diabetes, (iii) published in English, (iv) used a cross-sectional, retrospective, randomised-controlled trial, or prospective study designs, (v) published between January 2010 to October 2021, and (vi) published in the book, book chapter, conference abstract, editorial. All duplicate articles in the four databases were eliminated. Animal studies, review articles and non-peer review articles were also removed.

The authors independently assessed the articles' eligibility to answer the research questions. The final search result was then compared and finalised into data analysis. Next, phase four was finalising the articles for analysis. The articles that did not meet the criteria were excluded. The extracted articles were further assessed to determine the eligibility to be included in the

final review analysis. In the final phase, phase five, the implication for future management and research were formulated for the conclusion.

Analysis

The finalised articles were evaluated for data extraction and analysis. The selected data extracted were not statistically combined and reanalysed. The data were broken down and summarised systematically from each study into a table, including the year of publication, author name/s, study location, subjects, study design, breastfeeding classification, and outcomes. Data extraction was done by reading the abstracts to define relevant themes and reading the full articles in depth. Codes were generated using a descriptive coding process. This stage involved searching for the theme by combining different codes within the data, which were comparable or considered the same variable. These codes were based on the research question identified during phase one. Thematic component analysis was used to describe the impact of breastfeeding on glycaemic control after delivery among women with a history of GDM. The codes were categorised into three themes: (i) breastfeeding duration, (ii) breastfeeding intensity, and (iii) development of postnatal diabetes.

Results

Study Selection and Characteristics

Table 1 shows the number of articles that result from searching from the four databases. Figure 1 shows the PRISMA flow chart of the article selection process. The initial search resulted in 1445 articles. After removing 600 duplicates and excluding 769 articles published before 2010, non-English articles, lab-based studies, and not peer-reviewed (i.e., book, book chapter, conference abstract, editorial), we assessed 76 full-text articles for eligibility. At the stage of the eligibility assessment, 67 articles were excluded due to excluded on abstract title level, study protocol, not involving women with GDM, and outcome measures unrelated to the scope. Nine articles were finally included in the last data set.

Table 1: Number of articles retrieved from databases

Cochrane Library	Medline	Science Direct	Scopus
743	215	382	105

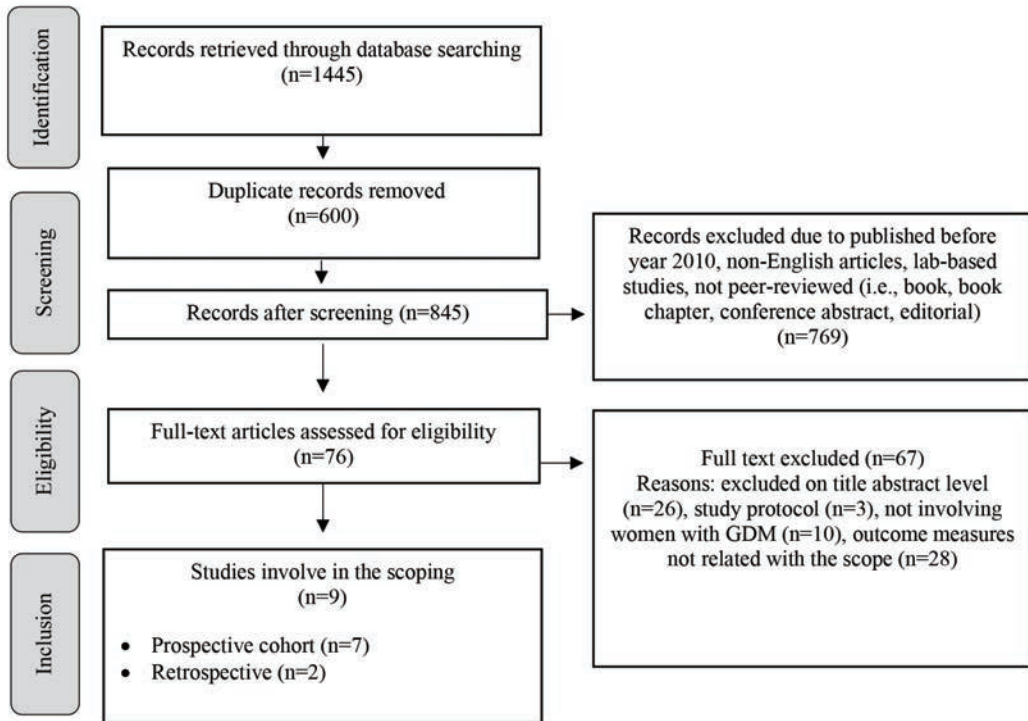


Figure 1: PRISMA flow chart describing the article selection process

The number of participants involved in these studies ranged from 114 to 4372. All participants were diagnosed with GDM. Seven of the nine studies included in this review were prospective cohort studies, while the other two were retrospective. The studies were undertaken in different countries, including The United States (2), Germany (2), Singapore (1), Japan (1), Australia (1), China (1), and Poland (1).

Table 2 presented the data from the nine articles that were charted according to the year of publication, author(s), country, subjects' criteria, study design, breastfeeding classification, breastfeeding duration and intensity, assessment timeline, and postnatal and glucose control incidence. Based on the studies, there are several

time points where breastfeeding is assessed in these studies: 6 weeks, 12 weeks, 6 months, and 12 months postnatal. The longest assessment timeline for postnatal diabetes incidence was 19 years postnatal from index pregnancy (Ziegler *et al.*, 2012).

Meanwhile, there were only 5 out of 9 studies reported breastfeeding intensity. Breastfeeding intensity was documented in several ways. Some studies recorded the quantities of formula milk intake by the babies within 24 hours (Gunderson *et al.*, 2015; Yasuhi *et al.*, 2019; Zurawska-Kliś *et al.*, 2019), while some studies were based on the percentage of formula milk intake compared to breastfeeding in a day (Ziegler *et al.*, 2012; Much *et al.*, 2016; Ley *et al.*, 2020; Hewage *et al.*, 2021).

Table 2: Studies on breastfeeding duration and intensity among women with prior GDM included in the review

Date of Data Retrieval	Year	Authors and Country	Subjects	Study Design	Breastfeeding Classification	Breastfeeding Duration and Intensity	Assessment Timeline	Incidence of Postnatal Diabetes and Glucose Control
24 th of September 2021	2012	Ziegler, A. G., Wallner, M., Kaiser, I., Rossbauer, M., Harsunen, M. H., Lachmann, L., Maier, J., Winkler, C., & Hummel, S. Germany	Women who were diagnosed with GDM who were followed up until 19 years postpartum (N=304)	Prospective study	<ul style="list-style-type: none"> No breastfeeding >3 months breastfeeding £3 months breastfeeding 	109 out of 264 (41.2%) women breastfeed for >3 months	Breastfeeding assessment: Nine months postnatal Diabetes risk assessment: 2- and 9-months postpartum; 2, 5, 8, 11, 15, and 19 years postnatal from the index pregnancy	48.4% of women with prior GDM developed diabetes in this study. The median diabetes-free duration was 7.9 years postnatal. The duration of full breastfeeding was strongly correlated with any breastfeeding duration ($r^2=0.71$; $P<0.0001$). It was also documented that the risk of postpartum diabetes was inversely associated with the duration of breastfeeding, with a lower 15-year risk in women who practised full breastfeeding for at least three months.
15 th March 2021	2015	Gunderson, E. P., Hurston, S. R., Ning, X., Lo, J. C., Crites, Y., Walton, D., Dewey, K. G., Azevedo, R. A., Young, S., Fox, G., Elmajian, C. C., Salvador, N., Lum, M., Sternfeld, B., Quesenberry, C. P., Selby, J., Ferrara, A., & Chiang, V. The United States	Women diagnosed with GDM at 35 weeks gestation (N=1010)	Prospective study	<ul style="list-style-type: none"> Exclusive lactation (no formula, foods, or liquids) Mostly lactation (>0 to 6 oz of formula per 24 hours) Mostly formula (>17 oz per 24 hours) Exclusive formula (no lactation) 	205 out of 959 (21%) women exclusively breastfed up to 9 weeks postnatal	Breastfeeding assessment: 6 to 9 weeks postdelivery Diabetes risk assessment: Two years postpartum	In this study, 113 (11.8%) women developed incidents of DM at one year and 6.9% at two years after delivery. Higher breastfeeding and longer duration were independently associated with lower incidences of DM after two years of delivery.

<p>25th of September 2021</p>	<p>2016 Much, D., Beyerlein, A., Kindt, A., Krumtsiek, J., Stückler, F., Rossbauer, M., Hofelich, A., Wiesenäcker, D., Hivner, S., Herbst, M., Römmisch-Margl, W., Prehn, C., Adamski, J., Kastemüller, G., Theis, F., Ziegler, A. G., & Hummel, S. Germany</p>	<p>Women who were diagnosed with GDM PINGUIN study and long-term POGO study (N=197)</p>	<p>Prospective study</p>	<ul style="list-style-type: none"> • <3 months • >3 months 	<p>☐ 68.5% of women breastfed their babies for >3 months</p>	<p><u>Breastfeeding and diabetes risk assessment:</u> PINGUIN study (median 0.7 years), POGO study (median 6.0 years)</p>	<p>Women with a history of GDM who breastfeed >3 months were significantly associated with a lower concentration of BCAA at 30 min OGTT within 0.7 years postpartum, linked to healthy adults after glucose challenge. The outcomes were similar when adjusted for insulin treatment.</p>
<p>25th September 2021</p>	<p>2019 Yasuhi, I., Yamashita, H., Maeda, K., Nomiyama, M., Mizunoe, T., Tada, K., Yorozu, M., Ogawa, M., Kodama, T., Yamaguchi, K., Okura, N., Kawakami, K., Maekawa, Y., & Hayashi, K Japan</p>	<p>Women who were diagnosed with GDM at 324 weeks (N=222)</p>	<p>Prospective study</p>	<p>Six categories of breastfeeding intensity</p> <ul style="list-style-type: none"> • Breastfeeding alone • Mostly breastfeeding with a minimal additional formula • <20% by formula • 30-40% by formula • >50% by formula • By formula alone 	<p>53% of women were exclusively breastfeeding their babies at early postpartum</p>	<p><u>Breastfeeding and diabetes risk assessment:</u> 6 to 12 weeks of postpartum</p>	<p>The HOMA-IR in the HIB women were reported to be significantly lower than women in the non-HIB group, although after adjusting the postpartum weight loss. Lower insulin resistance was also associated with the HIB group with adjusted postpartum weight loss. However, this effect was only seen in obese subjects.</p>

15 th March 2021	2019	Shen, Y., Leng, J., Li, W., Zhang, S., Liu, H., Shao, P., Wang, P., Wang, L., Tian, H., Zhang, C., Yang, X., Yu, Z., Hou, L., Tuomilehto, J., & Hu, G. China	Women who were diagnosed with GDM from 2005 to 2009 (N=1260)	Prospective cohort	<ul style="list-style-type: none"> • Exclusive formula • Mixed feeding • Exclusive lactation <p>Duration:</p> <ul style="list-style-type: none"> • 0-6 months • 6-12 months • 12-18 months • 18 months 	36% of women diagnosed with T2DM exclusively breastfed, compared to 44.4% of women with normal glucose.	<p><u>Breastfeeding assessment:</u> Postpartum baseline Diabetes risk assessment: Three years</p>	In 3 years and six months, the study documented 114 cases of diabetes and 417 (27%) cases of prediabetes among 1260 women. This study discovered an inverse association of breastfeeding duration with the risks of diabetes and prediabetes. This study suggested that longer breastfeeding duration and higher lactation intensity significantly reduce the risk of diabetes and prediabetes among women with GDM.
16 th March 2021	2019	Zurawska-Kliś, M., Wójcik, M., Zieleniak, A., Kosiński, M., Mazur, B., Woźniak, L., & Cypryk, K. Poland	Women who were diagnosed with GDM between 26 and 30 weeks of gestation from 2013 to 2016 (N=114)	Prospective cohort study	<ul style="list-style-type: none"> • Longer (>12 weeks) • Shorter (≤12 weeks) • More intensively (>70% of milk consumption) • Less intensively (<70% of milk consumption) 	77.9% of women breastfed a baby >12 weeks, and 76.4% of women fed breastmilk to their babies	<p><u>Breastfeeding and diabetes assessment:</u> 18 months postdelivery</p>	Women who breastfed for more than 12 weeks had intensive lactation and had significantly higher BMI than women with shorter breastfeeding duration. Women who breastfed more intensively had significantly lower HOMA 2 IR than women who breastfeed less intensively.
15 th March 2021	2019	Shub, A., Miranda, M., Georgiou, H. M., McCarthy, E. A., & Lappas, M. Australia	Women with GDM at week 6-10 gestation between 2012 and 2017 (N=243)	Retrospective cohort study	<ul style="list-style-type: none"> • Exclusively breastfeeding • Exclusively formula feeding • Mixture method 	66.7% of women with GDM breastfed their baby	<p><u>Breastfeeding and diabetes assessment:</u> 6 to 10 weeks postpartum</p>	There was a positive relationship between exclusive breastfeeding at 6 to 10 weeks of gestation and reduced fasting blood glucose but not in lipid profile.

15 th March 2021	2020	Ley, S. H., Chavarro, J. E., Li, M., Bao, W., Hinkle, S. N., Wander, P. L., Rich-Edwards, J., Olsen, S., Vaag, A., Damm, P., Grunnet, L. G., Mills, J. L., Hu, F. B., & Zhang, C. The United States (N=4372)	Women with a history of GDM between 2012 to 2014 from The Nurses' Health Study (N=4372)	Prospective cohort	<ul style="list-style-type: none"> • 0 month • >0 to 6 months • >6 months to 12 months • >12 to 24 months • >24 months 	20.1% of women breastfeed for more than 24 months lifetime duration of lactation	<p><u>Breastfeeding assessment:</u> In the years 1993, 1997 and 2003, lifetime breastfeeding duration was associated with a lower risk of getting T2DM among women with GDM. It was also associated with lower HbA1c, plasma insulin, and C-peptide concentration.</p>	<p>This study documented that 873 out of 4372 (19.1%) women were diagnosed with T2DM. A longer lifetime breastfeeding duration was associated with a lower risk of getting T2DM among women with GDM. It was also associated with lower HbA1c, plasma insulin, and C-peptide concentration.</p>
25 th September 2021	2021	Hewage, S. S., Koh, X. Y. H., Soh, S. E., Pang, W. W., Fok, D., Cai, S., Müller-Riemenschneider, F., Yap, F., Tan, K. H., Chua, M. C., Lim, S. B., Godfrey, K. M., Colega, M. T., Chong, Y. S., Chan, S. Y., Yoong, J., & Chong, M. F. F. Singapore	Women who were diagnosed with GDM from the GUSTO mother-offspring cohort study who were recruited between June 2009 and September 2010 (N=124)	Retrospective cohort	<ul style="list-style-type: none"> • <1 month • 1 to <6 months • 3 to 6 months 	38.8% of women had breastfed their babies for six months	<p><u>Breastfeeding assessment:</u> Three weeks postnatal to every three months until 12 months postnatal</p> <p><u>Diabetes risk assessment:</u> Diabetes risk for less than one month. Women who breastfeed for > 6 months are recorded to have the lowest IRR of 0.42.</p>	<p>44% of women had abnormal postpartum oral glucose tolerance tests, 11.2% had T2DM and 32.8% with prediabetes. The covariate-adjusted IRR of women who breastfeed for 1 to <6 months) was 0.67 compared to women who breastfeed for less than one month. Women who breastfeed for > 6 months are recorded to have the lowest IRR of 0.42.</p>

GDM = gestational diabetes mellitus, DM = diabetes mellitus, PINGUIN = short-term postpartum intervention in women with GDM using insulin, POGO = long-term postpartum outcomes in women with GDM and their offspring study, BCAA = branch chain amino acid, HOMA-IR = homeostatic model assessment for insulin resistance test, HIB = high-intensity breastfeeding, HbA1c = haemoglobin A1c, IRR = incidence rate ratio

Breastfeeding Duration

Among the nine studies, the most prolonged breastfeeding duration was up to 48 months, as it accumulated mothers' lifetime duration of breastfeeding (Ley *et al.*, 2020). Lifetime breastfeeding duration was calculated from the months the mother reported breastfeeding at each birth.

Meanwhile, a prospective study by Shen *et al.* (2019) assessed breastfeeding duration as a continuous variable up to three years postpartum in a single pregnancy. One study recruited participants as early as 22 weeks of gestation and evaluated the participants' breastfeeding duration until 10 to 18 months postpartum (Zurawska-Kliś *et al.*, 2019). Two prospective studies conducted in Germany used three months duration as their cutting point in assessing the breastfeeding duration (Ziegler *et al.*, 2012; Much *et al.*, 2016), while a study in Singapore used six months duration for evaluating breastfeeding (Hewage *et al.*, 2021). Three studies in this review examined the short-term effects of breastfeeding among women with prior GDM: two cohort studies by Gunderson *et al.* (2015) and Yasuhi *et al.* (2019) and one retrospective study analysis from cohort study by Shub *et al.* (2019) carried out breastfeeding duration assessment shortly after delivery which was between 6 and 10 weeks postnatal. Most of the studies in this review documented breastfeeding duration in categorical data. Remarkably, 20.1% of women in The United States studied by Ley *et al.* (2020) had breastfed their babies for more than 24 months for a lifetime breastfeeding duration. Two studies captured six months of exclusively breastfeeding women with a percentage of 38.8 and 36, respectively (Shen *et al.*, 2019; Hewage *et al.*, 2021).

Studies that assessed the breastfeeding duration during the early postnatal period mostly documented a higher percentage of exclusively breastfeeding rate (Ziegler *et al.*, 2012; Much *et al.*, 2016; Shub *et al.*, 2019; Yasuhi *et al.*, 2019; Zurawska-Kliś *et al.*, 2019). Nevertheless, the rate of breastfeeding at nine weeks postnatal

seemed to be low (21%) among women in California (Gunderson *et al.*, 2015).

Breastfeeding Intensity

We reviewed the authors' approach to analysing the feeding practices regarding breastfeeding intensity. It is noticed that five out of nine studies assessed breastfeeding duration together with breastfeeding intensity (Gunderson *et al.*, 2015; Shen *et al.*, 2019; Shub *et al.*, 2019; Yasuhi *et al.*, 2019; Zurawska-Kliś *et al.*, 2019). Two cohort studies reported breastfeeding intensity as exclusive formula, exclusive lactation, or mixed (Shen *et al.*, 2019; Shub *et al.*, 2019). Remarkably, some studies documented breastfeeding intensity in detail. A study in Japan by Yasuhi *et al.* (2019) demonstrated breastfeeding intensity into two categories independent of post-partum weight change (PWC). Those who exclusively breastfed their babies or greater than or equal to 80% were included in the high-intensity breastfeeding (HIB) category, while other breastfeeding statuses were categorised under non-HIB. This study recorded 74.7% of the women categorised in the HIB group.

Similarly, a prospective cohort study in Poland by Zurawska-Kliś *et al.* (2019) also reported that breastfeeding intensity in percentage $> 70\%$ of total infant milk consumption comes from breastfeeding (more intensively) and $< 70\%$ of total infant milk consumption coming from breastfeeding. This study documented that 76.4% of the women breastfeed their babies intensively. A prospective observational cohort study in The United States by Gunderson *et al.* (2015) reported that only 21.3% of women exclusively breastfed their babies up to nine weeks postnatal. This study explained the assessment of breastfeeding intensity by measuring the amount of breastmilk given to the baby. They were categorised into the intensive lactation (≤ 6 oz of formula milk per 24 hours since delivery) or intensive formula feeding (≥ 14 oz of formula per 24 hours for three weeks, no breast milk, or previous breastfeeding and weaned in \leq three weeks) group.

Development of Postnatal Diabetes and Glycaemic Control

Five out of nine studies included in this review reported the incidence of postnatal diabetes among their participants (Ziegler *et al.*, 2012; Gunderson *et al.*, 2015; Shen *et al.*, 2019; Ley *et al.*, 2020; Hewage *et al.*, 2021). According to the longest study in this review by Ley *et al.* (2020), only 19.1% of the women with prior GDM developed diabetes over 25 years. However, another long-term study has documented that nearly half (48.8%) of the women involved in their study were diagnosed with diabetes over 19 years. Meanwhile, a retrospective study in Singapore by Hewage *et al.* (2021) with 4 to 7 years of observation documented that 44% of women had abnormal postpartum OGTT, 11.2% developed diabetes, and another 32.8% had prediabetes. A small number of women (11.8%) developed diabetes after two years of observation by Gunderson *et al.* (2015). In a three-year prospective cohort study in China, 114 women out of 417 (27%) were diagnosed with GDM. Regardless of the assessment duration, the findings consistently showed an inverse association between breastfeeding duration and intensity with the risk of postnatal diabetes, suggesting that breastfeeding has a protective effect on women with prior GDM, even in a short period. This has been proven in a long-term cohort study that showed the risk of postpartum diabetes to be lower at 15 years in women with prior GDM who practised full breastfeeding for at least three months (Ziegler *et al.*, 2012). It is important to note that women who breastfeed for more than three months were significantly associated with a lower branch chain amino acid (BCAA) concentration at 30 minutes OGTT (Much *et al.*, 2016). A low concentration of BCAA has been observed in a healthy adult after the glucose challenge. Interestingly, high intensity and longer duration of breastfeeding have been observed to lower insulin resistance (Yasuhi *et al.*, 2019) in women with prior GDM, even after adjusting the BMI and postnatal weight loss (Zurawska-Kliś *et al.*, 2019). Longer breastfeeding duration and high

breastfeeding intensity seemed to positively impact several metabolic parameters, including fasting blood glucose, HOMA-IR, HbA1C, fasting insulin, and C-peptides (Shub *et al.*, 2019; Zurawska-Kliś *et al.*, 2019; Ley *et al.*, 2020).

Discussion

This scoping review investigated breastfeeding duration and intensity among women with a medical history of GDM after delivering a baby. The information was extracted on breastfeeding practices, women with a history of GDM, and glycaemic control during postpartum. Despite the vast benefits of breastfeeding for women with a history of GDM, evidence suggests a lower rate of exclusive breastfeeding among women with GDM than among women with a healthy pregnancy (Shub *et al.*, 2019). This review has included studies that observe short breastfeeding duration, as early as six to nine weeks postnatal until a lifetime breastfeeding duration among women with prior GDM. Interestingly, the outcomes were consistent regardless of the breastfeeding duration. The favourable effects of breastfeeding on postnatal glycaemic control can be observed as early as six to ten weeks postpartum (Gunderson *et al.*, 2015; Much *et al.*, 2016; Shub *et al.*, 2019; Yasuhi *et al.*, 2019).

In a prospective study by Gunderson *et al.* (2015), they found that more women who exclusively feed formula milk to their babies developed postnatal diabetes two years after delivery than women who exclusively breastfeed their babies for nine weeks postnatal. These findings were testified by the evidence in North Carolina by Stuebe *et al.* (2016), which supported the idea of the short-term benefits of breastfeeding. The effects were more pronounced with longer breastfeeding duration (Ley *et al.*, 2020). Longer lifetime breastfeeding duration was associated with lower HbA1c, plasma insulin, and c-peptide protein (Ley *et al.*, 2020). Breastfeeding confers many favourable metabolic changes, including lower fasting and

postprandial glycaemic level, insulin, greater insulin sensitivity, triglycerides, and plasma HDL-C (Gunderson *et al.*, 2014).

The benefits of breastfeeding among women with prior GDM have been well observed. Nine articles in this review suggested that breastfeeding is a low-cost prevention strategy in combating non-communicable diseases among women with prior GDM. One prospective study that observed the development of T2DM among women with GDM within 20 years postdelivery found that the median time to develop T2DM after delivery was 12.3 years for women who breastfeed versus 2.3 years for women who did not breastfeed their children. On top of that, mothers who breastfeed their children for more than three months had a lower risk of developing T2DM than mothers who breastfeed for less than three months (Ziegler *et al.*, 2012).

During lactation, glucose is converted to milk via noninsulin-mediated pathways taken by the mammary gland. Thus, breastfeeding women exhibit lower blood glucose (Bell & Bauman, 1997). In an animal study by Moon *et al.* (2020), the breastfeeding hormone, which is prolactin, will induce β -cells to produce serotonin. Intracellular serotonin is an antioxidant that suppresses oxidative stress and improves β -cell survival. This study suggested that serotonin offers long-term effects of lactation on women by reducing oxidative stress and increasing β -cell proliferation.

However, of interest, findings in some studies have been inconsistent. In a retrospective study of the Nurses Health cohort, breastfeeding did not lower the risk of T2DM at 14 years (Wenstrom, 2016). Likewise, in a retrospective study by Kjos *et al.* (1998), breastfeeding did not affect the progression of T2DM within a follow-up of 7.5 years post-delivery. The discrepancy among the different types of studies might result from diverse ethnic backgrounds, lifestyle behaviours, follow-up time postpartum, sample size, breastfeeding assessment, the severity of GDM, study design, and subject attrition rate. It is challenging to ensure the precision of the information and the data assessment

due to the nature of the studies. Some study designs, mainly in retrospective studies, rely on observational and require self-recall information on breastfeeding assessment, and therefore are most probably affected by recall bias.

Seven out of nine studies included in this review were prospective studies. The self-reported breastfeeding assessment at the time of data collection was less likely to be affected by recall bias. However, different breastfeeding assessments may further compound the breastfeeding intensity and duration discrepancy. It is undeniable that breastfeeding intensity is challenging to assess compared to formula feeding. In this review, three studies (Gunderson *et al.*, 2015; Yasuhi *et al.*, 2019; Zurawska-Kliś *et al.*, 2019) were very detailed in reporting that breastfeeding intensity can guide future studies.

Findings may be inconsistent if postpartum follow-up is conducted at various time points. For instance, Zurawska-Kliś *et al.* (2019) indicated that nursing reduced mothers' postpartum body weight after 18 months of delivery. At the same time, a different prospective study by Gunderson *et al.* (2015) found an inverse relationship between mother's BMI and breastfeeding intensity from weeks 6 to 9 postpartum.

Most of the studies in this review faced the same problem: high subjects' attrition rate during follow-up (Shen *et al.*, 2019; Shub *et al.*, 2019; Yasuhi *et al.*, 2019; Zurawska-Kliś *et al.*, 2019). This might be because women with GDM had lower breastfeeding intentions (Stuebe *et al.*, 2016) and were less likely to breastfeed their child exclusively (Shub *et al.*, 2019). This is consistent with one review paper stating that women with GDM were less likely to breastfeed their babies exclusively and have shorter breastfeeding duration than those with normal pregnancies (Nguyen *et al.*, 2019).

It was well documented that obese and older women with prior GDM have delayed breastfeeding initiation and lactogenesis (Kim H. *et al.*, 2010), which increases the probability of formula milk feeding (Much *et al.*, 2014). According to our observation, many women in the study exclusively breastfeed their babies. How-

ever, when examining the assessment period, most studies evaluated breastfeeding patterns as early as six weeks after delivery (Shub *et al.*, 2019). In five of the nine studies, breastfeeding exclusivity was evaluated rather than just duration (Gunderson *et al.*, 2015; Shen *et al.*, 2019; Shub *et al.*, 2019; Yasuhi *et al.*, 2019; Zurawska-Kliś *et al.*, 2019).

Recent evidence suggested that breastfeeding intention is significantly associated with breastfeeding knowledge, positive attitude, and health beliefs, such as perceived knowledge and self-efficacy of a mother (Hossain *et al.*, 2018). Nevertheless, research has shown that improved breastfeeding rate and self-efficacy among women with prior GDM can be achieved by individualised breastfeeding education during antenatal check-ups based on self-efficacy theory. Women who received the antenatal breastfeeding intervention seemed to have higher exclusive breastfeeding rates and higher scores in breastfeeding self-efficacy (Stuebe *et al.*, 2016; You *et al.*, 2020).

Despite all discrepancies and limitations, it has been confirmed that breastfeeding benefits glycaemic control and insulin sensitivity after delivery among women with a history of GDM. The results seemed to be more pronounced and evident with a longer duration of breastfeeding and higher breastfeeding intensity. Hence, it is strongly suggested that breastfeeding education for women with GDM is feasible and efficacious to improve breastfeeding practices among women with prior GDM as they face more breastfeeding challenges than in a normal pregnancy.

In the future investigation, it might be possible to conduct a randomised controlled trial study with a long-term observation on breastfeeding education in women with a history of GDM, analyse the glucose-related parameter changes, and compare it with the control group. This could draw a clearer picture of the causal relationship between breastfeeding and glycaemic control parameters among women with GDM. This review has argued on the discrepancy in the breastfeeding assessment. A further study focusing on standardised breastfeeding assessment is

therefore suggested. This is to ensure that the evaluation of breastmilk intake by the baby is more consistent and comparable. Lastly, it might be possible to precisely record the pregnancy and early postpartum clinical parameters in the future investigation, including weight changes, body fat percentage, BMI, pregnancy outcomes, and infant weight gain. This could be used as a mediator of breastfeeding and the progression of diabetes and enables the evaluation of the association beyond two years of follow-up.

Conclusion

In summary, the women in this review seemed to have a short breastfeeding duration. Only three-quarter of women with GDM have exclusively breastfed their babies for six months, as recommended by WHO. Studies that assessed the breastfeeding duration during the early postnatal period mostly documented a higher percentage of exclusivity and intensity of breastfeeding rate, especially during the first 6 weeks of postnatal. Overall, these results suggest that breastfeeding offers favourable effects on glycaemic control in the short and long term among women with prior GDM. The results were more distinct with longer breastfeeding duration and high-intensity breastfeeding. There was an inverse association between breastfeeding duration and intensity with the risk of developing T2DM in the future among women with prior GDM. The study proposes intensive breastfeeding support during pregnancy among women with prior GDM and observes the changes in metabolic parameters, including glycaemic control, lipid profile, and high sensitivity C-reactive protein (hs-CRP). Further research targeting a specific population of more diverse socioeconomic status is warranted to develop optimal prevention routes.

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