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Secular trend in prevalence and socioeconomic correlates of diabetes in pregnancy in Taiwan

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Synopsis
Diabetes in pregnancy, particularly pre-pregnancy type 2 diabetes, has been increasing in Taiwan, and it shows obvious socioeconomic inequality and urban–rural disparity.

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CLINICAL ARTICLE

Clinical Article Obstetrics

Secular trend in prevalence and socioeconomic correlates of diabetes in pregnancy in Taiwan

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Abstract

Objective: To assess the trend in prevalence and socioeconomic correlates of diabetes in pregnancy (DIP) in Taiwan from 2007 to 2014.

Methods: In all, 1 606 344 pregnancies, including 199 383 DIP (1693 with pre-pregnancy type 1 diabetes [T1DM], 17 171 with pre-pregnancy type 2 diabetes [T2DM], and 180 519 with gestational diabetes mellitus [GDM]) were investigated. Logistic regression models were performed to identify the covariates significantly associating with DIP.

Results: Over the study period, the prevalence of pre-pregnancy T2DM increased by 568.44%; the prevalence of T1DM and GDM also increased but with a smaller magnitude. However, only the prevalence of pre-pregnancy T2DM showed an increase after socioeconomic variables were considered. Compared with immigrant mothers, native-born mothers had a significantly higher adjusted odds ratio of DIP, particularly pre-pregnancy T1DM (3.33, 95% confidence interval 1.57–7.05). Additionally, indigenous mothers and those from rural areas had a higher prevalence of pre-pregnancy T2DM but lower prevalence of GDM. Lower maternal education and income were associated with higher prevalence of pre-pregnancy T1DM but lower prevalence of pre-pregnancy T2DM and GDM.

Conclusion: Socioeconomic variables largely accounted for the increased secular trend in pre-pregnancy T1DM and GDM, but the prevalence of pre-pregnancy T2DM still doubled, which was independent of socioeconomic covariates.

KEYWORDS
diabetes in pregnancy, epidemiology, prevalence, socioeconomic status

1 | INTRODUCTION

Diabetes in pregnancy (DIP) primarily includes pre-existing type 1 (T1DM) and type 2 (T2DM) diabetes and gestational diabetes (GDM) diagnosed during pregnancy.[1] Previous studies showed that women with GDM were likely to have T2DM after delivery, and pre-existing diabetes and GDM were often accompanied by pre-eclampsia leading to high-risk pregnancies and long-term risks of cardiovascular disease and stroke.[2] DIP may also confer higher risks of preterm birth, fetal or infant deaths, fetal/neonatal hypertrophic cardiomyopathy, neonatal respiratory problems, congenital anomalies, hypoglycemia, macrosomia, and birth trauma.[3,4]

The prevalence of DIP has been growing in many parts of the world. The incidence of GDM rapidly increased by 1.8-fold in Taiwan

Chin-Li Lu and Jia-Ling Wu contributed equally to this work.

from 2004 to 2015[5] and by threefold in South Korea from 2006 to 2010.[6] Although GDM accounts for the majority (86.4%) of overall cases of DIP,[1] pre-existing diabetes is also emerging as an important source of DIP in several countries. For example, pre-pregnancy T2DM but not GDM rapidly increased in Sweden between 1998 and 2012.[7] The incidence of T2DM in adolescents is increasing in many countries, and the increasing trend just lagged behind the increase of obesity. Among US youth, the greatest increases of T2DM incidence were seen in Asian/Pacific Islander youth and Hispanic youth.[8] Given a notable increase in the prevalence of T1DM and T2DM among adolescents and young adults in many Asian countries, including Taiwan,[9] women of childbearing age in many Asian societies are at increased risk of DIP. However, population-based data of DIP prevalence from Asia and information of the secular trend in DIP prevalence and its socioeconomic contributors are rarely available. Therefore, we used nationwide health data to estimate the DIP prevalence in Taiwan during 2007–2014 and to investigate the major socioeconomic contributors to each type of DIP.

2 | MATERIALS AND METHODS

The study proposal was approved by the Institutional Review Board of the National Cheng Kung University Hospital (No. B-ER-107-014). All research data were analyzed on-site and the analytical results are only available as table data. Therefore, the Institutional Review Board also issued an approval on a waiver of consent from the study participants.

Data were retrieved from several national data sets supervised by the Health and Welfare Data Science Center, Ministry of Health and Welfare, Taiwan. These data sets comprised several population-based registries, including Birth Notifications (2007–2014), Household Registration (2007–2014), and beneficiary registry and medical claims of the National Health Insurance (NHI) program (2007–2014). The contents of these data sets were available from our previous publications.[5]

In Taiwan, it is compulsory to report all births with gestational age no less than 20 weeks or weighing no less than 500 g, including stillbirths and deaths. We conducted a time-series analysis based on a total of 1 618 551 pregnancies, including fetal deaths, in 1 245 228 mothers that were registered in Birth Notifications between 2007 and 2014 in Taiwan. The difference between the number of pregnancies and that of mothers is a result of mothers showing multiparity during the study period. We first excluded the pregnancies with missing information on mother's Personal Identification Number ($n = 9$) or maternal age at delivery ($n = 11\,736$). Pregnancies with maternal ages of less than 15 or more than 50 years ($n = 462$) at delivery were further excluded, leaving 1 606 344 pregnancies in this study. Singletons and multiple births were all included. Among these pregnancies, 1693 were in mothers with pre-pregnancy T1DM (International Classification of Diseases 9th edition clinical modification [ICD-9CM]: 250.x1 or 250.x3), 17 171 in mothers with pre-pregnancy T2DM (ICD-9CM: 250.x0 or 250.x2), and 180 519 in mothers with GDM (ICD-9CM: 648.0 or 648.8).

During our study period (i.e. 2007–2014), the screening method of GDM generally included the two-step approach containing a first 50-g screen followed by a 100-g oral glucose tolerance test for those who screen positive (criteria stated by National Diabetes Data Group or Carpenter & Coustan) and the one-step 75-g oral glucose tolerance test (criteria stated by International Association of the Diabetes and Pregnancy Study Groups criteria, IADPSG). The choice was primarily an obstetrician's preference. However, the IADPSG one-step method has been recommended by the Taiwan Society of Perinatology since 2011[10] and has been included on the list of reimbursements of the National Health Insurance since 2020.

Continuous variables and number (percentage) for categorical variables were described and compared using mean ± standard deviation. We then calculated the bi-annual crude, age-specific, and age-standardized prevalence of DIP over the study period using pregnant women in 2007–2008 as reference. Univariate and multivariate logistic regression models were used to calculate crude (OR) and adjusted (aOR) odds ratios and 95% confidence intervals (CIs) of DIP in relation to various socioeconomic characteristics. The generalized estimation equation, which specified an exchangeable structure of a working correlation matrix to consider the within-subject correlations,[11] was used in the logistic regression models to account for pregnancies with the same mothers. All statistical analyses were performed using SAS statistical software (SAS System for Windows, Version 9.4, SAS Institute Inc.). Those results with two-sided P values less than 0.05 were considered statistically significant.

3 | RESULTS

Distributions of various maternal socioeconomic characteristics significantly varied with DIP status. Compared with those without DIP, pregnancies with DIP were associated with older age, married status, and native-born mothers. Mothers with pre-pregnancy T1DM were socioeconomically disadvantaged. They were likely to be indigenous people, less educated, living in non-urban areas, and having lower income. In contrast, mothers with pre-pregnant T2DM and GDM had higher educational and income levels (Table 1). The crude ORs of DIP in relation to the selected socioeconomic characteristics are shown in the Supplementary material (Table S1).

Table 2 shows the overall, age-specific, and age-standardized prevalence of DIP over time. Pre-pregnancy T2DM showed the most notable increase, from 2.63‰ in 2007–2008 to 17.58‰ in 2013–2014, representing an increase of 568.44%. Such an increase was more evident in older mothers. The prevalence of pre-pregnancy T1DM also doubled from 0.65‰ to 1.42‰ (an increase by 118.46%) in 2007–2008, and mothers aged 30–34 years experienced the greatest increase (158.00%). The prevalence of GDM only slightly increased by 29.3%, from 91.17‰ to 125.64‰. The aforementioned secular trends were slightly lessened after maternal age was standardized (Figure 1).

Compared with non-DIP, the aORs of pre-pregnancy T2DM and GDM, but not of pre-pregnancy T1DM, increased in recent years.

TABLE 1 Demographic characteristics of all pregnancies in 2007–2014 (n = 1 606 344)[a]

Covariates	Non-diabetic pregnancy (n = 1 406 961)		Pre-pregnancy T1DM (n = 1693)		Pre-pregnancy T2DM (n = 17 171)		GDM (n = 180 519)		P value
Calendar year									
2007–2008	361 031	(25.66)	261	(15.42)	1057	(6.16)	38 999	(21.60)	<0.001
2009–2010	318 038	(22.60)	341	(20.14)	3158	(18.39)	39 384	(21.82)	
2011–2012	378 348	(26.89)	509	(30.06)	5773	(33.62)	50 795	(28.14)	
2013–2014	349 544	(24.84)	582	(34.38)	7183	(41.83)	51 341	(28.44)	
Maternal socioeconomic characteristics									
Maternal age at delivery, y	30.51 ± 4.75		31.32 ± 5.07		32.75 ± 4.21		31.81 ± 4.56		<0.001
15–30	622 055	(44.21)	661	(39.04)	4187	(24.38)	59 770	(33.11)	<0.001
30–34	547 513	(38.91)	616	(36.39)	7826	(45.58)	77 571	(42.97)	
35–40	207 790	(14.77)	344	(20.32)	4518	(26.31)	36 823	(20.40)	
40–50	29 603	(2.10)	72	(4.25)	640	(3.73)	6355	(3.52)	
Married	1 208 957	(85.93)	1503	(88.78)	16 134	(93.96)	163 515	(90.58)	<0.001
Born in Taiwan	965 963	(68.66)	1400	(82.69)	15 637	(91.07)	134 816	(74.68)	<0.001
Indigenous people	45 823	(3.52)	86	(5.20)	747	(4.48)	4722	(2.74)	<0.001
Education level									
Junior high school or below	88 357	(6.28)	136	(8.06)	744	(4.33)	7853	(4.35)	<0.001
Senior high school	522 264	(37.12)	710	(41.91)	5448	(31.73)	60 329	(33.43)	
University	707 983	(50.32)	764	(45.12)	9336	(54.37)	97 751	(54.15)	
Master or above	88 357	(6.28)	83	(4.91)	1643	(9.57)	14 586	(8.08)	
Residence									
Metropolitan	638 479	(45.38)	719	(42.47)	7622	(44.39)	90 873	(50.34)	<0.001
Satellite city/town	429 123	(30.50)	549	(32.43)	4581	(26.68)	49 246	(27.28)	
Rural area	339 359	(24.12)	425	(25.10)	4968	(28.93)	40 400	(22.38)	
Income level (NTD)									
$0–$20 099	462 327	(32.86)	668	(39.46)	4657	(27.12)	52 729	(29.21)	<0.001
$20 100–$23 099	334 435	(23.77)	406	(23.98)	3920	(22.82)	41 718	(23.11)	
$24 000–$38 199	322 898	(22.95)	381	(22.50)	4162	(24.24)	42 639	(23.62)	
≥$38 200	287 301	(20.42)	238	(14.06)	4432	(25.81)	43 433	(24.06)	
Birth outcomes									
Gender of fetus (male)	730 036	(51.91)	877	(51.89)	8944	(52.11)	95 183	(52.73)	<0.001
Gestational age, wk	38.11 ± 2.34		36.75 ± 3.27		37.49 ± 2.65		38.20 ± 1.65		<0.001
Preterm	138 118	(9.82)	476	(28.12)	2932	(17.08)	17 689	(9.80)	<0.001
Birth weight, g	3033.92 ± 522.83		3088.17 ± 827.31		3059.14 ± 636.82		3098.01 ± 474.70		<0.001

Abbreviations: GDM, gestational diabetes mellitus; NTD, New Taiwan Dollar (1 USD ≡ 31 NTD); T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

[a]Data are presented as mean ± standard deviation or as number (percentage).

TABLE 2 Secular trend in crude and age-standardized prevalence of diabetes in pregnancy[a]

Total no. of pregnancy	Calendar year 2007–2008 (n = 401 348)		2009–2010 (n = 360 921)		2011–2012 (n = 435 425)		2013–2014 (n = 408 650)		Change[b] (%)
Crude prevalence (per 1000)									
Pre-pregnancy T1DM	261	0.65	341	0.95	509	1.17	582	1.42	118.46
15–30 years	137	0.65	145	0.89	183	1.07	196	1.37	110.77
30–34 years	69	0.50	113	0.81	211	1.15	223	1.29	158.00
35–40 years	47	1.01	68	1.35	95	1.33	134	1.65	63.37
40–50 years	8	1.25	15	2.00	20	1.92	29	2.35	88.00
Pre-pregnancy T2DM	1057	2.63	3158	8.75	5773	13.26	7183	17.58	568.44
15–30 years	443	2.11	972	5.95	1363	7.99	1409	9.88	368.25
30–34 years	430	3.11	1436	10.28	2720	14.86	3240	18.80	504.50
35–40 years	165	3.55	664	13.19	1477	20.71	2212	27.19	665.92
40–50 years	19	2.96	86	11.45	213	20.46	322	26.10	781.76
GDM	38 999	97.17	39 384	109.12	50 795	116.66	51 341	125.64	29.30
15–30 years	16 192	77.10	13 918	85.16	15 465	90.64	14 195	99.55	29.12
30–34 years	15 617	112.82	17 040	122.02	22 651	123.73	22 263	129.15	14.47
35–40 years	6227	133.94	7216	143.39	10 797	151.39	12 583	154.70	15.50
40–50 years	963	150.16	1210	161.12	1882	180.77	2300	186.45	24.17
Age-standardized prevalence[c] (per 1000)									
Pre-pregnancy T1DM	261	0.65	341	0.93	509	1.14	582	1.39	113.85
Pre-pregnancy T2DM	1057	2.63	3158	8.37	5773	12.03	7183	15.22	478.71
GDM	38 999	97.17	39 384	105.83	50 795	110.53	51 341	117.54	20.96

Abbreviations: GDM, gestational diabetes mellitus; T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

[a]Data are presented as number (percentage).

[b]Change (%): percentage of change in the prevalence of diabetic pregnancy between 2007 and 2014.

[c]Standardized for maternal age using the age composition of mothers who gave birth in 2007–2008 as the reference.

Older maternal age was associated with higher aORs of all types of DIP. Native-born mothers had higher aORs of pre-pregnancy T1DM and T2DM of 3.33 (95% CI 1.57–7.05) and 3.07 (95% CI 2.36–4.00), respectively, but had only slightly higher aOR of GDM of 1.11 (95% CI 1.05–1.18). Mothers of indigenous people had higher aOR (1.56, 95% CI 1.44–1.68) of pre-pregnancy T2DM but lower aOR of GDM (0.95, 95% CI 0.92–0.98). Rural residence was associated with a higher aOR of pre-pregnancy T2DM (1.49, 95% CI 1.44–1.55) but a lower aOR of GDM (0.94, 95% CI 0.93–0.95). Increasing levels of education and income were inversely associated with pre-pregnancy T1DM but positively associated with pre-pregnancy T2DM and GDM (Table 3).

4 | DISCUSSION

This study was the first nationwide and population-based report in Taiwan to describe the prevalence of DIP and its secular trend and socioeconomic determinants. An increasing trend in DIP has been observed in many population-based studies from western societies,[7] but it was rarely studied in Asia. The GDM prevalence in a southern city of China was stable between 2012 and 2017,[12] whereas it increased in South Korea between 2006 and 2010.[6] A recent Taiwanese study reported a 1.8-fold increase in GDM prevalence between 2004 and 2015.[5]

Our study noted that the age-standardized prevalence of pre-pregnancy T1DM and T2DM showed a one-fold and five-fold increase, respectively, during 2007–2014. In addition, GDM only slightly increased by 20%. However, when various socioeconomic variables and urbanization were adjusted, the significantly increasing trend was observed only for pre-pregnancy T2DM. Lu et al.[13] reported that the annual incidence rate of T1DM among Taiwanese children aged less than 15 years was stable at 5.3 per 100 000 in 2003–2008 irrespective of age and gender. Updated analysis of data in 2005–2014 suggested that the age-standardized incidence of

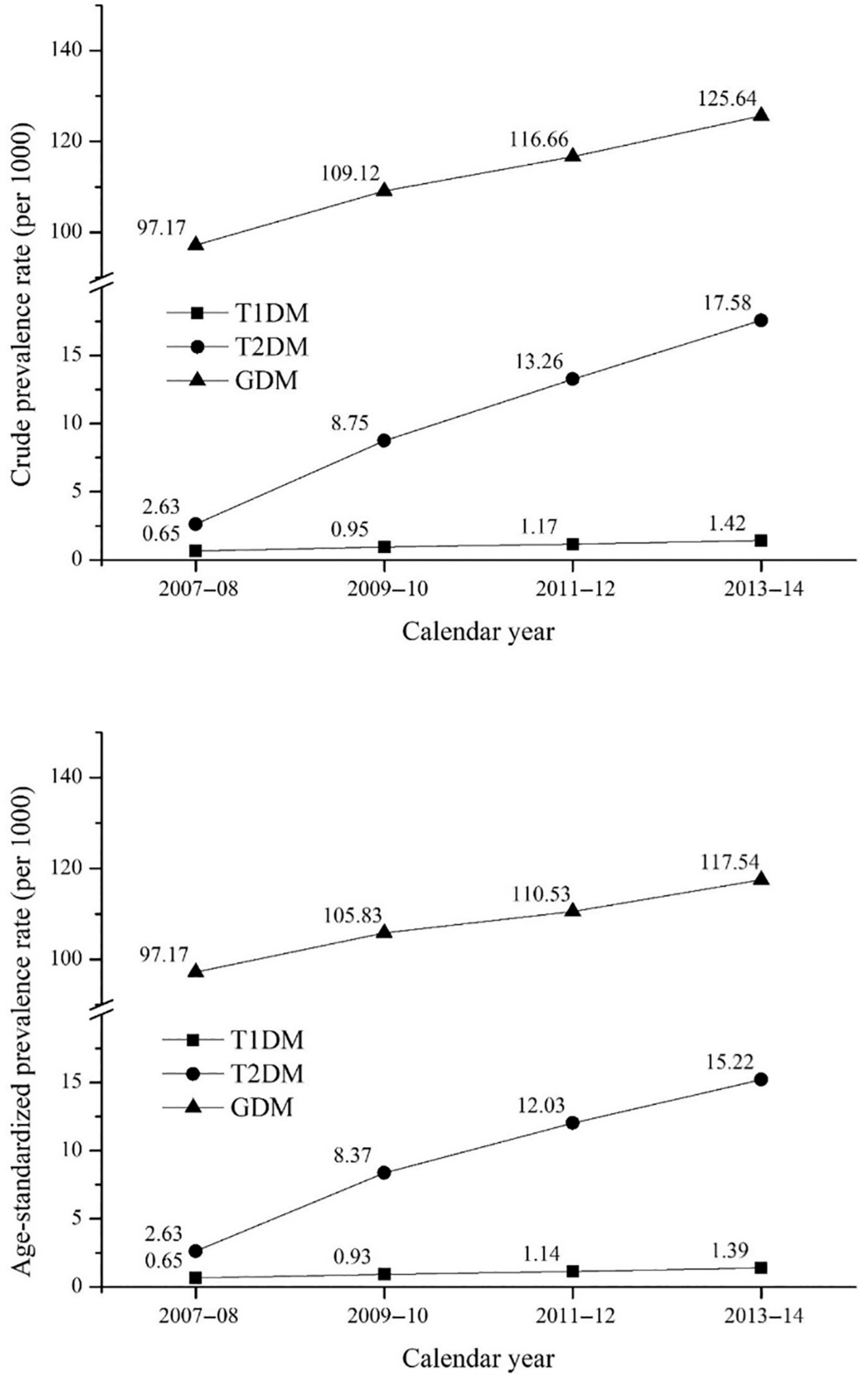

FIGURE 1 Secular trend in the crude (top) and age-standardized (bottom) prevalence of diabetes in pregnancy (DIP). *Tests for trend in crude and standardized DIP of various types are all significant at *P* values less than 0.05, which is based on the generalized estimation equation to fit the Poisson regression model, including calendar year as a continuous variable that considers the inter-correlation of pregnancies by the same mother and yields robust standard errors estimated in the model.

T1DM slightly decreased by 11% ($P = 0.118$), and the standardized prevalence of T1DM slightly increased from 0.04% to 0.05%,[9] which was consistent with our findings, that is, the prevalence of pre-pregnancy T1DM showed a slight reduction after socioeconomic variables were considered. Based on previous reports, young-onset T2DM has increased in many Asian countries, including Taiwan.[9] The incidence of T2DM increased from 15 to 19 per 100000 (26.7%) in women younger than 20 years and from 94 to 126 per 100000 (34.0%) in women aged 30–39 years in Taiwan.[9] An apparent increase in the incidence of T2DM among younger women may contribute to the increase in pre-pregnancy T2DM in Taiwan. The more rapid increase in pre-pregnancy T2DM prevalence rather than GDM may be largely contributed by changes of socioeconomic status-related risk factors in Taiwan during our study period. Compared with the non-diabetes group, the OR for pre-pregnancy T2DM in 2013–2014 relative to that in 2007–2008 markedly decreased from 7.02 to 2.00

TABLE 3 Covariates adjusted odds ratios of diabetes in pregnancy in relation to the selected socioeconomic characteristics of pregnant women

	Pre-pregnancy T1DM vs. Non-diabetes			Pre-pregnancy T2DM vs. Non-diabetes			GDM vs. No-diabetes		
Covariates	**aOR**	**95% CI**		**aOR**	**95% CI**		**aOR**	**95% CI**	
Calendar year									
2007–2008	1.00			1.00	–		1.00		–
2009–2010	0.44*	0.21	0.95	1.08	0.82	1.41	1.00	0.94	1.07
2011–2012	0.55	0.26	1.18	1.54*	1.17	2.01	1.03	0.97	1.09
2013–2014	0.65	0.31	1.40	2.00*	1.52	2.62	1.09*	1.03	1.16
Age at delivery, y									
15–30	1.00			1.00			1.00		
30–34	1.10	0.98	1.23	1.82*	1.75	1.90	1.35*	1.33	1.36
35–40	1.56*	1.36	1.79	2.63*	2.51	2.75	1.67*	1.64	1.69
40–50	2.26*	1.76	2.89	2.67*	2.45	2.91	2.08*	2.02	2.14
Marital status									
Otherwise	1.00			1.00			1.00		
Married	0.86	0.72	1.02	1.78*	1.63	1.94	1.20*	1.17	1.23
Natively born in Taiwan									
No	1.00			1.00			1.00		
Yes	3.33*	1.57	7.05	3.07*	2.36	4.00	1.11*	1.05	1.18
Indigenous people									
No	1.00			1.00			1.00		
Yes	1.26	1.00	1.58	1.56*	1.44	1.68	0.95*	0.92	0.98
Education level									
Junior high school or below	1.00			1.00			1.00		
Senior high school	0.92	0.76	1.11	1.14*	1.06	1.24	1.27*	1.23	1.30
University	0.76*	0.63	0.93	1.18*	1.09	1.28	1.40*	1.36	1.44
Master or above	0.71*	0.53	0.95	1.25*	1.14	1.38	1.47*	1.42	1.51
Income level (NTD)									
$0–$20 099	1.00			1.00			1.00		
$20 100–$23 099	0.91	0.80	1.03	1.21*	1.16	1.27	1.07*	1.06	1.09
$24 000–$38 199	0.85*	0.74	0.97	1.17*	1.12	1.23	1.02*	1.01	1.03
≥ $38 200	0.59*	0.50	0.70	1.30*	1.24	1.36	1.05*	1.04	1.07
Residence									
Metropolitan	1.00			1.00			1.00		
Satellite city/town	1.11	0.99	1.25	1.02	0.98	1.06	0.87*	0.86	0.88
Rural area	1.05	0.93	1.20	1.49*	1.44	1.55	0.94*	0.93	0.95

Abbreviations: aOR, adjusted odds ratio, estimated from multivariate logistic regression model with all covariates listed in Table 3 simultaneously adjusted in the model; GDM, gestational diabetes mellitus; NTD, New Taiwan Dollar (1 USD ≡ 28 NTD); T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

*$P < 0.05$.

after adjusting for age and socioeconomic factors; whereas the OR for GDM only slightly changed from 1.36 to 1.09 after covariate adjustment. In addition, previous studies showed that the one-step screening of GDM may lead to a higher diagnosed rate of GDM.[14]

Based on the IDF Diabetes Atlas, Southeast Asia exhibited the world's highest prevalence of DIP in 2019.[15] However, our study showed that immigrant mothers from South and Southeast Asia had a lower risk of DIP (7.2%) compared with native-born mothers (13.6%) or mothers who came from East Asia (13.0%). Such phenomena might be related to the healthy migrant effect[16] caused by immigrant mothers' younger ages and healthier physical conditions. Pregnancies of indigenous mothers were found to be associated with a higher pre-pregnancy T2DM prevalence but a lower GDM prevalence in this study. Some previous studies reported a high prevalence of metabolic syndromes and substance use, including cigarette smoking and alcohol drinking, in indigenous women before pregnancy,[17] which could lead to a higher pre-pregnancy T2DM in indigenous mothers. A meta-analysis, including 84 cross-sectional studies in Asia, found a high prevalence of GDM in this region, and common risk factors may include history of previous GDM, congenital anomalies, and macrosomia.[18] Whether these unadjusted risk factors were responsible for a lower GDM among indigenous women in Taiwan needs further investigation.

Mothers with higher education and income level were more likely to have GDM and pre-pregnancy T2DM but less likely to have pre-pregnancy T1DM. Unlike our study, previous studies found that people with higher socioeconomic status tended to have better health literacy,[19] adequate nutrient intake,[20] lower obesity rate,[21] and lower gestational weight gain,[22] and these factors may prevent the development of T2DM and GDM. However, previous studies found that people with higher socioeconomic status tended to consume fewer carbohydrates and more protein and fat in their total energy intake composition,[23] and they had higher psychological stress.[24] Greater consumption of protein or fat in energy intake could increase the risk of GDM and T2DM, and psychological stress and mood disorders may elevate cortisol levels leading to increased risk of GDM.[25] Whether the above-mentioned lifestyle factors may have contributed to the high GDM and pre-pregnancy T2DM in Taiwanese pregnant women with higher education and income levels warrants further investigations.

In this study, a negative association between socioeconomic status and pre-pregnancy T1DM might be related to the early-life infection as a risk factor of T1DM. Enteroviruses, which have been endemic in Taiwan for decades, are the most notable contributor to the pathogenesis of T1DM.[26] An earlier case–control study in Taiwan demonstrated that childhood infection was associated with an increased risk of T1DM in 46% of children younger than 15 years.[27] People with lower socioeconomic status tended to experience unsatisfactory environment and crowded living space, leading to a greater risk of enterovirus infection.

As populations move toward a more urban environment, higher rates of obesity and T2DM have been observed,[28] which result from changes in lifestyles and health behaviors (i.e. diet and physical activity)[28] and probably the changing socioeconomic make-up of these new urban populations. Inconsistent with the above-mentioned observation, our study showed a higher pre-pregnancy T2DM in rural rather than in urban areas of Taiwan. Although rural residents have less exposure to the adverse urban environment, living in rural areas might hamper access to healthcare consultation and preventive programs,[29] which might result in a higher risk of pre-pregnancy T2DM. In addition, a lower screening rate for GDM was found in areas with limited healthcare resources in Taiwan,[5] which could also explain, at least to a certain extent, the low GDM among mothers in rural areas.

This study exhibits several strengths. First, this study is the first nationwide population-based report for DIP prevalence and its secular trend and socioeconomic determinants in Taiwan, which is located in a region with high DIP and with 5%–10% of mothers being immigrants from Southeast Asia. Second, the analysis was based on the notional registries, which are complete and representative, and the association of a number of demographic and socioeconomic characteristics with DIP can be examined simultaneously.

This study also has limitations that might have affected interpretations. First, our estimated ORs might be subject to residual confounding because of incomplete consideration of certain potential risk factors for DIP, including parity, family history of diabetes, obesity, and adverse lifestyle such as smoking, alcohol drinking, and physical inactivity. Considering that most of the above-mentioned adverse lifestyles were presumably more common in lower socioeconomic status mothers, failure to account for these risk factors may result in difficulty in interpreting the association between socioeconomic status and DIP. The reported association between parity and GDM in the literature was a conflict.[5,30] A prediction model with good validity of GDM revealed that the association may be modified with or without GDM in the previous pregnancy.[31] However, the parity structure of babies born in Taiwan in each year was quite stable during our study period (2007–2014).[32] Among the total number of newborns in each year, 53% were primipara, 37% were second para. It is unlikely that parity posed sizable confounding that explained more rapid increase in pre-pregnancy T2DM than in GDM during the study period. Second, we relied on diagnosis codes of claim data to identify DIP cases, which were subject to disease misclassification and likely attenuated the true association between socioeconomic status and DIP.

In conclusion, the age-standardized prevalence of all types of DIP increased during the study period, and only the prevalence of pre-pregnancy T2DM remained elevated after various socioeconomic variables and urbanization were adjusted, suggesting the imperative contributions of socioeconomic variables and urbanization to the increasing trend of DIP in Taiwan. Clinicians and health policy makers should pay attention to the evident socioeconomic inequality and urban–rural disparity in DIP, and strategies that can effectively reduce DIP in socioeconomically vulnerable pregnant women are necessary.

AUTHOR CONTRIBUTIONS

CLL, JLW, HYL, SM, and CYL designed the study, contributed to the interpretation of results, and drafted the initial manuscript. CLL, JLW, and CYL performed the statistical analyses. CYL, HYL, and SM revised the manuscript.

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CONFLICT OF INTEREST

The authors report no conflicts of interest.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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