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RESEARCH

Association between adherence to anti-diabetic therapy and adverse maternal and perinatal outcomes in diabetes in pregnancy

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Objectives: To analyse the association between adherence to anti-diabetic therapy (diet, physical activity and medications) and perinatal outcomes.
Methods: A cohort design was used. Participants were 157 pregnant women with diabetes, and the setting was Mbuya Nehanda and Chitungwiza Maternity Hospitals, Harare, Zimbabwe.
Results: Main outcome measures were maternal and perinatal outcomes. Mean adherence to anti-diabetic therapy was 66.7%. Perinatal outcomes observed were hypertensive disorders (34.5%), Caesarean delivery (45.9%), maternal diabetic ketoacidosis (5.1%), maternal hypoglycaemia (15.9%), and candidiasis (19.7%). Neonatal outcomes were perinatal mortality (15.9%), low Apgar score at 1 minute (26.8%), low Apgar score at 5 minutes (24.8%), macrosomia (33.8%), neonatal hypoglycaemia (15.3%), and neonatal hyperbilirubinemia (7.6%). There were significant associations between adherence and Caesarean delivery (RR 1.9, 95% CI 1.28 to 2.81, $p = 0.0014$), candidiasis (RR 3.95, 95% CI 1.65 to 9.47, $p = 0.002$), low Apgar score at 1 minute (RR 2.15, 95% CI 1.16 to 3.98, $p = 0.015$) and at 5 minutes (RR 1.95, 95% CI 1.03 to 3.69, $p = 0.039$), and perinatal mortality (RR 3.08, 95% CI 1.11 to 8.52, $p = 0.018$).
Conclusions: Adherence to anti-diabetic therapy was sub-optimal and was associated with some adverse perinatal outcomes. Promotion of adherence, through routine individualised counselling, monitoring and assessment, is vital to minimise adverse outcomes.

Keywords: anti-diabetic therapy, diabetes, maternal outcomes, perinatal outcomes, pregnancy

Introduction

Diabetes mellitus is a non-communicable disease which is a predominant cause of mortality in Africa.[1] Its global prevalence has risen from 4.7% in 1980 to 8.5% in the adult population.[1] The prevalence of diabetes in Zimbabwe is 5.7%.[2] GDM is glucose intolerance diagnosed during pregnancy after the 24th week of gestation while type I and II diabetes in pregnancy are overt diabetes in previously diagnosed women. The prevalence of pre-gestational type I and type II diabetes is included in the prevalence of diabetes mellitus.

The prevalence of GDM varies between 1% and 14% in all pregnancies depending on the genetic characteristics, environment of the population under study, screening and diagnostic methods employed and prevalence of type II diabetes mellitus.[3] Diabetes in pregnancy increases the risk for various maternal and foetal complications such as pre-eclampsia, postpartum haemorrhage, infection, birth asphyxia, stillbirth and large for gestational age (LGA) infants.[4] High rates of Caesarean delivery then result in macrosomia due to such reasons as cephalo-pelvic disproportion and foetal distress.[4] The Hypoglycaemia and Adverse Pregnancy Outcomes (HAPO) cohort study demonstrated strong evidence of a continuous rather than threshold relationship of pregnancy outcomes with rising hyperglycaemia.[5] Women with well-controlled blood glucose levels can give birth to healthy neonates.[6]

Adherence in pregnant women with diabetes is compromised by overload of advice from different healthcare professionals, self-monitoring of blood glucose (SMBG) and strict dietary manipulation.[7] Physiological demands of pregnancy such as nausea and vomiting compromise adherence to therapy. The main purpose of the study was to develop an adherence promotion framework for women with diabetes in pregnancy to improve adherence and perinatal outcomes. This article focuses on the association between non-adherence and perinatal outcomes.

Methods

This study was conducted at three central hospitals in Zimbabwe with a cohort of 157 pregnant women with diabetes in pregnancy. Consecutive sampling was used. Ethical approval was granted by the respective ethical review boards. All participants gave informed consent. Included in the study were pregnant women aged 18–45 years with diabetes in pregnancy. Excluded from the study were women who had not undergone adherence counselling, the very ill, the institutionalized and those who had previously participated in either the pilot or the main study. Data collection was done from September 2015 to January 2017 through an interviewer-administered questionnaire. The questionnaire had sections on demographics, past and current health history, adherence to diet, physical activity and medications and perinatal outcomes. Adherence level of at least 80%, measured by self-reports, was classified as good adherence while levels below 80% were poor. Participants were followed up from 20–24 weeks' gestation up to 6 weeks post-delivery. Level of adherence was measured after recruitment and respondents were classified as either having good adherence or poor adherence. They were then followed up till 6 weeks after delivery for monitoring of perinatal outcomes. Data were analysed using the statistical package for Social Sciences (SPSS®) version 20 (IBM Corp, Armonk, NY, USA) and STATA (StataCorp LLC, College

Table 1: Demographic variables (n = 157)

Variable	Frequency	Percentage	Cumulative percentage
Type of diabetes:			
Type I	40	25.5	25.5
Type I1	69	43.9	69.4
GDM	48	30.6	100
Age in years:			
18–24	21	13.4	13.4
25–29	37	23.6	36.9
30–34	50	31.8	68.8
35–39	38	24.2	93
40–44	11	7	100
Marital status:			
Single	21	13.4	13.4
Married	130	82.8	96.2
Cohabiting	6	3.8	100
Level of education:			
None	1	0.6	0.6
Primary	18	11.5	12.1
Ordinary	113	72	84.1
Advanced	10	6.4	90.4
Tertiary	15	9.6	100
Employment status:			
Unemployed	91	58	58
Self employed	39	24.8	82.8
Employed	27	17.2	100

Station, TX, USA). Descriptive statistics were used to analyse demographics, adherence levels and perinatal outcomes. Generalised linear regression modelling was used to analyse associations between adherence and perinatal outcomes and was reported as risk ratios.

Results

Demographic variables

Table 1 presents demographic variables. Forty (25.5%) participants had type I diabetes mellitus, 69 (43.9%) had type II while 48 (30.6%) had GDM. Fifty (31.8%) participants were aged between 30 and 34, 130 (82.8%) were married 113 (72.0%) had attained the ordinary level of education while 91 (58%) were unemployed.

Adherence to anti-diabetic therapy

Table 2 presents adherence to anti-diabetic therapy ranges. Twenty-six (16.6%) scored below 50%, 12 (7.6%) scored from 50–59%, 19 (12.1%) scored from 60–69%, 42 (26.8%) scored from 70–79%, 56 (35.6%) scored from 80–89% while 2 (1.3%) scored 90% and above. Fifty-eight (36.9%) scored 80% and above.

Perinatal outcomes

Table 3 presents perinatal outcomes. Fifty-four (34.4%) had hypertensive disorders while 72 (45.9%) had Caesarean delivery. Fifty-three (33.8%) had macrosomia, 42 (26.8%) had low Apgar score at 1 minute and 39 (24.8%) had low Apgar score at 5 minutes.

Table 2: Adherence to anti-diabetic therapy ranges (n = 157)

Variable	Frequency	Percentage	Cumulative percentage
< 50	26	16.6	16.6
50–59 (Poor)	12	7.6	24.2
60–69 (Poor)	19	12.1	36.3
70–79 (Poor)	42	26.8	63.1
80–89 (Good)	56	35.6	98.7
90–100 (Very good)	2	1.3	100.0

Table 3: Perinatal outcomes (n = 157)

Variable	Frequency	Percentage
PIH/pre-eclampsia/eclampsia	54	34.4
Caesarean delivery	72	45.9
Maternal DKA	8	5.1
Maternal hypoglycaemia	25	15.9
Candidiasis/vaginitis	31	19.7
Preterm birth	8	5.1
Perinatal mortality	25	15.9
Low Apgar score at one minute	42	26.8
Low Apgar score at five minutes	39	24.8
Macrosomia	53	33.8
Low birth weight	11	7
Neonatal hypoglycaemia	24	15.3

Table 4: Associations between level of adherence and perinatal outcomes (n = 157)

Variable	Risk ratio	Confidence interval	*p*-value
Maternal outcomes:			
Caesarean delivery	1.90	0.8 to 2.03	0.001*
Hypertension	1.28	0.8 to 2.03	0.305
Maternal DKA	1.76	0.38 to 4.59	0.473
Maternal hypoglycaemia	1.50	0.68 to 3.34	0.312
Preterm birth	1.76	0.38 to 8.23	0.473
Vaginitis/candidiasis	3.95	1.65 to 9.47	0.002*
Neonatal outcomes:			
Apgar < 7 at 1 minute	2.15	1.16 to 3.98	0.015*
Apgar < 7 at 5 minutes	1.95	1.03 to 3.69	0.039*
Macrosomia	0.89	0.57 to 1.4	0.619
Neonatal hypoglycaemia	0.41	0.19 to 0.86	0.019*
Perinatal mortality	3.08	1.11 to 8.52	0.018*

Table 4 presents associations between level of adherence and perinatal outcomes. There were significant associations with Caesarean delivery, vaginitis/candidiasis, low Apgar score at 1 minute and at 5 minutes and perinatal mortality.

Discussion

The pregnancy state in diabetes requires even stricter adherence to therapy because of the detrimental effects of hyperglycaemia on both the mother and the foetus. In terms of type of diabetes,

30.6% participants had GDM, 43.9% had pre-gestational type II diabetes while 25.5% had pre-gestational type I diabetes. This translates to 69.4% pre-gestational diabetes. Many studies conducted have reported much higher percentages of GDM in diabetes in pregnancy.[8–11] The lower proportion of GDM in this study could be a reflection of inadequate screening for GDM in the setting due to lack of resources. In high-income countries GDM screening is an established part of antenatal care with specific procedures clearly defined in national guidelines while screening and management of GDM often is not part of routine care in the majority of low-resource settings.[12] Guidelines are often absent in low-resource settings where, until now, GDM has received less attention than other causes of perinatal morbidity and mortality.[12]

The majority (82.8%) of participants were married. This presents an opportunity for male engagement in the care of women with diabetes in pregnancy. Spouses may provide social support to affirm healthy behaviours and social control to modify health behaviours in their partner's diabetes management.[13]

This is even more relevant in this study where 58% were unemployed, meaning they could have depended on their husbands for support. In terms of education 88% had attained at least an ordinary level of education. Education is an important factor that has an influence on an individual's attitude and outlook on various aspects of life.[14] This presents an opportunity for effective health education of patients as they are able to internalise information given. The patient should know the basic principles regarding diet, maintenance of body weight, resting, and prevention of hypoglycaemia or deregulation of blood sugar. Optimum glucose control is vital in pregnancy and the intensity required necessitates a patient to learn, commit and execute.[15] Findings of a study conducted in China revealed a positive correlation between knowledge of diabetes and self-care behaviours. The score of self-care behaviours was positively related to diabetes knowledge ($r = 0.176$, $p < 0.05$) and attitude ($r = 0.256$, $p < 0.01$).[16]

Adherence to anti-diabetic therapy

Adherence to anti-diabetic therapy in this study referred to adherence to diet, medications and physical activity. Though measured separately, a composite score of overall adherence to therapy was calculated. Mean adherence to anti-diabetic therapy was 68.79%. This was low relative to the 80% adherence required for effective glycaemic control in diabetes. Fifty-eight (36.9%) participants scored above the recommended 80% or higher level of adherence. The majority of research on diabetes in pregnancy highlights its epidemiological, pathological and biological aspects with few authors researching the social and behavioural effects of the diagnosis from the viewpoint of the women affected.[17] Adherence to therapy is one such social behavioural effect of diabetes in pregnancy. Such studies have been done in non-pregnant diabetic populations and similar rates of suboptimal adherence have been reported.[18,19] Non-adherence in diabetes in pregnancy is a very significant problem because diabetes affects pregnant women more than the non-pregnant population due to the presence of more than the usual pregnancy discomforts. Glycaemic control in PGDM is complicated by the presence of physiological pregnancy changes while the need to learn about diabetes and management in a short space of time in GDM is a major challenge. Strict adherence to healthy lifestyle habits must be advocated in health policies worldwide to control diabetes mellitus, particularly in developing countries like Zimbabwe where access to health care and quality of health care are huge problems.

Perinatal outcomes

The most common maternal perinatal outcomes reported in the study were Caesarean delivery (45.9%) and PIH (34.4%). Caesarean delivery is common in diabetic pregnant mothers due to macrosomia.[8] The incidence of macrosomia in this study was 33.8%. The incidence of Caesarean delivery in this study is lower than incidences reported elsewhere in the literature. Rates of Caesarean delivery as high as 92.8%[20] in India, and 89%[21] in Nigeria have been reported in the literature. Some rates of Caesarean delivery reported were 74.3%,[22] in Nigeria and 56% and 39.8% in GDM and in insulin-dependent groups respectively[23] in South Africa. González-Quintero *et al*. (2007) reported a Caesarean delivery rate of 48.5% in the USA.[24] Studies have also demonstrated an increased risk of Caesarean delivery in diabetes in pregnancy.[25] Vaginal delivery of such babies has been associated with shoulder dystocia, birth asphyxia and birth injury, thus the high rates of Caesarean delivery. Other studies have reported lower rates of Caesarean delivery than the one reported in this study. Ozumba *et al*. (2004) revealed an overall Caesarean section rate of 36% among diabetics in a study conducted in Nigeria.[8] Previous Caesarean section and cephalo-pelvic disproportion were the common indications for Caesarean delivery. Another study conducted in Taiwan reported a rate of Caesarean delivery of 31.6%.[4] Hypertensive disorders in pregnancy are also indications for Caesarean delivery and in this study 34.4% participants had hypertensive disorders.

Hypertensive disorders of pregnancy are common in diabetes in pregnancy where they lead to higher maternal and foetal morbidity and also increase the risk for future cardiovascular events.[26] The incidence of hypertensive disorders in this study was 34.4%. Poor adherence in this study that consequently influences glycaemic control, which is a risk factor for hypertension,[27] could explain the high incidence of hypertensive disorders. This is lower than the incidence of hypertension complicating pregnancy of 40% to 45% in women with PGDM as reported by Cundy *et al*. (2002).[28] Huddle (2005) reported an incidence of 13.1% of hypertension in an audit of outcome of diabetic pregnancy conducted in South Africa.[23] Billionet *et al*. (2017) reported an increased risk of pre-eclampsia/eclampsia in PGDM mothers compared with GDM mothers in a study conducted in France.[29]

The rate of macrosomia in this study was 33.8%. Macrosomia is common in diabetes in pregnancy due to a rapid growth rate of the foetus as a result of high glucose levels crossing the placenta by facilitated diffusion during pregnancy.[30] This rate is comparable to rates reported in other studies. González-Quintero *et al*. (2007) reported rates of 15.7% and 19.8% for macrosomia and LGA respectively in the United States. Wang *et al*. (2013)[31] reported a rate of macrosomia of 17%. Other studies have reported even higher rates of macrosomia. Murphy *et al*. (2011) reported a rate of macrosomia of 37.6% in type II diabetics and 52.9% in type I diabetics,[32] while John *et al*. (2015) reported a rate of 49%.[21] Opara *et al*. (2010) reported a rate of 61.7%. Billionet *et al*. (2017)[29] and Wahabi *et al*. (2013)[25] reported an increased risk of macrosomia in GDM. A high incidence of some complications of diabetes in pregnancy such as macrosomia may indicate poorer care for women with diabetes in pregnancy in low-resource settings.[33]

The rate of neonatal hypoglycaemia in this study was 15.3%. Hypoglycaemia is one of the most frequent complications of diabetes in the baby[30,34] and the incidence ranges from 30% to 50% depending on maternal glucose control during pregnancy, duration of labour, blood glucose level at the time of delivery and whether there was early or late feeding.[30] This rate is higher than 9.3% reported by González-Quintero *et al*. (2007) in the USA.[24] It is much lower than 63.8% reported by Opara *et al*. (2010) in Nigeria.[22]

The rate of perinatal mortality in the study was 15.9%. Perinatal mortality rate (PMR) is an important perinatal health indicator and is always higher in diabetic pregnancies than in the background PMR.[35] It is driven by congenital malformations of the neonate.[36] This rate could be comparable to the 124 per 1 000 perinatal mortality rate reported earlier in the same setting.[37] Chirenje (1992) reported a PNM of 124 per 1 000 in infants born to diabetic mothers compared with 44 per 1 000 in those born to non-diabetic mothers.[37] However, the higher rate observed in this current study could be attributed to the rising incidence of type II diabetes mellitus coupled with improved screening for GDM compared with almost three decades ago. High perinatal mortality rate might reflect poorer glycaemic control and poorer management of diabetes in pregnancy in the setting. Yang *et al*. (2006) reported a perinatal mortality rate of 11.5 per 1 000, compared with 4.8 per 1 000 that was estimated in 62 079 normal pregnancies in Nova Scotia.[39] A French study on 289 pregnancies with type-1 diabetes mellitus reported an incidence of 66 per 1 000,[18,38–43] while a British study in 1 706 women with type 1 diabetes mellitus reported an incidence of intrauterine deaths of 25.8 per 1 000 and an incidence of perinatal mortality of 31.7 per 1 000.[36] High PNM rates could be indicative of poorer perinatal outcomes, probably due to poor glycaemic control and challenges in the management of diabetes in pregnancy in the setting. Lower rates have also been reported in the literature. Huddle (2005) reported a PNM of 4.5% in infants born to diabetic mothers.[23] John *et al*. (2015) reported 11 perinatal deaths (perinatal mortality rate 90 per 1 000 deliveries) in women with diabetes in pregnancy.[21] Other studies have reported an increased risk of perinatal mortality in PGDM compared with GDM.[29,44] Comparison of PGDM and GDM in this setting might be difficult due to under-diagnosis of GDM resulting in small numbers compared with GDM, late booking of pregnancies and limited access to tests such as HBA1C to distinguish between true GDM and undiagnosed PGDM. In Saudi Arabia Wahabi *et al*. (2017)[11] reported an increased risk of stillbirth (OR 3.66; 95% CI 1.98–6.72) in neonates of mothers with pre-GDM while González-Quintero *et al*. (2007)[24] reported a rate of still births in GDM of 0.3%.

The rate of prematurity in this study was 5.1%. This rate is lower than the rates reported by Murphy *et al*. (201) of 17.5% and 37.1% in type II and type I diabetes respectively.[32] The high rate reported by Murphy could reflect the preference for premature delivery in the presence of significant complications in order to save the mother's and the baby's health.[45] Prematurity is a risk factor for other complications such as intrauterine growth restriction, low birth weight, respiratory distress syndrome, hypoglycaemia, hypocalcaemia, polycythaemia, intrauterine death, hyperbilirubinemia, several types of malformations, hypertrophic cardiomyopathy and asphyxia.[45] Some studies have reported no differences in incidence of prematurity in women with GDM and those without[25] while others have reported an increased risk of prematurity in diabetes in pregnancy.[29]

Other neonatal outcomes observed in the study were low Apgar score at 1 minute (26.8%), low Apgar score at 5 minutes (24.8%) and low birth weight (7%). Rates of low Apgar score could have been due to macrosomia and prematurity in the study. Hyperbilirubinemia may be seen in the first 24 to 72 hours of life. The presence of hyperglycaemia and hyperinsulinemia in diabetes in pregnancy result in impairment of placental blood flow and transplacental exchanges resulting in a state of chronic relative hypoxaemia.[34] The rate of neonatal hyperbilirubinemia in this study was 7.6%. Gonzalez *et al*. (2007)[23] reported a rate of 10.1% in the USA while Opara *et al*. (2010)[22] reported a rate of 57.4% in Nigeria. Hyperbilirubinemia is common even in neonates born to non-diabetic mothers. In diabetes in pregnancy it is worsened by hyperglycaemia and hyperinsulinemia.

Association between adherence to anti-diabetic therapy and perinatal outcomes was a calculated composite score of total adherence to diet, physical activity and medications. It was measured using self-reports following an interviewer-administered questionnaire. The study was conducted in a resource-limited setting where FPG, 1 hour and 2 hour postprandial glucose readings could not be done. Participants who had poor adherence (< 80%) were 1.9 times more likely to deliver by Caesarean section (risk ratio (RR) 1.9, 96% confidence interval (CI) 1.28–2.81, $p = 0.0014$) compared with women who had high adherence (≥ 80%). Findings of the HAPO study that looked at the association between maternal glycaemia and perinatal outcomes revealed a significant association between maternal glycaemia and Caesarean delivery.[46] Adjusted odds ratios were calculated for adverse pregnancy outcomes associated with an increase in the fasting plasma glucose level of 1 SD (6.9 mg per decilitre [0.4 mmol per litre]), one-hour plasma glucose level of 1 SD (30.9 mg per decilitre [1.7 mmol per litre]), and two-hour plasma glucose level of 1 SD (23.5 mg per decilitre [1.3 mmol per litre]). The risk of Caesarean delivery was 1.11 (95% CI, 1.06–1.15), 1.10 (1.06–1.15), and 1.08 (1.03–1.12). The risk of giving birth by Caesarean section increased by 11%, 10% and 8% with an increase in fasting, one-hour and two-hour postprandial blood glucose. This translates to increased risk with rising glycaemia For birth weight above the 90th percentile, the risk increased by 38%, 46% and 38% with an increase in fasting, one-hour and two-hour postprandial blood glucose respectively. For cord-blood serum C-peptide level above the 90th percentile, which is a measure of hyperinsulinemia, the risk increased by 55%, 46% and 37% with an increase in fasting, one-hour and two-hour postprandial blood glucose respectively. For neonatal hypoglycaemia, the risk increased by 8%, 13% and 10% with an increase in fasting, one-hour and tw-hour postprandial blood glucose respectively.

Participants with poor adherence (< 80%) were 3.95 times more likely to have vaginal infections (RR 3.95, 95% CI 1.65–9.47, $p = 0.002$) compared with women who had high adherence (≥ 80%). Diabetes and yeast infection can co-occur during pregnancy.[47] Uncontrolled blood sugar in diabetes in pregnancy is a major risk factor for candidiasis.[47]

The associations between adherence and other maternal perinatal outcomes were not significant. The relative risks for other maternal outcomes were hypertensive disorders (RR 1.28, 95% CI 0.8–2.03, $p < 0.305$), maternal DKA (RR 1.76, 95% CI 0.38–4.59, $p < 0.473$), maternal hypoglycaemia (RR 1.50, 95% CI 0.68–3.34, $p < 0.312$) and preterm birth (RR 1.76, 95% CI 0.38–8.23, $p < 0.473$). The Hypoglycaemia and Adverse Pregnancy Outcomes (HAPO) cohort study demonstrated strong evidence of a continuous rather than threshold relationship of pregnancy outcomes with rising hyperglycaemia.[5]

The independent associations between adherence and hypertensive disorders, maternal hypoglycaemia, maternal DKA and preterm birth were not significant. However, larger studies have shown significant associations between maternal glycaemia, represented by level of adherence in this study, and these perinatal outcomes. The differences from the findings of this study could be due to differences in sample sizes and the subjective methods of measuring adherence used. Other studies used objective measures, namely fasting plasma glucose levels and post-prandial glucose levels.

Participants with poor adherence (< 80%) were 2.15 times more likely to have a baby with low Apgar at one minute (RR 2.15, 95% CI 1.16–3.98, $p = 0.015$) and 1.15 times more likely to have a baby with low Apgar score at 5 minutes (RR 1.95, 95% CI 1.03–3.69, i = 0.039) compared with women who had high adherence (≥ 80%). A low Apgar score is one of the complications of macrosomia.

Participants with poor adherence (< 80%) were 3.08 times more likely to have perinatal mortality (RR 3.08, 95% CI 1.11–8.52, $p = 0.018$) compared with women who had good or very good adherence (≥ 80%). Though major contributors are intrauterine growth restriction, pre-eclampsia, foetal hypoxia and congenital malformations, more than half of stillbirths are unexplained. However, the majority are characterised by maternal hyperglycaemia.[48] This was reflected in the present study where mean adherence to anti-diabetic therapy was suboptimal, which might have resulted in maternal hyperglycaemia.

There was a non-significant association between low adherence and having a macrosomic baby (RR 0.89, 95% CI 0.57–1.40, $p < 0.619$). This is in disagreement with findings of the HAPO study and Farrar *et al*.,[49] which revealed a significant association between maternal hyperglycaemia and macrosomia. Many other studies have reported an increased risk of macrosomia with rising glycaemia. The differences in findings could be a result of different sample sizes. Farrar *et al*. revealed that the odds ratios for large for gestational age per 1 mmol/l increase of fasting and two-hour post-load glucose concentrations (after a 75 g OGTT) were 2.15 (95% confidence interval 1.60–2.91) and 1.20 (1.13–1.28), respectively.[49]

There was an unusual association between low adherence and neonatal hypoglycaemia (RR 0.14, 95% CI 0.19–0.86, $p > 0.019$). The finding insinuates that low adherence is protective of hypoglycaemia. This finding is biologically implausible and could be a result of small numbers. The sample size for the quantitative phase of the study was 157. A number of studies have demonstrated significant increases in risk of neonatal hypoglycaemia with rising maternal glycaemia. Neonatal hypoglycaemia occurs in approximately 8–30% of infants of diabetic mothers.[50] Findings of this study underscore the importance of strict glycaemic control in pregnancy through adherence to anti-diabetic therapy in a resource-limited setting.

Disclosure statement – No potential conflict of interest was reported by the authors.

Limitations of the study – Data were collected by self-reports, which could have overestimated adherence to anti-diabetic therapy. Though objective measures such as drug levels for adherence to medication and the doubly labelled water technique for physical activity are the best, they are very expensive and not feasible in a resource-limited setting.

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