diabetesresearchandclinicalpractice 204 (2023) 110893

Contents lists available at ScienceDirect

Diabetes Research and Clinical Practice

journal homepage: www.journals.elsevier.com/diabetes-research-and-clinical-practice

The incidence and risk factors of postpartum diabetes in women from Bangladesh, India and Sri Lanka (South Asia) with prior gestational diabetes mellitus: Results from the LIVING study

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ARTICLE INFO

Keywords:
Gestational diabetes
South Asia
Postpartum
Diabetes
Risk factors
Women

ABSTRACT

Aim: To study, the incidence and risk factors for postpartum diabetes (DM), in women with gestational diabetes mellitus (GDM) from South Asia (Bangladesh, India and Sri Lanka), followed for nearly two years after delivery.
Methods: Women with prior GDM diagnosed using IADPSG criteria were invited at 19 centres across Bangladesh, India and Sri Lanka for an oral glucose tolerance test (OGTT) following childbirth, and were enrolled in a randomized controlled trial. The glycaemic category (outcome) was defined from an OGTT based on American Diabetes Association criteria.
Results: Participants (n = 1808) recruited had a mean ± SD age of 31.0 ± 5.0 years. Incident DM was identified, between childbirth and the last follow-up, in 310 (17.1 %) women [incidence 10.75/100 person years], with a median follow-up duration of 1.82 years after childbirth. Higher age, lower education status, higher prior pregnancy count, prior history of GDM, family history of DM, and postpartum overweight/obese status were significantly associated with incident DM. Women in Bangladesh had a higher cumulative incidence of DM [16.49/100 person years] than in Sri Lanka [12.74/100 person years] and India [7.21/100 person years].
Conclusions: A high incidence of DM was found in women with prior GDM in South Asia, with significant variation between countries. Women from Bangladesh had a significantly higher pregnancy count, family history of DM and overweight/obese status, despite having significantly lower age, which could be responsible for their higher rates of DM.
Registration of this study: The study was registered with the Clinical Trials Registry of India (CTRI/2017/06/008744), Sri Lanka Clinical Trials Registry (SLCTR/2017/001), and ClinicalTrials.gov (NCT03305939).

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https://doi.org/10.1016/j.diabres.2023.110893
Received 12 March 2023; Received in revised form 24 August 2023; Accepted 30 August 2023
Available online 31 August 2023

1. Introduction

Gestational diabetes mellitus (GDM) is defined as hyperglycaemia in pregnancy which is not overt diabetes [1]. Relative risk for diabetes mellitus (DM) is ten times higher for women with prior GDM than those with normoglycaemia in pregnancy [2]. In a *meta*-analysis of six studies using International Association of the Diabetes and Pregnancy Study Groups (IADPSG) criteria, the risk of DM was 6.4-fold higher in women with prior GDM [3]. The prevalence of GDM is high, affecting nearly one in four pregnancies in South Asia [4]. Given the high rate of dysglycaemia (DM and prediabetes) in women with prior GDM, and the high baseline cardiometabolic risk in women from South Asia, it is essential to understand natural history to inform strategies to prevent or delay the onset of DM. The LIVING randomized controlled study, conducted in Bangladesh, India, and Sri Lanka, evaluated the effectiveness of a low-intensity intervention in women in diverse cultures and resource-constrained settings [5]. The intervention did not help prevent the worsening of the glycaemic status or decrease weight compared to usual care (trial overview have been provided in the supplementary file).

The aim of this sub-study was to evaluate the incidence and risk factor associations of DM in South Asian women from Bangladesh, India and Sri Lanka with prior GDM who were followed for nearly two years as part of the LIVING study. There is limited evidence on the burden of postpartum DM, especially in women with prior GDM from South Asia [6]. Most previous data on the prevalence of DM post GDM in this population have been derived from small studies, and predominantly from India [6]. In India, high rates of DM in women with prior GDM has been reported, with Carpenter and Coustan criteria, and, most recently, with IADPSG criteria [7–8]. The results suggested that the prevalence of DM and prediabetes were 10.5 % and 47.2 % in women with prior GDM (diagnosed using IADPSG criteria) when evaluated at a median of 20 months after childbirth [8]. This burden of DM and prediabetes appears higher than described for women of other ethnicities [9–12]. However, since our prior study involved a single tertiary care centre, the results lack generalisability. Recently, the HAPO study reported its findings on postpartum DM [9], but this study lacked participation from South Asian countries. Thus the LIVING study provides a unique opportunity to address the existing evidence gap on glycaemic disease burden post GDM, in South Asia.

2. Methods

2.1. Settings and study design

LIVING was an investigator-initiated trial involving 19 clinical centres in Bangladesh, India, and Sri Lanka. All study centres were urban tertiary care facilities, with nearly 75 % being public hospitals catering predominantly to lower income communities. Ethics Review Committees of the All India Institute of Medical Sciences (India), icddr,b (Bangladesh), University of Kelaniya (Sri Lanka), Centre for Chronic Disease Control (CCDC) (India) and the University of Sydney (Australia), and (where required) individual hospitals approved the study. Written informed consent was obtained from all the study participants.

2.2. Study objectives

1. To assess the incidence of DM after childbirth based on oral glucose tolerance test (OGTT) results in women with prior GDM. For this objective, all women with an actual date of delivery available were included in the analyses. The last available OGTT was used to calculate incident DM.
2. To evaluate the progression to DM in women who had normoglycaemia (NGT), impaired fasting glucose (IFG), impaired glucose tolerance (IGT), or both IFG and IGT at the first postpartum visit (pre-randomization visit for the LIVING trial).
3. To report on risk factor associations of incident DM. We further report data on country specific differences.

2.3. Participant identification, inclusion and exclusion criteria

Eligible study participants were women diagnosed with GDM using IADPSG criteria based on OGTT or isolated fasting plasma glucose (FPG) results at 24–34 weeks of gestation [13,14]. Women with GDM diagnosed before 24 weeks using the IADPSG criteria were enrolled if they were on pharmacotherapy. Exclusion criteria were for the main study and included [5].

I. travel time to hospital $>$ 2 h,
II. lack of availability of a household mobile telephone,
III. use of steroids during pregnancy (other than for foetal lung maturation), and
IV. high likelihood of moving residence within the subsequent three years.

2.4. Procedure on the day of testing

The first postpartum visit for an oral glucose tolerance test (OGTT) (minimum fast of 8 h) between 3 and 18 months following childbirth, was conducted after completion of exclusive breastfeeding. The samples for the venous plasma glucose were collected in the fasting state, and 2 h after ingestion of 82.5 g of glucose monohydrate (equivalent to 75 g of anhydrous glucose), dissolved in 250–300 ml water and consumed over 5–10 min. Except two, labs of all study centres were part of external quality assurance program for glucose. Information was collected on demographics, education, employment, prior history of GDM, and other relevant medical/obstetric history. Blood pressure was measured using an automated sphygmomanometer (Omron JPN1), with the average of two readings after 5 min rest recorded. Body weight was measured using digital scales (Omron HN286) wearing light clothing, while waist circumference was measured halfway between the lowest rib palpable in the mid-axillary line and top of the iliac crest [15].

2.5. Definitions of outcomes

Glycaemic category was defined based on fasting and 2-hour blood glucose levels from the OGTT: normal glucose tolerance [$<$ 5.6 mmol/L fasting and $<$ 7.8 mmol/L 2-hour]; impaired fasting glucose (IFG) [5.6–6.9 mmol/L fasting and $<$ 7.8 mmol/L 2-hour]; impaired glucose tolerance (IGT) [$<$5.6 mmol/L fasting and 7.8–11.0 mmol/L 2-hour]; IFG and IGT [5.6–6.9 mmol/L fasting and 7.8–11.0 mmol/L 2-hour]; and DM [$\geq$7.0 mmol/L fasting or $\geq$ 11.1 mmol/L 2-hour]. Prediabetes was defined as IFG, IGT or both IFG and IGT [16]. Overweight and obese were defined as having a body mass index (BMI) $\geq$ 25 and 30 kg/m^2, respectively.

2.6. Statistical analysis

Data were summarised using descriptive statistics, as frequency and proportion for categorical variables, and as mean and standard deviation (SD) or median and interquartile range (IQR) for continuous variables. Person-time and incidence rate of DM (i.e. number of events divided by the person time) were calculated from (i) the date of delivery, and (ii) first postpartum visit after delivery to the diagnosis of DM (for participants who experienced the event) or to the last date of OGTT (for participants who did not experience the event). The calculation from date of delivery included all participants with OGTT at pre-randomization visit (n = 1808), while the calculation from the first post-partum visit after delivery only included those randomized participants (n = 1601; this is a subset of the study population which excluded participants who were ineligible for the trial e.g., diagnosed with DM prior to the first postpartum visit) and for whom we had at least one OGTT on follow-up

Table 1
Baseline characteristics.

Variables	Bangladesh ($n = 430$)	India ($n = 865$)	Sri Lanka ($n = 513$)	Overall ($n = 1808$)[1]	P value*
Age, years (mean, SD)	29.6 (5.3)	31.0 (4.5)	32.1 (5.1)	31.0 (5.0)	<0.001
Education (n, %)					
Secondary school or below	240 (56.9)	377 (45.3)	425 (85.3)	1042 (59.4)	
Higher than secondary school	182 (43.1)	456 (54.7)	73 (14.7)	711 (40.6)	<0.001
Employment (n, %)					
Unemployed	368 (87.2)	640 (76.8)	420 (84.3)	1428 (81.5)	<0.001
Currently employed	54 (12.8)	193 (23.2)	78 (15.7)	325 (18.5)	
Gravida (median, IQR)	2 (2–3)	2 (1–3)	2 (1–3)	2 (1–3)	<0.001
Prior history of gestational diabetes (n, %)					
Without prior history	388 (91.9)	762 (91.5)	455 (91.4)	1605 (91.6)	0.946
With prior history	34 (8.1)	71 (8.5)	43 (8.6)	148 (8.4)	
Family history of diabetes in first degree relatives (n, %)					
Without family history	183 (43.4)	458 (55.0)	241 (48.4)	882 (50.3)	<0.001
With family history	239 (56.6)	375 (45.0)	257 (51.6)	871 (49.7)	
Body weight, kg (mean, SD)	63.7 (10.6)	63.9 (12.9)	63.8 (11.5)	63.8 (12.0)	0.981
Body mass index, kg/m^2 (mean, SD)	27.6 (4.3)	26.4 (4.9)	26.6 (4.4)	26.8 (4.6)	<0.001
Body mass index classification (n, %)[2]					
Underweight	9 (2.2)	25 (3.0)	10 (2.0)	44 (2.5)	
Normal weight	100 (24.2)	324 (39.0)	181 (36.4)	605 (34.7)	
Overweight	190 (45.9)	298 (35.9)	206 (41.4)	694 (39.8)	
Obese	115 (27.8)	183 (22.1)	101 (20.3)	399 (22.9)	<0.001
Waist circumference, cm (mean, SD)	92.8 (11.5)	89.5 (12.4)	88.5 (11.1)	90.0 (12.0)	<0.001
Systolic blood pressure, mmHg (mean, SD)	115.9 (12.8)	112.8 (9.4)	111.3 (12.5)	113.1 (11.3)	<0.001
Diastolic blood pressure, mmHg (mean, SD)	76.0 (11.2)	74.5 (7.9)	74.6 (9.1)	74.9 (9.2)	0.021
Fasting plasma glucose during pregnancy, mg/dL (mean, SD)	97.2 (11.5)	97.3 (10.5)	97.7 (10.5)	97.4 (10.7)	0.674
Glucose 2 h post OGTT during pregnancy, mg/dL (mean, SD)	152.3 (26.4)	142.8 (30.9)	149.7 (26.6)	147.1 (29.0)	<0.004

[1] N varies by variable.
[2] BMI classification: *underweight* (<18.5 kg/m2); *normal weight* (18.5–24.9 kg/m^2); *overweight* (25.0–29.9 kg/m^2); *obese* (>30.0 kg/m^2).
* p values presented are for statistical difference for the variables between the countries.

(n = 1308). Median follow-up time was calculated by reversing the Kaplan-Meier estimate as suggested by Schemper and Smith 1996 [17]. Cox proportional hazards model was used (i) to analyse time to the development of DM by country (i.e., Bangladesh *vs* India *vs* Sri Lanka), and by baseline glycaemic status (i.e., normal glucose tolerance *vs* IFG *vs* IGT *vs* IFT and IGT); and (ii) to determine risk factor associations of incident DM with study centre as random effect. Adjusted analyses were conducted by including age, education, employment, time from delivery to first postpartum visit, prior GDM history, family history of DM, pregnancy count, insulin use during pregnancy, BMI category, and treatment allocation in the model. Analyses were conducted in STATA BE V17.0 for Windows (StataCorp LLC, College Stations, TX, USA). No imputation for missing data was conducted.

3. Results

3.1. Baseline characteristics

In this study, there were 1808 women (23.8 %, 47.8 %, and 28.4 % from Bangladesh, India, and Sri Lanka respectively) who participated, had mean ± SD age of 31.0 ± 5.0 years, and duration of 6.6 ± 3.0 months from childbirth to first postpartum visit (details regarding study numbers for this particular study have been provided in the supplementary file). Of them, 325 women (18.5 %) were employed, and 1042 (59.4 %) had school education up to or less than secondary school level (≤10 years). Prior history of GDM preceding the index pregnancy was present in 148 (8.4 %) women. The median (IQR) gravida number, i.e., pregnancy count, was 2 (1,3). Overweight/obesity was present in 62.7 % of women. The total median follow-up time was 1.82 (1.34–2.32) years, with follow up time from date of delivery to first post-partum visit after delivery being 0.50 (0.37–0.65) years and first post-partum visit after delivery to last visit being 1.40 (1.10–1.87) years. Detailed information on baseline characteristics, including country wise data are presented in Table 1.

3.2. The burden of postpartum diabetes

A diagnosis of DM was made in 157 (8.7 %) and prediabetes in 618 (34.2 %) women at first postpartum visit at 6.6 ± 3.0 months after childbirth. The cumulative events of incident DM from time of childbirth till the last follow-up occurred in 310 (17.1 %) [incidence 10.75 (9.62–12.02)/100 person years] women with a median follow-up of 1.82 years (Table 2) (Incidence of 10.75/100 person years implies that if 100 women are observed for one year, we would expect 10.75 women to be newly diagnosed with DM). Data for deterioration of glycaemic category [prediabetes (IFG, IFG, both) to DM; normoglycaemia to prediabetes or DM] calculated from the first visit until the last follow-up visit were available for 810 women with normal glucose tolerance (NGT) and 498 women with prediabetes. DM was diagnosed in 32 (4.0 %), 31 (15.8 %), 29 (18.0 %) and 62 (44.0 %) women with NGT, IFG, IGT, and IFG + IGT respectively. The incidence rate for progression of glycaemia was 30.46 per 100 women years in those with IFG + IGT compared to 2.76 per 100 women-years) in women with NGT at baseline. The adjusted hazard ratio for progression to DM was 9.23 (95 % CI: 5.86, 14.53) in those with IFG + IGT compared to women with NGT at baseline (Table 3). The Kaplan Meier plot for the progression of glycaemia is presented as Fig. 1. A higher proportion of women with isolated IGT had regression to normoglycaemia at follow-up (51.6 %) compared to isolated IFG (32.1 %) and IFG + IGT state (13.5 %).

3.3. Risk factor associations of incident diabetes at first postpartum visit

In a Cox proportional hazards model, higher age, lower educational status, higher pregnancy count, prior history of GDM (other than the index pregnancy), family history of DM, and overweight/obese status were significantly associated with incident DM (Table 4).

3.4. Country-specific incident diabetes

Women evaluated in Bangladesh had a higher cumulative incidence of DM [16.49 (13.54–20.08)/100 person years] than women in Sri

Table 2
Incidence rates of diabetes per 100 person-years and median follow-up time.

Cohort	Person-time	Events	Incidence rate (95 % CI)	Follow-up time, years (Median, IQR)
From date of delivery to last follow-up visit				
Total	**2882.75**	**310**	**10.75 (9.62–12.02)**	**1.82 (1.34–2.32)**
Bangladesh	600.44	99	16.49 (13.54–20.08)	1.69 (1.20–2.17)
India	1442.25	104	7.21 (5.95–8.74)	1.85 (1.36–2.30)
Sri Lanka	840.06	107	12.74 (10.54–15.39)	1.84 (1.44–2.46)

Lanka [12.74 (10.54–15.39)/100 person years], and India [7.21 (5.95–8.74)/100 person years] [Table 2]. The hazard ratio for incident DM in women from Bangladesh was 2.34 (1.77–3.08) and 1.33 (1.01–1.75) compared to India and Sri Lanka respectively. The hazard ratio for incident DM in women from Sri Lanka was 1.76 (1.35–2.31) compared to India (Table 5). The mean BMI of women from Bangladesh was significantly higher than those from India ($p < 0.001$) and Sri Lanka ($p = 0.009$) (Table 1). The combined prevalence of overweight and obesity was 73.7 %, 58.0 % and 61.7 % in Bangladesh, India, and Sri Lanka, respectively.

3.5. Country-specific risk factors

Out of the risk factors associated with incident DM (Table 4), women from Bangladesh had significantly higher pregnancy count, family history of DM and overweight/obese status, despite having significantly lower age. Sri Lanka had significantly lower educational status (Table 1). There was no significant difference among three countries for the prior history of GDM (other than the index pregnancy).

Table 3
Change in glycaemic status among randomized participants.

Baseline status (n, %)		Follow-up status (n, %)			Incidence rates of diabetes (95 % CI) per 100 person-years	Median follow-up time (IQR), years	HR for deterioration in glycaemic status[1]	
		Normal	Prediabetes	Diabetes			Unadjusted	Adjusted[2]
NGT	810 (61.9)	533 (65.8)	245 (30.3)	32 (4.0)	2.76 (1.95–3.90)	1.31 (1.07–1.74)	REF	REF
IFG	196 (15.0)	63 (32.1)	102 (52.0)	31 (15.8)	10.24 (7.20–14.56)	1.63 (1.18–1.99)	3.36 (2.02–5.59)	3.08 (1.84–5.15)
IGT	161 (12.3)	83 (51.6)	49 (30.4)	29 (18.0)	12.11 (8.41–17.42)	1.52 (1.14–1.96)	5.03 (2.99–8.45)	4.40 (2.62–7.38)
IFG + IGT	141 (10.8)	19 (13.5)	60 (42.6)	62 (44.0)	30.46 (23.75–39.07)	1.83 (1.20–2.29)	10.36 (6.66–16.11)	9.23 (5.86–14.53)

The analyses include randomized participants that had an end-of-study follow-up OGTT or at least 1 follow-up OGTT [**N = 1308**]. The calculation of time-to-event is from the **first post-partum visit after delivery (i.e. registration visit) to the last follow-up visit**.

[1] Deterioration in glycaemic status defined as having diabetes at follow-up visit; NGT as reference.

[2] Adjusted for baseline age, education, employment, time since delivery, prior history of GDM, family history of diabetes, gravida, insulin use during pregnancy, baseline BMI category, and treatment allocation.

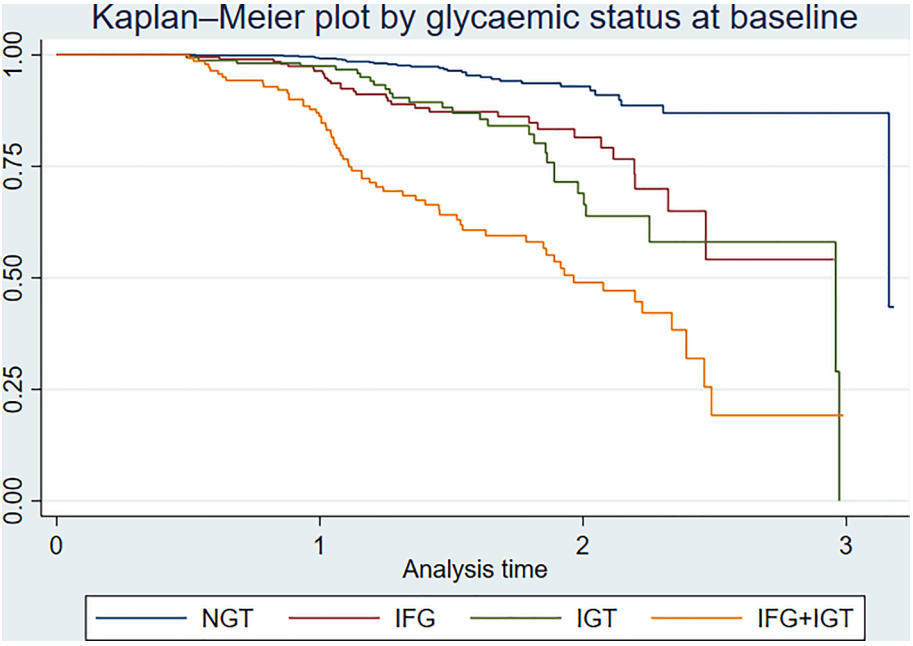

Fig. 1.

Table 4
Factors associated with incidence of diabetes.

Variables	Adjusted HR (95 % CI)	p-value
Age, years	1.04 (1.01–1.06)	0.008
Education		
Secondary school or below	REF	
Higher than secondary school	0.56 (0.41–0.76)	<0.001
Employment		
Unemployed	REF	
Currently employed	0.78 (0.56–1.11)	0.168
Gravida, count	0.89 (0.79–0.99)	0.038
Prior history of gestational diabetes		
Without prior history	REF	
With prior history	1.79 (1.29–2.49)	0.001
Family history of diabetes in first degree relative		
Without family history	REF	
With family history	1.36 (1.06–1.74)	0.015
Body mass index classification		
Normal or underweight	REF	
Overweight	1.57 (1.18–2.10)	0.002
Obese	1.68 (1.22–2.32)	0.001

Note: Cox-proportional hazards model, with study center as random effect. In evaluation of association between a risk factor and outcome, all risk factors included in this table were adjusted.

Table 5
Difference in risk of diabetes between countries.

Comparison	HR (95 % CI)[1]	p-value
From date of delivery to last follow-up visit		
Bangladesh *vs* India (reference)	2.34 (1.77–3.08)	<0.001
Sri Lanka *vs* India (reference)	1.76 (1.35–2.31)	<0.001
Bangladesh *vs* Sri Lanka (reference)	1.33 (1.01–1.75)	0.045

[1] Estimated from a Cox proportional hazard model.

4. Discussion

There was a high burden of DM (17.1 %), with incidence of 10.75 (95 % CI: 9.62–12.02)/100 person years at a median follow-up of 1.82 years in women with prior GDM, in this multi-centre study in which we evaluated 1808 women from three South Asian countries (Bangladesh, India, Sri Lanka). Age, lower education status, higher pregnancy count, prior history of GDM (other than the index pregnancy), family history of DM, and overweight/obese status were significantly associated with incident DM. Interestingly, a significantly higher incidence of DM at follow-up was found among women in Bangladesh when compared to India and Sri Lanka.

In our earlier work, we evaluated a cohort of women diagnosed using IADPSG criteria in a single-centre study. We reported the long-term follow-up on these women (five years since diagnosis) and found that DM rates were low (10.5 %), but prediabetes rates were still high (47.2 %) [8]. The current study adds incident data on DM after first postpartum visit, which was not available in our previous study [8], and even from other studies from South Asia [6]. South Asians have high rates of cardiovascular diseases seen at a relatively younger age and lower BMI compared to Caucasians [18]. GDM has an independent association with increased cardiovascular disease irrespective of development of DM in future [19]. However, the development of DM increases the strength of the association between GDM status and the development of cardiovascular disease [20]. As the IADPSG criteria are a relatively newer entity, and the risk of DM is not the same as those diagnosed with GDM with the Carpenter and Coustan criteria, more studies to understand the rate of development of DM and future cardiovascular diseases are required [20].

There have been some recent data regarding postpartum DM in other ethnic groups. In a European study (Belgium), the prevalence of prediabetes and DM were 26.1 % and 1.9 % when women with GDM were evaluated at 11.8 (3.1) weeks postpartum [10]. In the Pandora study among First Nations women from Australia, the postpartum prediabetes and DM among women with GDM over a median of 2.5 years follow-up, was present in 13 % each [11]. The results on long-term follow-up of women diagnosed with GDM using IADPSG criteria were also reported from the HAPO study. The rates of DM and prediabetes in the HAPO study were 10.7 % and 41.5 % at a median follow-up of 11.4 years after childbirth [9]. We found a higher burden of DM (17.1 %) but at a median follow-up of 1.82 years, a difference of a decade which is significant from a clinical perspective. Moreover, in the HAPO study, women diagnosed with GDM did not receive any lifestyle modification or pharmacotherapy advice [21]. They were unaware of their disease state, compared to women in our study who were aware and had an opportunity to modify their lifestyle. Our study results add to the available data, as the HAPO study did not represent the South Asian countries, which have a large population base. The comparison of data with those from other regions suggest that rates of prediabetes and DM are relatively higher in South Asians when compared to other ethnicities.

Higher age, prior history of GDM (other than the index pregnancy), and overweight/obese status were significantly associated with prediabetes and DM. The women who were educated higher than secondary school had a significantly lower risk for DM. Women with a family history of DM had a significantly higher risk for DM. In a recent systematic review and *meta*-analysis of studies from Asia, family history of DM, gestational age at diagnosis of GDM, insulin use during pregnancy, and pre-pregnancy BMI were associated with postpartum DM [22]. Older age and higher BMI (postpartum) at evaluation were reported to have a significant association with DM in women with prior GDM, with similar findings as in this study [8]. This suggests that with increasing age and BMI at conception, not only will the prevalence of GDM increase, but a higher proportion of women will develop DM. This could translate into huge absolute number of women living with DM.

Though figures were consistently high across the three nations, there were regional variations. Interestingly, we saw a significantly higher incidence of DM at follow-up in women in Bangladesh when compared to India and Sri Lanka. The differences in risk between the countries could be due to differences in the sociodemographic factors. Given this heterogeneity among country and with possibility of the same even among centres within same country, study centre was included as random effect in the models. Similar regional variations were also found by another study, but for prevalence of GDM during pregnancy. The prevalence of GDM was found to be higher in immigrant women from Bangladesh (7.4 %), followed by Sri Lanka (6.3 %) and India (4.4 %), compared to non-immigrant women (0.8 %) [23]. Similar regional variations have been reported for atherosclerotic cardiovascular disease. In the U.K. Biobank study, participants of Bangladesh origin had higher

incidence of atherosclerotic cardiovascular disease followed by migrants from Sri Lanka and India. The understanding of the risk of future DM is essential, more so in South Asians as comparison of population-attributable fractions of cardiovascular risk factors in this U.K. Biobank study found that DM might explain 22 % of the risk of future atherosclerotic cardiovascular events in South Asians *vs* 7 % in Europeans [24]. Out of the risk factors associated with incident DM, women from Bangladesh had significantly higher pregnancy count, family history of DM and overweight/obese status, despite having significantly lower age, which could be responsible for higher rates of DM in women from Bangladesh.

There are significant strengths of this study. Prior studies were conducted at single centres, predominantly in India. These data from 19 centres from three nations have greater value for the South Asian region. Most studies are cross-sectional, and data on incident DM seen after the first postpartum visit is limited [6]. Here, we report data separately for the first postpartum visit, cumulative events till the last follow-up, and rates of progression of DM seen after the first postpartum evaluation. This study also has some limitations. We report findings till a median of 1.82 years after diagnosis of GDM, so long term data are not included in this analysis. We do not have a comparator group with normoglycaemia during pregnancy, as the data for this study was acquired from a lifestyle intervention program undertaken in women with prior GDM. The women were mainly from urban areas, so the results may not reflect the disease burden of the rural Asian population. Plasma glucose was analysed in laboratories of respective centres except Bangladesh, where it was centralized. Laboratories in all except two out of nineteen participating centres participated in an external quality assurance program. Though all centres were urban tertiary care facilities, country related differences due to heterogeneity in centres, glucose related analytical methods, or due to demographic factors cannot be ruled out.

To conclude, a high prevalence of DM was found in women with prior GDM in South Asia diagnosed with the IADPSG criteria. High-risk women, especially those with both IFG and IGT, higher age, BMI, and family history of DM, had a higher risk of incident DM. The risk was high in all three countries but significantly higher in women from Bangladesh than in Sri Lanka and India. This study confirms the very high cardiometabolic risk in Women in South Asia and emphasises the need to identify and intervene early to reduce future risk of DM. Future global guidelines need to establish and implement effective strategies for follow-up and intervention taking into account the ethnicity, glycaemia status at the first postpartum visit, and individual non-glycaemic risk factors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Author **Contributions:** NT and AP conceived the study and obtained funding. YG, NT and AP wrote the first draft. JS did the statistical analysis. All other authors contributed to concept, design or operational aspects the study and contributed to revisions of the draft. NT and AP had full access to all of the data in the study and take responsibility for the integrity of the data and accuracy of the data analysis. All members of the LIVING Collaborative Group are listed in the Supplement.

Data sharing

Data, protocols, and all documentation around the analyses presented here will be made available to academic and other researchers after approval of a Data Access Request. A request form can be obtained by email to DSC@georgeinstitute.org.

Funding

This study was funded by Global Alliance for Chronic Disease grants from the Indian Council of Medical Research (NO.58/1/1/GACD/NCD-II) and Australian National Health and Medical Research Council (1093171). Additional funding was received from USV Pharmaceuticals Ltd. and Lupin Pharmaceuticals Ltd. for sub-studies (data not reported here).

Role of the funders

The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2023.110893.

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