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ORIGINAL ARTICLE ***Reproductive epidemiology***

Effects of paternal and maternal lifestyle factors on pregnancy complications and perinatal outcome. A population-based birth-cohort study: the GECKO Drenthe cohort

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STUDY QUESTION: Do paternal and maternal lifestyle factors influence the risk of hypertensive pregnancy complications, gestational diabetes mellitus (GDM), spontaneous preterm birth and small-for-gestational-age (SGA)?

SUMMARY ANSWER: Paternal lifestyle factors do not exert an independent effect on the investigated outcomes while maternal prepregnancy BMI and maternal smoking during pregnancy influence the risk of hypertensive pregnancy complications, GDM and SGA.

WHAT IS KNOWN ALREADY: Maternal lifestyle factors are associated with perinatal complications, but the impact of paternal lifestyle factors is unclear.

STUDY DESIGN, SIZE, DURATION: Data from the GECKO (Groningen Expert Center for Kids with Obesity) Drenthe cohort, a prospective population-based birth-cohort of children born between April 2006 and April 2007 in a northern province of The Netherlands, were analysed. The parents of 2958 children (62% of those approached) gave their consent to participate in the study and the data of 2264 (77%) couples were available for analysis.

PARTICIPANTS/MATERIALS, SETTINGS, METHOD: All pregnant women in the Dutch province of Drenthe with an expected date of delivery between April 2006 and April 2007 were invited to participate and included during the third trimester of their pregnancy or within 6 months after delivery. All consenting couples received extensive questionnaires including lifestyle, biological and socio-demographic-related questions covering the period of 6 months prior to conception. Outcome data were obtained from midwives and hospital registries. Univariable and multivariable logistic regression analyses were used to determine the impact of the lifestyle factors on the primary outcome measures.

MAIN RESULTS AND THE ROLE OF CHANCE: Of all 2264 women, 241 women (10.6%) developed a hypertensive pregnancy complication, 50 women (2.2%) developed GDM, 79 (3.5%) children were spontaneously delivered preterm and 155 children (6.8%) were SGA. All paternal and maternal lifestyle factors were positively correlated. Multivariable analysis showed that paternal lifestyle factors did not have an independent influence on the investigated outcomes. Of the maternal factors, prepregnancy BMI was independently associated with an increased risk of a hypertensive disorder during pregnancy (odds ratio (OR): 1.12, 95% CI 1.09–1.16), a higher risk of GDM (OR BMI >23 kg/m^2, per BMI unit: 1.13, 95% CI 1.08–1.18) and with a decreased risk of SGA (OR per BMI point 0.94, 95% CI 0.90–0.99). Maternal smoking during pregnancy was significantly associated with SGA (OR 3.00, 95% CI 1.80–4.99) in multivariable analysis.

LIMITATIONS, REASONS FOR CAUTION: The retrospective nature of the questionnaire may have induced recall bias. Selection bias might have occurred, as ethnic minorities were less willing to co-operate in the GECKO Drenthe study. The possibility of

misclassification bias regarding the primary outcome measures cannot be ruled out. Inclusion bias might have occurred as not all questionnaires of the parents of the children participating in the GECKO Drenthe cohort were completed.

WIDER IMPLICATIONS OF THE FINDINGS: Paternal lifestyle factors do not have an independent effect on the investigated adverse pregnancy outcomes. However, as paternal and maternal lifestyles are positively correlated, both partners should be involved in preconception counselling regarding the investigated outcome measures.

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Key words: lifestyle / pregnancy complications / pregnancy outcome

Introduction

To optimize preconception counselling, it is important to know which maternal as well as paternal modifiable lifestyle factors are associated with an increased risk of pregnancy complications and, hence, worse perinatal outcome. Hypertensive pregnancy complications such as pregnancy-induced hypertension (PIH) and (pre)eclampsia are associated with an increased risk of maternal and perinatal morbidity and mortality (Duley, 2009) and complicate four up to nine per cent of all pregnancies (Silva *et al.*, 2008; Jansen *et al.*, 2009). High age and obesity are known maternal lifestyle risk factors for the development of hypertensive disorders during pregnancy, while smoking seems to decrease this risk (Cnattingius and Lambe, 2002; Parazzini *et al.*, 2003; Yang *et al.*, 2006). It has been suggested that paternal lifestyle factors such as advanced age and obesity may act as risk factors for the development of hypertensive complications in their pregnant partner (Dekker *et al.*, 2011). However, evidence regarding the impact of paternal factors is scarce and conflicting (Harlap *et al.*, 2002; Chen *et al.*, 2006).

Gestational diabetes mellitus (GDM) complicates from one up to seven per cent of all pregnancies and is associated with an increased risk of Caesarean delivery, intrauterine fetal death, fetal macrosomia, hypoglycaemia and jaundice (American Diabetes Association, 2004). Besides, women with GDM are at an increased risk for the development of diabetes type II. Potentially known modifiable maternal risk factors for the development of GDM are obesity, advanced age, cigarette smoking and stress (Solomon *et al.*, 1997; Sebire *et al.*, 2001; Hosler *et al.*, 2011). It is not known whether paternal lifestyle factors influence the development of GDM in their partners.

Small-for-gestational-age (SGA) and preterm birth are two of the four most important characteristics predicting infant morbidity and mortality (Petrini *et al.*, 2009; Bonsel *et al.*, 2010; McCormick *et al.*, 2011; Woythaler *et al.*, 2011; Baron *et al.*, 2012). Congenital anomalies and Apgar score beneath seven are the other two variables among these 'Big 4' risk factors.

Periconceptional maternal lifestyle factors such as smoking, diet, stress and occupational exposures are associated with lower birthweight and an increased risk of preterm birth (Bonsel *et al.*, 2010; Li *et al.*, 2010; Burdorf *et al.*, 2011). Data on the influence of paternal lifestyle factors on perinatal outcome are scarce. In a systematic review performed by Shah (2010), the authors concluded that further studies are needed to examine the influence of paternal factors on preterm birth and SGA birth (Shah, 2010).

The purpose of the current study was to assess the associations between paternal and maternal lifestyle factors and hypertensive pregnancy complications, GDM, spontaneous preterm birth and SGA infants in order to support counselling guidelines aimed at optimizing pre-pregnancy health and pregnancy outcomes

Methods

The Groningen Expert Center for Kids with Obesity (GECKO) Drenthe study is a population-based prospective birth-cohort study of children born in Drenthe between April 2006 and April 2007, one of the northern provinces of the Netherlands (L'Abee *et al.*, 2008). The study has been approved by the Medical Ethics Committee of the University Medical Center Groningen. The present study is a sub-analysis within the GECKO Drenthe study.

All pregnant women in Drenthe with expected date of delivery between April 2006 and April 2007 were invited by midwives, general practitioners or gynaecologists to participate in this study. After informed consent was obtained, these women were included during the third trimester of their pregnancy or within 6 months after delivery. All women and their male partners received questionnaires on biological, lifestyle and socio-demographic factors covering the period of 6 months prior to conception up to delivery. The questionnaires included questions on their own birthweight, age at conception, weight, height, number of previous pregnancies and their outcome, type of contraception used prior to the current pregnancy (categorized as: (i) no contraception, (ii) condoms, (iii) oral contraceptives (OC), (iv) an intrauterine device or (v) contraceptive injections containing progesterone). Both partners were individually asked about their smoking habits (number of cigarettes/day) and their consumption of alcohol (units/week). Furthermore, their level of physical activity was recorded (dichotomously categorized with positive defined as at least moderate intensity for 30 min per day once a week or more).

Both parents were asked about their educational level, paid working hours/week and household income. The educational level was categorized into three categories: (i) lower education including primary and/or secondary school and/or lower professional school (preparatory vocational education), (ii) medium education including medium professional school (intermediate vocational education) and (iii) higher education including higher professional school (higher vocational education) and/or university. The number of paid working hours/week was categorized into: (i) no paid work, (ii) <16 h/week, (iii) 16–32 h/week or (iv) 32 h or more/week. Household income was divided into five categories: (i) <850 euros/month, (ii) 850–1150 euros/month, (iii) 1151–3050 euros/month, (iv) 3051–3500 euros/month or (v) 3501 euros or more/month. Shortly after delivery, the midwife or gynaecologist guiding the pregnancy and/or the delivery completed a questionnaire on maternal smoking behaviour and alcohol use

during pregnancy, complications during pregnancy and delivery, perinatal outcome and Apgar score. In addition, mothers were asked on the amount of weight gain during pregnancy. It was then determined whether women were within, above or below the recommended weight gain during pregnancy according to the guidelines of the Institute of Medicine (IOM; Table I).

Data on pregnancy complications and outcome were prospectively collected, while data on paternal and maternal biological, lifestyle and socio-demographic factors were retrospectively collected. Missing information on pregnancy complications and outcome in the GECKO database was completed using the medical records of the participants of the GECKO study released by midwives, general practitioners and gynaecologists.

Primary outcome measures were: (i) hypertensive pregnancy complications, (ii) GDM, (iii) spontaneous preterm birth and (iv) SGA. Hypertensive pregnancy complications were defined as the presence of PIH (systolic blood pressure of at least 140 mmHg and/or diastolic blood pressure of at least 90 mmHg, measured on two occasions), pre-eclampsia (PIH combined with proteinuria (>300 mg/24 h)), HELLP syndrome (combination of haemolysis, elevated liver enzymes and low platelet count) or eclampsia (presence of seizures which cannot be attributed to other causes). GDM was defined as diabetes mellitus with onset or first recognition during pregnancy. Spontaneous preterm birth was defined as the spontaneous birth of an infant below gestational age of 37 weeks. SGA was defined as birthweight below the tenth percentile of weight corrected for gestational age (birthweight percentiles according to The Netherlands Perinatal Registry: http://www.perinatreg.nl/referentiecurven). The investigated lifestyle factors were paternal and maternal age and BMI at conception, prior contraception use, maternal weight gain during pregnancy, paternal and maternal smoking behaviour, alcohol use, level of physical activity and working hours prior to the pregnancy and maternal smoking behaviour, alcohol use and physical activity during pregnancy. Information regarding the following biological and socio-demographic variables was available: paternal and maternal ethnicity, maternal gestational age, birthweight, pregnancy intention, gravidity, parity, method of conception (spontaneously or with fertility treatment), sex of the new born, paternal and maternal educational level and net income. We investigated if these variables influenced the association between the lifestyle factors and the primary outcome measures. As the definition of SGA already accounts for the variables sex of the newborn and parity, we did not investigate the effect of these biological variables on SGA. We also investigated the effect of the pregnancy complications on the other primary outcomes.

Twins were excluded from the current analysis.

Statistical analysis

Statistical analysis was carried out with Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL, USA) and Stata (Statacorp, College Station, TX, USA). Spousal concordance was first investigated, indicating the degree of similarity within cohabitating couples by assessing the correlation between the investigated paternal and maternal factors. Correlations between paternal and maternal prepregnancy age and BMI were assessed using Pearson's correlation coefficient. Spearman's rank correlation was used to assess correlations between paternal and maternal prepregnancy smoking, alcohol consumption and working hours. Associations between paternal and maternal physical activity were assessed using chi-square and the Phi coefficient (a measure of association for two binary variables) (Davenport and El-Sanhury, 1991). A P-value of <0.05 was considered statistically significant.

The relation between the continuous variables age and BMI and primary outcomes was assessed by restricted spline regression analysis. Non-linearity was tested by comparing the log odds for the outcome across spline intervals of the predictors. In case of non-linearity, cut-off values were determined by visual inspection of spline regression plots. Associations between the investigated lifestyle factors and the primary outcomes were analysed by univariable logistic regression analyses. Associations between biological and socio-demographic factors and the primary outcomes were assessed by univariable logistic regression analyses as well (data not shown). Afterwards, all factors with a P-value <0.10 were assessed in multivariable logistic regression analyses with a backward elimination strategy.

Odds ratios (OR) and 95% confidence interval (CI) are presented. The OR represents the odds of developing pregnancy complications or adverse perinatal outcome (Altman, 1991). For categorical variables, the OR represents the ratio of the odds for the respective category when compared with the reference category. For nominal and categorical variables, the category with the highest frequency was used as reference category.

Table I Recommendations for total weight gain during pregnancy, by prepregnancy weight according to the guidelines of the Institute of Medicine.

Prepregnancy BMI	BMI (kg/m^2)	Total weight gain (kg)
Underweight	<18.5	12.7–18.1
Normal weight	18.5–24.9	11.3–15.9
Overweight	25.0–29.9	6.8–11.3
Obese	≥30.0	5.0–9.1

Adapted from http://www.iom.edu/pregnancyweightgain

Results

The number of children born in Drenthe from April 2006 to April 2007 was 4778. The parents of 2997 children (63%) gave their consent to participate in the study. The informed consent of 39 children was withdrawn (children were born before the first of April 2006 or after the first of April 2007 or the parents did not want to participate after all). Of 2314 children, the father, mother and midwife or gynaecologist completed the questionnaires. As twins were excluded ($n = 25$), the data of 2264 children (1145 males (51%) and 1119 females (49%)) were available for analysis (Fig. 1).

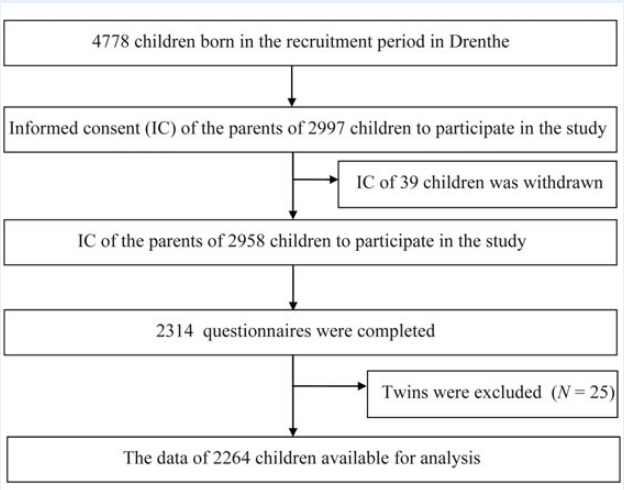

Figure 1 GECKO Drenthe study flow chart.

Table II Biological, socio-demographic and lifestyle characteristics of the parents of 2264 children participating in the GECKO Drenthe study.

	Father	Mother (prior to pregnancy)	Mother (during pregnancy)
	N (%)/mean ± SD	*N* (%)/mean ± SD	*N* (%)/mean ± SD
Biological characteristics			
Ethnicity			NA
Western	2165 (96)	2163 (96)	
Non-western	91 (4)	93 (4)	
Unknown	8	8	
Birthweight			NA
<3.0 kg	236 (13)	420 (20)	
3.0–4.5 kg	1304 (69)	1616 (78)	
>4.5 kg	339 (18)	29 (1)	
Unknown	385	199	
Gestational age			NA
<37 weeks	55 (5)	151 (7)	
37–40 weeks	741 (73)	1361 (66)	
>40 weeks	222 (22)	543 (26)	
Unknown	1246	209	
Gravidity	NA		NA
Nulligravidity		739 (34)	
Multigravidity		1461 (66)	
Unknown		64	
Parity	NA		NA
Nulliparity		883 (40)	
Multiparity		1315 (60)	
Unknown		66	
Method of conception current pregnancy	NA		NA
Spontaneous		2119 (94)	
Fertility treatment		133 (6)	
Unknown		12	
Socio-demographic characteristics			
Educational level			NA
Low	393 (18)	198 (9)	
Medium	971 (44)	994 (45)	
High	846 (38)	1024 (46)	
Unknown	54	48	
Household income		NA	NA
Less than €850/month	18 (1)		
€850–€1150/month	65 (3)		
€1151–€3050 per month	1321 (67)		
€3051–€3500 per month	324 (17)		
> €3500 per month	233 (12)		
Unknown	303		
Lifestyle characteristics			
Age prior to conception (years)			NA
Mean ± SD	33.2 ± 5.0	30.5 ± 4.4	
Unknown	25	17	

Continued

Table II *Continued*

	Father	Mother (prior to pregnancy)	Mother (during pregnancy)
	***N* (%)/mean ± SD**	***N* (%)/mean ± SD**	***N* (%)/mean ± SD**
Prepregnancy BMI (kg/m^2)			NA
Mean ± SD	25.5 ± 3.4	24.8 ± 4.7	
Unknown	151	67	
Weight gain mother during pregnancy[a]	NA	NA	
Less than IOM recommendation			357 (19)
IOM recommendation			724 (39)
More than IOM recommendation			784 (42)
Unknown			399
Prior contraception use	NA		NA
OC		1366 (61)	
None		355 (16)	
Condom		382 (17)	
Intrauterine device		136 (6)	
Contraceptive injection		10 (0)	
Unknown		15	
Smoking			
None	1564 (70)	1712 (76)	1927 (88)
1–10 cigarettes/day	347 (15)	340 (15)	196 (9)
>10 cigarettes/day	329 (15)	188 (8)	74 (3)
Unknown	24	24	67
Alcohol consumption			
None	374 (17)	1035 (46)	2120 (96)
1–7 units/week	1173 (53)	1156 (51)	88 (4)
>7 units/week	659 (30)	56 (2)	1 (0)
Unknown	58	17	55
Working hours			NA
None	56 (2)	223 (10)	
<16 h/week	10 (0)	160 (7)	
16–32 h/week	56 (2)	1031 (47)	
>32 h/week	2124 (95)	791 (36)	
Unknown	18	59	
Physical activity[b]			
<1/week	694 (31)	576 (25)	797 (36)
≥1/week	1562 (69)	1684 (75)	1434 (64)
Unknown	8	4	33

NA, not applicable; OC, oral contraceptives.
[a]According to the guidelines of the Institute of Medicine (IOM).
[b]Positive defined as once a week or more of at least moderate intensity for 30 min per day.

The characteristics of the fathers and the mothers of the children participating in this study are presented in Table II. Median maternal weight gain during pregnancy was 13 kg (range: 0–37). Of the included children, the mean gestational age was 39.8 weeks (SD 1.6) and mean birthweight was 3563 g (SD 538). Of the 2264 women, 241 (10.6%) developed a hypertensive pregnancy complication: 234 (10.3%) PIH, 52 (2.3%) pre-eclampsia (47 women were earlier diagnosed with PIH), 9 (0.4%) HELLP (5 women were earlier diagnosed with PIH and pre-eclampsia) and 1 (0.04%) eclampsia. Fifty women (2%) developed GDM (eight in combination with a hypertensive disorder). Seventy-nine (3%) children were delivered spontaneously preterm and 155 children (7%) were SGA.

Correlations between paternal and maternal factors are shown in Table III. All correlations were statistically significant. Most were weak, except for maternal and paternal age, which were strongly associated (correlation coefficient 0.68).

Table III Correlations between paternal and maternal prepregnancy lifestyle factors.

Variable	Correlation coefficient	Phi
Age prior to conception	0.68	NA
Prepregnancy BMI	0.23	NA
Smoking	0.34	NA
None		
1–10 cigarettes/day		
>10 cigarettes/day		
Alcohol consumption	0.05	NA
None		
1–7 units/week		
>7 units/week		
Working hours	0.07	NA
None		
<16 h/week		
16–32 h/week		
>32 h/week		
Physical activity[a]	NA	0.25
<1/week		
≥1/week		

Correlations between paternal and maternal prepregancy age and BMI were assessed using Pearson's correlation coefficient. Spearman's rank correlation was used to assess correlations between paternal and maternal prepregnancy smoking, alcohol consumption and working hours. Associations between paternal and maternal physical activity were assessed using chi-square and the Phi coefficient. All correlations and associations were statistically significant.
[a]Positive defined as once a week or more of at least moderate intensity for 30 min per day.

The spline analyses showed that the continuous variables paternal and maternal age and BMI were linearly associated with the primary outcomes hypertensive pregnancy complications, spontaneous preterm birth and SGA. Paternal age was linearly associated with GDM as well. Maternal BMI appeared to have a non-linear relationship with GDM, with a threshold value of 23 kg/m^2. As a result, women with a BMI ≤23 kg/m^2 were defined as reference category in GDM analyses (Fig. 2).

Univariable and Multivariable analyses

Hypertensive pregnancy complications

Univariable analysis showed that maternal prepregnancy BMI (OR per BMI point: 1.11, 95% CI 1.08–1.14), prior condom use (OR 0.61, 95% CI 0.40–0.92) and more than the recommended maternal weight gain during pregnancy (OR 1.50, 95% CI 1.07–2.10) were significantly associated with hypertensive pregnancy complications (Table IV). In multivariable analysis, only maternal prepregnancy BMI retained a statistically significant relationship with an increased risk of a hypertensive disorder during pregnancy (OR per BMI point: 1.12, 95% CI 1.09–1.15).

Gestational diabetes mellitus

In the univariable analysis, increasing paternal BMI was associated with an increased risk of GDM (OR per BMI point: 1.10, 95% CI 1.02–1.18). Women with a BMI >23 kg/m^2 were at an increased risk of developing GDM as well (OR per BMI point >23 kg/m^2: 1.13, 95% CI 1.08–1.18).

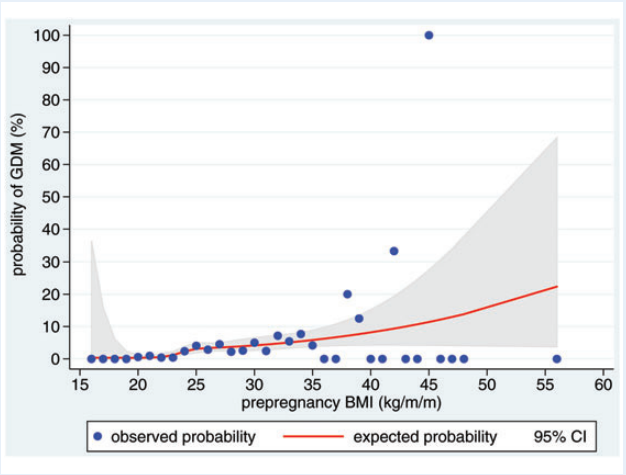

Figure 2 Maternal BMI has a non-linear relationship with GDM, with a threshold value of 23 kg/m^2. The grey area represents 95% confidence intervals. GDM, gestational diabetes mellitus.

In multivariable analysis only maternal BMI remained significantly associated with GDM (OR per BMI point >23 kg/m^2: 1.13, 95% CI 1.08–1.18).

Spontaneous preterm birth

In univariable analysis, prior use of condoms (OR 0.40, 95% CI 0.18–0.89) or contraceptive injections (OR 5.38, 95% CI 1.12–25.88) for birth control, maternal alcohol consumption prior to pregnancy (>7 units per week: OR 2.75, 95% CI 1.04–7.27) and maternal working hours (women who did not work: OR 0.34, 95% CI 0.12–0.95; women who worked 16–32 h per week: OR 0.53, 95% CI 0.33–0.86) were associated with spontaneous preterm birth. In multivariable analysis, none of the investigated lifestyle factors remained associated with spontaneous preterm birth.

Small-for-gestational-age

Univariable analysis showed that paternal smoking (OR 1–10 cigarettes per day: 1.69, 95% CI 1.10–2.59 and OR < 10 cigarettes per day: 2.25, 95% CI 1.51–3.37), maternal prepregnancy BMI (OR per BMI point: 0.95, 95% CI 0.91–0.99), less than the recommended maternal weight gain (OR 1.80, 95% CI 1.14–2.82), maternal prepregnancy smoking (OR 1–10 cigarettes per day: 2.13, 95% CI 1.42–3.19 and OR > 10 cigarettes per day: 2.82, 95% CI 1.77–4.48) and maternal smoking during pregnancy (OR 3.17, 95% CI 2.15–4.67) were associated with an increased risk of SGA. In multivariable analysis, maternal BMI (OR per BMI point 0.94, 95% CI 0.90–0.99) and maternal smoking during pregnancy (OR 3.00, 95% CI 1.80–4.99) were the lifestyle factors which remained significantly associated with SGA.

Discussion

In this Dutch birth-cohort, we investigated the influence of several pregnancy-related paternal and maternal lifestyle factors on hypertensive pregnancy complications, GDM, spontaneous preterm birth and SGA. Paternal lifestyle factors were not associated with the investigated

Table IV The influence of paternal and maternal lifestyle factors on hypertensive pregnancy complications, gestational diabetes mellitus (GDM), spontaneous preterm birth and small-for-gestational-age (SGA) in univariable and multivariable logistic regression analysis.

Characteristic	Hypertensive pregnancy complications				GDM				Spontaneous preterm birth			SGA			
	Univariable analysis		Multivariable analysis[a]		Univariable analysis		Multivariable analysis[b]		Univariable analysis		Multivariable analysis[c]	Univariable analysis		Multivariable analysis[d]	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI		OR	95% CI	OR	95% CI
Age father															
per year	1.01	0.98–1.03			1.01	0.96–1.07			0.99	0.95–1.04		1.01	0.98–1.04		
Age mother															
per year	1.01	0.98–1.04			1.04	0.97–1.11			1.02	0.96–1.07		0.99	0.96–1.03		
Prepregnancy BMI father															
Per BMI point	1.04	1.00–1.08*			**1.10**	**1.02–1.18**			0.99	0.93–1.06		0.96	0.91–1.01		
Prepregnancy BMI mother					NA										
Per BMI point	**1.11**	**1.08–1.14**	**1.12**	**1.09–1.15**					0.99	0.94–1.04		**0.95**	**0.91–0.99**	**0.94**	**0.90–0.99**
Prepregnancy BMI mother	NA								NA			NA			
≤23 kg/m^2					Ref		Ref								
>23 kg/m^2, per BMI point					**1.13**	**1.08–1.18**	**1.13**	**1.08–1.18**							
Prior contraception use															
OC	Ref				Ref				Ref			Ref			
None	0.87	0.59–1.26			1.58	0.74–3.27			0.50	0.24–1.06*		0.96	0.60–1.52		
Condom	**0.61**	**0.40–0.92**			1.55	0.77–3.23			**0.40**	**0.18–0.89**		0.80	0.50–1.29		
Intrauterine device	0.59	0.30–1.15			1.63	0.56–4.77			0.32	0.08–1.33*		0.82	0.39–1.72		
Contraceptive injection	1.86	0.39–8.83			–	–			**5.38**	**1.12–25.88**		1.57	0.20–12.70		
Weight gain mother during pregnancy[+]															
Below IOM recommendation	1.00	0.63–1.57			1.21	0.55–2.66			1.28	0.68–2.41		**1.80**	**1.14–2.82**	1.57	0.93–2.63
Within IOM recommendation	Ref				Ref				Ref			Ref		Ref	
Above IOM recommendation	**1.50**	**1.07–2.10**			1.09	0.57–2.09			0.78	0.44–1.39		0.81	0.52–1.26	0.47	0.40–1.29
Smoking father															
None	Ref				Ref				Ref			Ref			
1–10 cigarettes/day	1.18	0.82–1.68			0.53	0.19–1.51			1.34	0.74–2.41		**1.69**	**1.10–2.59**		
>10 cigarettes/day	0.83	0.55–1.25			1.42	0.70–2.91			1.13	0.59–2.14		**2.25**	**1.51–3.37**		
Smoking mother prior to pregnancy															
None	Ref				Ref				Ref			Ref			
1–10 cigarettes/day	0.74	0.49–1.12			0.71	0.28–1.81			1.23	0.68–2.24		**2.13**	**1.42–3.19**		
>10 cigarettes/day	1.00	0.62–1.62			2.04	0.93–4.45*			1.11	0.50–2.46		**2.82**	**1.77–4.48**		
Smoking mother during pregnancy															
None	Ref				Ref				Ref			Ref		Ref	

≥1 cigarette(s)/day	0.95	0.62–1.44			1.48	0.69–3.21	1.45	0.79–2.67	**3.17**	**2.15–4.67**	**3.05**	**1.86–4.99**
Alcohol consumption father												
None	1.01	0.69–1.46			1.72	0.84–3.51	1.43	0.80–2.56	1.02	0.65–1.62		
1–7 units/week	Ref				Ref		Ref		Ref			
>7 units/week	0.96	0.70–1.30			1.12	0.57–2.12	1.08	0.64–1.83	1.07	0.73–1.56		
Alcohol consumption mother prior to pregnancy												
None	1.15	0.88–1.51			1.03	0.59–1.81	0.90	0.56–1.43	0.82	0.59–1.15		
1–7 units/week	Ref				Ref		Ref		Ref			
>7 units/week	1.08	0.45–2.56			–	–	**2.75**	**1.04–7.27**	1.90	0.83–4.35		
Alcohol consumption mother during pregnancy												
None	Ref				Ref		Ref		Ref			
≥1 unit(s)/week	0.70	0.32–1.53			–	–	0.97	0.30–3.14	1.16	0.53–2.56		
Working hours father												
None	1.02	0.43–2.41			1.61	0.38–6.78	1.69	0.51–5.53	1.36	0.53–3.48		
<16 h/week	1.63	0.79–3.38			–		2.21	0.78–6.26	0.76	0.23–2.45		
16–32 h/week	2.13	0.45–10.10			–		–	–	1.45	0.18–11.55		
>32 h/week	Ref				Ref		Ref		Ref			
Working hours mother												
None	0.68	0.41–1.14			1.56	0.67–3.60	**0.34**	**0.12–0.95**	1.02	0.57–1.82		
<16 h/week	0.76	0.43–1.34			0.80	0.24–2.75	0.47	0.17–1.32	0.88	0.44–1.76		
16–32 h/week	0.83	0.62–1.12			0.81	0.43–1.54	**0.53**	**0.33–0.86**	0.86	0.60–1.25		
>32 h/week	Ref				Ref		Ref		Ref			
Physical activity father^{++}												
<1/week	1.28	0.97–1.70*			1.29	0.72–2.32	0.76	0.45–1.27	1.33	0.95–1.87		
≥1/week	Ref				Ref		Ref		Ref			
Physical activity mother prior to pregnancy^{++}												
<1/week	1.31	0.98–1.76*	1.40	0.96–2.03*	0.64	0.31–1.33	1.21	0.74–2.00	1.28	0.90–1.83		
≥1/week	Ref		Ref		Ref		Ref		Ref			
Physical activity mother during pregnancy^{++}												
<1/week	1.12	0.84–1.48			1.08	0.60–1.96	0.99	0.62–1.59	1.00	0.71–1.41		

Continued

Table IV *Continued*

Characteristic	Hypertensive pregnancy complications				GDM				Spontaneous preterm birth				SGA			
	Univariable analysis		Multivariable analysis[a]		Univariable analysis		Multivariable analysis[b]		Univariable analysis		Multivariable analysis[c]		Univariable analysis		Multivariable analysis[d]	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
≥1/week	Ref				Ref				Ref				Ref			

OR, odds ratio; CI, confidence interval; NA, not applicable; ref, reference category; OC, oral contraceptives.
[a]Maternal birthweight, parity, gravidity and paternal education were also assessed in multivariable logistic regression analyses.
[b]Pregnancy intention was also assessed in multivariable logistic regression analyses.
[c]Parity, gravidity and maternal education were also assessed in multivariable logistic regression analyses.
[d]Maternal birthweight, maternal educational level, maternal ethnicity and the presence of hypertensive pregnancy complications were also assessed in multivariable logistic regression analyses.
*P-value 0.05–0.10, +According to the guidelines of the Institute of Medicine (IOM), ++Positive defined as once a week or more of at least moderate intensity for 30 min per day.
The bold values are significant.

outcomes after adjustment for maternal factors. Of the maternal lifestyle factors, increased prepregnancy BMI was independently associated with an increased risk of hypertensive pregnancy complications, with an increased risk of GDM and with a decreased risk of SGA. Maternal smoking during pregnancy was independently associated with an increased risk of SGA.

This is one of a few studies in which the effect of paternal lifestyle factors in addition to maternal factors on pregnancy complications and outcome has been explored. In previous studies, the effect of only one or a very few factors on pregnancy outcomes has been investigated (Cnattingius et al., 1998; Djelantik et al., 2011). So far, most researchers focused on the influence of maternal factors, not taking the possible effect of paternal factors into account. Other strengths of the present study are the prospective population-based design in which the current analyses were conducted, the availability of numerous lifestyle, biological and socio-demographic-related paternal and maternal factors and the fact that both parents of the children filled in the questionnaires themselves instead of interviewing the mothers about their partner's lifestyle. In contrast, most previous studies collected data of the father by interviewing the mother as a proxy reporter (Misra et al., 2010). Interviewing the father himself increases the reliability of the detailed information, in particular regarding the amount of smoking and drinking habits (Passaro et al., 1998).

A limitation of this study is the retrospective nature of the questionnaire. This may have induced recall bias. In addition, the risk of recall bias may be higher in women included after delivery compared with women included during pregnancy. Women who completed the questionnaire after delivery would be aware of complications and would be more likely to recall possibly damaging lifestyle factors, whereas those who filled in the questionnaire beforehand would not. Selection bias might have occurred as ethnic minorities were less willing to co-operate in the GECKO Drenthe study. Although the data in the current study were prospectively collected, we cannot rule out the possibility of misclassification bias regarding the primary outcome measures. As not all questionnaires of the parents of the included children were completed (see Fig. 1, 78% of the questionnaires were completed), inclusion bias cannot be excluded.

Another limitation was the absence of more detailed information on maternal and paternal smoking behaviour, alcohol use and physical activity. In addition, as maternal weight was self-reported, and women tend to underreport their weight, it is likely that the effect of maternal weight and maternal weight gain during pregnancy on the outcome measures was underestimated (Connor Gorber et al., 2007).

The current study showed that the risk of hypertensive pregnancy complications was increased in women with increased BMI, which is concordant with results from many large studies (Linn, 2004; Weiss et al., 2004; Rode et al., 2005). The pathophysiological mechanism between increasing weight and an increased risk of hypertensive pregnancy complications is yet unclear, although it has been postulated that insulin resistance, endothelial dysfunction, dyslipidaemia, inflammatory up-regulation, alteration in immune function and prothrombotic changes as well as dietary factors and inadequate physical activity are all involved in this process (Callaway et al., 2009).

The known association between overweight and obesity in women and the increased risk of the development of GDM was confirmed in our study (Sebire et al., 2001; Linn, 2004; Weiss et al., 2004; Rode et al., 2005). We showed that even women with a BMI of 24 kg/m^2 were at an increased risk of developing GDM.

Women with a higher maternal prepregnancy BMI were at a decreased risk of delivering a SGA child, while maternal smoking increases the risk of SGA. These outcomes are in concordance with two large studies performed in a Swedish population-based birth register (Cnattingius *et al.*, 1998; Cnattingius and Lambe, 2002).

Interestingly, our results showed that paternal lifestyle factors did not have an independent influence on the investigated pregnancy complications and perinatal outcome. However, the investigated paternal and maternal lifestyle factors were all positively correlated, which implicates that unhealthy behaviour such as overweight and smoking is present in both partners. As women are less likely to optimize their lifestyle if their men continue their unhealthy behaviour, men can cause indirect harm to their future infant (van der Zee *et al.*, 2013). Preconception counselling should therefore involve both women as men.

In conclusion, increasing maternal BMI and smoking behaviour during pregnancy are independently associated with the risk of hypertensive pregnancy complications, GDM or SGA. Paternal lifestyle factors do not seem to have an independent effect on these adverse outcomes. However, as unhealthy lifestyle is likely to be present in both partners of a couple, men should not be neglected in preconception counselling regarding hypertensive pregnancy complications, GDM, spontaneous preterm birth and SGA.

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Authors' roles

All authors were involved in conception and design of the study. MA.Q.M. and H.G. performed the statistical analyses. M.A.Q.M. drafted the manuscript. All authors critically reviewed and approved the final manuscript.

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Conflict of interest

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