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Considering parents as a unit: Associations of gestational diabetes and gestational hypertension with postpartum diabetes and hypertension in couples

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ABSTRACT

Objectives: To evaluate the associations of a combined indicator of gestational diabetes mellitus (GDM) and gestational hypertension (GH) with diabetes and with hypertension in parental couples as a 'unit'.
Study design: Utilizing administrative health data, GH was identified in matched pairs (GDM vs. no GDM) of mothers with singleton live births (Quebec, Canada; cohort inception 1990–2007). Couples were categorized based on GDM/GH status s ('neither'; 'either'; or 'both'). Using validated administrative health database definitions, associations of this indicator with diabetes and with hypertension in both members of the couple (12 weeks postpartum to March 31, 2012) were evaluated through adjusted Cox proportional hazard models.
Results: In 63,438 couples over a mean of 12.8 years (SD 5.4), diabetes risk was 9-fold higher (HR: 8.9; 95% CI 6.4, 12.2) in couples with either GDM/GH and 16-fold higher (HR 16.0; 95% CI 10.9, 23.5) in couples with both conditions compared to those with neither. Hypertension risk was 2-fold higher (HR: 1.8; 95% CI 1.5, 2.0) in couples either GDM/GH and 6-fold higher (HR 5.8; 95% CI 4.9, 7.0) in couples with both conditions compared to those with neither condition.
Conclusions: GDM/GH predict diabetes and hypertension in couples as a unit underscoring the concept of shared couple risk. These findings may help foster couple collaboration for cardiovascular risk reduction in the household.

1. Introduction

Genetic, behavioral and environmental factors predispose individuals to diabetes and hypertension. As spousal pairs do not typically share genetic links, analyses of couples allows for the assessment of determinants of diseases related to behaviour and environment. The Framingham Heart Study demonstrated that spouses, when compared to friends and siblings, had the strongest concordances in food patterns [1]. Furthermore, studies have reported high correlation in fruit, vegetable, egg and milk consumption within spousal pairs [2,3]. Several studies have confirmed that spouses influence each other's physical activity; the Atherosclerosis Risk in Communities Study, the Health and Retirement Study and the English Longitudinal Study of Ageing demonstrated that when one partner increased or decreased his or her physical activity level so did the spouse [4–6].

Paralleling shared dietary habits and physical activity, there is increasing data on spousal concordance of diabetes and hypertension. Our group has demonstrated a 26% diabetes concordance (effect estimate: 1.26; 95% CI 1.08–1.45) between partners through a systematic review and *meta*-analysis [7]. Subsequent cross-sectional studies in United Arab Emirates, China, Brazil and Mexican-American couples also determined that diabetes and hypertension were more frequent among women whose husbands had the same conditions [8–11].

Among women who become pregnant, gestational diabetes mellitus (GDM) and gestational hypertension (GH) identify those at higher risk for type 2 diabetes, hypertension, and cardiovascular disease [12]. In view of shared cardiovascular risk factors between partners, we previously identified an 18% risk increase (HR 1.18; 95% CI 1.09–1.27) of incident diabetes in fathers whose partners had a GDM pregnancy compared to fathers whose partners did not have GDM [13]. Additionally, we recently demonstrated that a combined GDM/GH exposure variable ('neither', 'either', 'both') is associated with a stepwise

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risk increase in incident diabetes, hypertension, and cardiovascular disease in mothers and incident diabetes in fathers [14].

In the present analyses, we evaluated the couple as a 'unit'; that is, associations of the GDM/GH indicator with the diagnosis of diabetes and of hypertension in both mother and father. Such associations have the potential to help patients and health care providers conceptualize GDM/GH as a couple issue rather than exclusively the mother's concern.

2. Methods and materials

2.1. Study design and construction of cohorts

A population-based retrospective cohort study in the province of Quebec (universal healthcare) utilizing administrative health data was performed. The construction of this cohort has been previously described [14]. Briefly, GH was identified in matched pairs (GDM vs. no GDM matched on age group, health region, year of delivery) of mothers with singleton live births (Quebec, Canada; 1990–2007). Using probabilistic exact matching strategy, fathers and offspring were identified by the Quebec Statistical Institute in the Birth Registry and, when applicable, the Death Registry [15]. Anonymized data including demographic information, pregnancy characteristics, and diagnostic codes from physician visits and hospital admission for the three years prior to the index delivery up to March 31, 2012 were received from the Régie de l'Assurance Maladie du Quebec (RAMQ).

If either partner had a previous history of diabetes or hypertension or the gestational age of infant, prematurity status and size of infant at birth were not available, the couple and their matched pair were excluded. Cohorts were constructed using SAS/STAT© version 9.4. Procedures were reviewed and approved by the Institutional Review Board of the McGill University Health Centre and the Quebec Access to Information Commission.

2.2. Participants' characteristics at baseline

We characterized the couples in terms of fathers' age group, cohabitation of couples at birth of offspring, co-morbid conditions, number of prior pregnancies together, ethnicity and socio-economic status. The reference ethnocultural group ('European origin') was defined as those born in North America, Europe, or Australia with first language of European origin. We used the Institute national de santé publique du Québec material deprivation index, a census dissemination area level score based on the education, employment/population ratio, and average income for a neighborhood, as a marker of socio-economic status [16]. If partner characteristics were discordant, the couple was classified into the non-reference category (i.e., if a mother was 'European origin' and the father was 'Non-European origin' the couple was classified as 'Non-European origin'). Comorbidities identified in > 5% of the cohort at baseline, history of psychiatric disease and airways disease and hospitalization in the three years prior to delivery were used as markers of comorbidity. If either member of the couple fulfilled the criteria for these conditions the couple was classified as having that co-morbidity (i.e. if the father had a diagnostic code for asthma, the couple was categorized as having an airways disease). In addition, we categorized infants delivered at < 37 weeks gestation as preterm and as small (weight < 10th percentile), appropriate (weight $\geq 10^{th}$ and $\leq$90th percentile), or large (weight > 90th percentile) for gestational age based on Canadian references [17].

2.3. Exposure and outcome measures

Couples were categorized based on GDM/GH status ('neither'; 'either'; or 'both'). GDM was defined as ≥ 2 outpatient physician billing diagnoses for GDM within six months of delivery and/or a hospitalization discharge GDM diagnosis at delivery. GH was defined as any hypertension diagnostic code between 22 weeks gestation and 12 weeks postpartum. Incident diabetes and hypertension were defined using validated administrative data definitions (≥2 outpatient within a 2-year period or one hospital discharge diagnosis) [14,18].

2.4. Statistical analysis

Baseline characteristics were examined by GH/GDM categories. The follow-up period was from 12 weeks postpartum to the time point at which both members of the couple fulfilled criteria for disease (diabetes and hypertension considered separately), departure from Quebec, death, or study end (March 31st, 2012). We computed diabetes and hypertension incidence rates and plotted Kaplan Meier curves for each of our three exposure categories. The risks of diabetes and of hypertension in couples were assessed using stratified Cox proportional hazards models. Variables included in the models were paternal age group, comorbidity, co-habitation at time of delivery, socioeconomic status, ethnicity, preterm delivery, infant's size at delivery and previous pregnancy together. Analyses were conducted using R version 3.2.5.

We conducted analyses on a subset of couples with a health administrative territory recorded for each member of the couple for each of follow-up. Using concordant health administrative territory as proxy for co-habitation during follow-up, couples were categorized as (1) 'together': partners who had concordant health administrative territories for the entirety of follow up and (2) 'separated': partners who were not in the same health administrative territory at any point during follow-up. Cox proportional hazards models were generated for each subcategory. Additionally, in the whole subset, Cox proportional hazards models adjusted for being 'separated' were also computed with and without and interaction term with GDM/GH status.

3. Results

3.1. Participants characteristics

Following the application of exclusion criteria, 63,438 matched couples were retained in the present analyses (Fig. 1). Overall, 3.5% (2252) of mothers had GH alone, 44.4% (28,198) had GDM alone (i.e., high proportion by design), and 5.6% (3521) had both GDM and GH (Table 1). Over half of fathers were 30–39 years old and approximately one third were under 30 years. Roughly half of the mothers were less than 30 years old and the rest were 30–39 years of age. There were more couples in the 'either' or 'both' categories where at least one partner had been hospitalized and had a history of airway disease in the 3 years prior to delivery compared to the couples in the 'neither' category. A stepwise increase in large for gestational age and premature infants was seen across the neither, either, or and both categories. Over 90% of couples were cohabitating at the time of the index delivery. Approximately one fifth of the cohort was non-European origin and over 90% of couples were composed of partners from the same ethnocultural background. A higher proportion of couples in the two most-deprived quintiles were seen in the GDM and/or GH exposure categories compared to those with neither.

3.2. GDM and GH as a diabetes risk indicator in couples

Over a mean 12.8 years (SD 5.4) the presence of either or both GDM and GH increased the risk for diabetes in the couple compared to those with neither GDM nor GH. Specifically, among couples with neither GDM nor GH the incidence of diabetes in both members of the couple was 0.10 (95% CI 0.08, 0.14) per 1000 person-years. In couples in the either GDM/GH category it was 0.98 (95% CI 0.88, 1.08) per 1000 person-years, and among those in the both GDM and GH category the incidence rate was 1.61 (95% CI 1.28, 2.02) per 1000 person-years (Fig. 2A; Table 2). Adjusted Cox regression models demonstrated an almost 9-fold higher risk (hazard ratio [HR]: 8.86; 95% CI 6.41, 12.23)

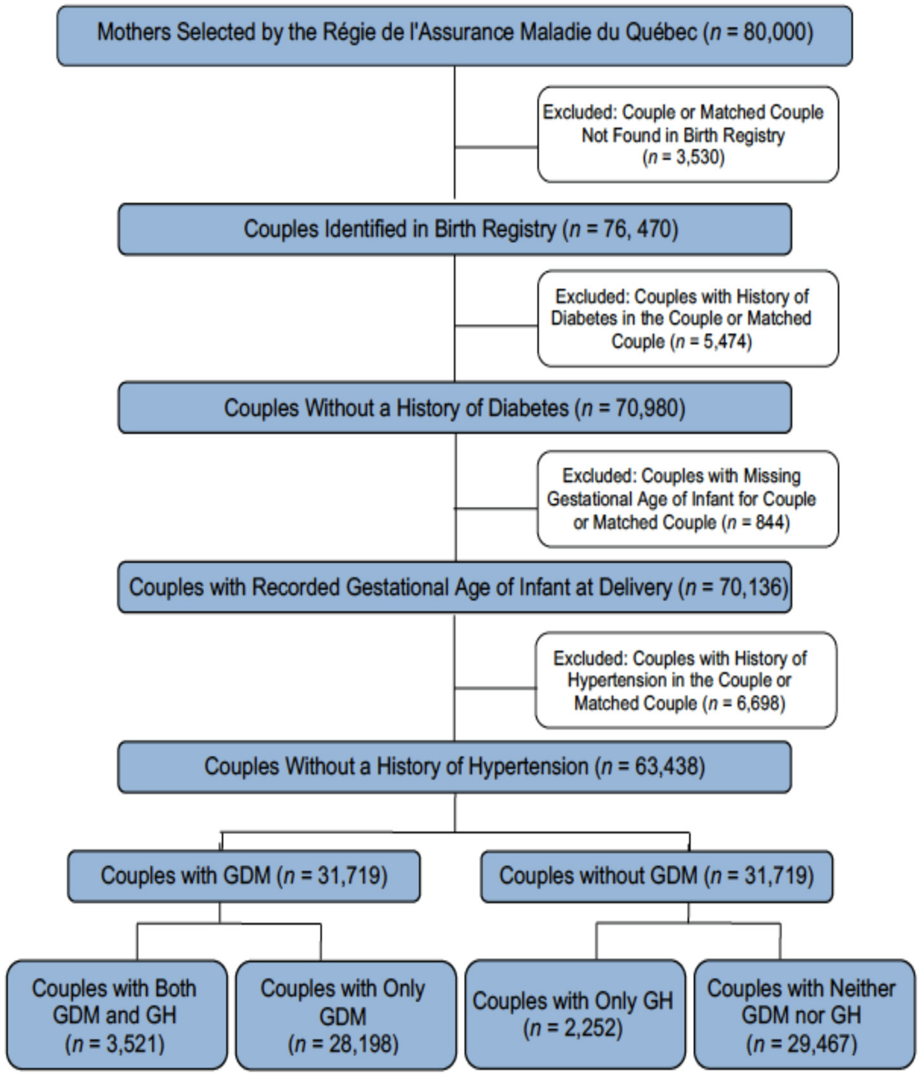

Fig. 1. Participant flow diagram.

in couples with either GDM or GH and a 16-fold risk increase in couples with a history of both GDM and GH (HR: 15.99; 95% CI 10.89, 23.48) compared to those with neither GDM nor GH (Table 2). Median time to diagnosis of diabetes in the couple as a unit was 15.1 years (IQR: 13.3, 18.0) in couples without a GDM or GH history, 12.9 years (IQR: 9.0, 16.3) in couples with a maternal history of GDM or GH and 11.6 years (IQR: 7.1, 15.4) in couples with a history of both GDM and GH (Table 2).

3.3. GDM and GH as a hypertension risk indicator in couples

Over a mean 12.8 years (SD 5.4), the hypertension incidence for couples in the neither, either and both GDM/GH categories were0.77 (95% CI 0.69, 0.86), 1.43 (95% CI 1.32, 1.55), and 4.25 (95% CI 3.70, 4.88) per 1000 person-years (Fig. 2B; Table 3), respectively. In adjusted Cox regression models, hypertension incidence was 77% higher (HR: 1.77; 95% CI 1.54, 2.04) in couples with either GDM or GH and nearly 6-fold higher in couples with a history of both GDM and GH (HR 5.83; 95% CI 4.86, 6.98) compared to those with neither condition (Table 3). Median time to diagnosis of hypertension in both members of the couple was 14.2 years (IQR: 10.6, 16.8) with neither GDM nor GH maternal history, 12.7 years (IQR: 9.3, 15.9) if the mother had either GDM or GH and 11.5 years (IQR: 8.2, 15.0) if there was a maternal history of both GDM and GH (Table 3).

3.4. Subgroup analyses

In the subset of couples whose health administrative territory was documented (N = 50,435), 55.5% (N = 27,983) of couples were categorized as 'together' and 44.5% (N = 22,452) were 'separated'. Risk estimates of incident diabetes in 'together' couples were: 'either'- HR 9.44 [5.56, 16.03] and 'both'-13.17 [6.95, 24.95]) and in 'separated' couples were: 'either'- HR 6.15 [3.78, 10.00] and 'both'- 11.70 [6.53, 20.98]). Regarding incident hypertension, the risk estimates for 'together' couples were: 'either'- HR 1.63 [1.34, 1.99] and 'both'- 5.21 [4.01, 6.77] and for 'separated' couples: 'either'- HR 1.82 [1.44, 2.31] and 'both'- 6.54 [4.88, 8.75]. Cox proportional hazards models adjusted for being 'separated' were also computed with and without and interaction term with GDM/GH status and this variable was not significant in any analyses for both diabetes and hypertension outcomes.

4. Discussion

Our results demonstrate that couples with a history of GDM or GH (i.e., in mother) have a higher risk of postpartum diabetes and of postpartum hypertension in both members of the couple compared to couples without GDM or GH history. The risks are even higher with a history of both GDM and GH. Specifically, either GDM or GH was associated with a 9-fold higher risk of postpartum diabetes; GDM and GH

Table 1
Couples' baseline characteristics.

	Neither GDM nor GH (N)	Either GDM or GH (N)	Both GDM and GH (N)
Total number of couples	56.4% (29,467)	48.0% (30,450)	5.6% (3,521)
Age of fathers			
Less than 30 years	33.6% (9,887)	30.9% (9,401)	35.3% (1,243)
30–39 years	55.0% (16,213)	56.9% (17,324)	53.5% (1,884)
40 years and above	11.4% (3,367)	12.2% (3,725)	11.2% (394)
Age of mothers			
Less than 30 years	45.9% (13,534)	45.5% (13,865)	49.5% (1,743)
30–39 years	51.0% (15,024)	51.3% (15,616)	47.1% (1,660)
40 years and above	3.1% (909)	3.2% (969)	3.4% (118)
Preterm delivery	5.5% (1,624)	7.9% (2,394)	15.1% (531)
Infants' size at delivery[a]			
Small for gestational age	10.8% (3,183)	8.7% (2,647)	13.0% (458)
Appropriate for gestational age	81.9% (24,144)	79.1% (24,084)	72.7% (2,559)
Large for gestational age	7.3% (2,140)	12.2% (3,719)	14.3% (504)
Previous pregnancy together	28.7% (8,458)	49.4% (15,057)	36.1% (1,271)
Living together at delivery	91.5% (26,965)	93.0% (28,310)	93.6% (3,294)
Couples' comorbidity			
Hospitalization in prior 3 years	27.3% (8,051)	39.7% (12,094)	34.5% (1,216)
Psychiatric disorders	23.8% (7,007)	24.4% (7,418)	25.6% (900)
Airway disease	17.6% (5,172)	20.2% (6,164)	22.5% (792)
Deprivation index[b]			
Two most-deprived quintiles	37.5% (11,037)	43.2% (13,155)	44.9% (1,582)
Ethnocultural background[c]			
Non-European origin	18.3% (5,380)	23.1% (7,026)	19.2% (675)
Concordant ethnocultural group	90.9% (26,799)	91.5% (27,868)	91.5% (3,222)

[a] Based on Canadian sex-specific birth data. Small for gestational age ≤ 10th percentile, average gestational ages 10–90th percentile and large for gestational age > 90th percentile.
[b] Neighborhood-level indicator of material deprivation.
[c] Based on primary language and country of birth. The ethnocultural groups considered non-Caucasian: South Asian, Southeast Asian, East Asian, West Asian, Afrocarribean, Central/South American, Indigenous.

together were associated with a 16-foldgreater risk of postpartum diabetes occurring in both members of the couple. Either GDM or GH was associated with a doubling of the postpartum hypertension risk; having both GDM and GH was associated with an almost 6-fold increase in risk of postpartum hypertension in the couple. These results highlight that pregnancy offers a unique window through which risk of future cardiometabolic disease may be identified in the couple as a unit and advocate a need for considering GDM/GH history in cardiovascular risk assessment.

In the current analyses the hazards ratios for the couple as a unit are lower than those reported in our previous analyses for mothers alone but higher than those for fathers alone [13,14]. Introducing a quantitative measure of couple risk may be leveraged for couple collaboration for cardiovascular risk reduction. Women with pregnancy-related disorders have a strong desire for partner collaboration to achieve health behaviour change [19–21]. Additionally, in couples, individuals feel more capable to change their behavior if their partner is also motivated to change; a study of American couples participating in a health screening program demonstrated that men and women reported less confidence in their capability to consume healthier diets, exercise more and lose weight if their spouse was is at a lower stage of readiness to change [22].

'Ripple effects' on spouses in health behaviour intervention studies have been noted. In the Look AHEAD trial, the delivery of an intensive lifestyle intervention to one spouse had beneficial effects on the untreated spouse; approximately one quarter of the spouses of participants in the intensive intervention arm lost 5% or more of baseline weight compared to less than 10% of spouses of participants in the control arm [33]. In the Dietary Intervention Randomized Controlled Trial (DIRECT), men were randomized to one of three diets (low-fat, Mediterranean or Low-carbohydrate) [23]. Their wives were invited to participate in three support group sessions during the first 6 months of the intervention focusing on the principles of the diet strategy to which their husbands had been randomized. Husbands whose wives took part in the group support lost more weight (−5.2 kg vs −3.5 kg) in 6 months compared to those whose wives did not take part in these sessions. Further, the wives themselves demonstrated improved eating habits and weight loss. Such ripple effects, however, are not always evident; in a study enrolling pregnant women and randomizing to a prenatal lifestyle intervention or standard care, the participants had less excessive gestational weight gain but their partners did not lose weight [24]. Partners may have to be explicitly engaged to collaborate. Understanding shared risk may help in this regard.

Engaging individuals in health behaviour change is challenging. It has been proposed that a couple's interdependence can be transformed to motivation for health-enhancing behaviour change by assigning meaning for the change to the relationships; the best interest of the self (person-centered) is converted to activities that are best for the partnership (relationship-centered) [25]. Supporting the hypothesis that couple-focused interventions may be more effective than individual-based interventions in facilitating behavioral changes, our group piloted a tailored type 2 diabetes prevention intervention, combining group cooking sessions, group exercise counselling, pedometers and on-site childcare for sessions [26]. In women within 5 years of a pregnancy with GDM, we demonstrated that although body mass index and body composition measures did not change, this intervention resulted in important changes in health behaviours, including increases in steps counts and fruit/vegetable intake and a decline in the proportion of couples reporting processed food consumption and dining out. Additionally, there were measureable improvements in glucose levels, insulin sensitivity and systolic blood pressure. Similar findings were seen in couples in primary care centers in in England and Australia who were enrolled in multi-modal health promotion programs [27,28]. In another study, overweight adults were randomized to a conventional behavioural weight loss program vs. an approach that engaged the partner and implemented some changes in the home environment (e.g., stationary bicycle or treadmill was brought into the home, televisions were equipped with a television allowance devices, etc.). A favourable effect overall was demonstrated in partners [29]. Engaging partners in such diabetes and hypertension prevention activities may be positively

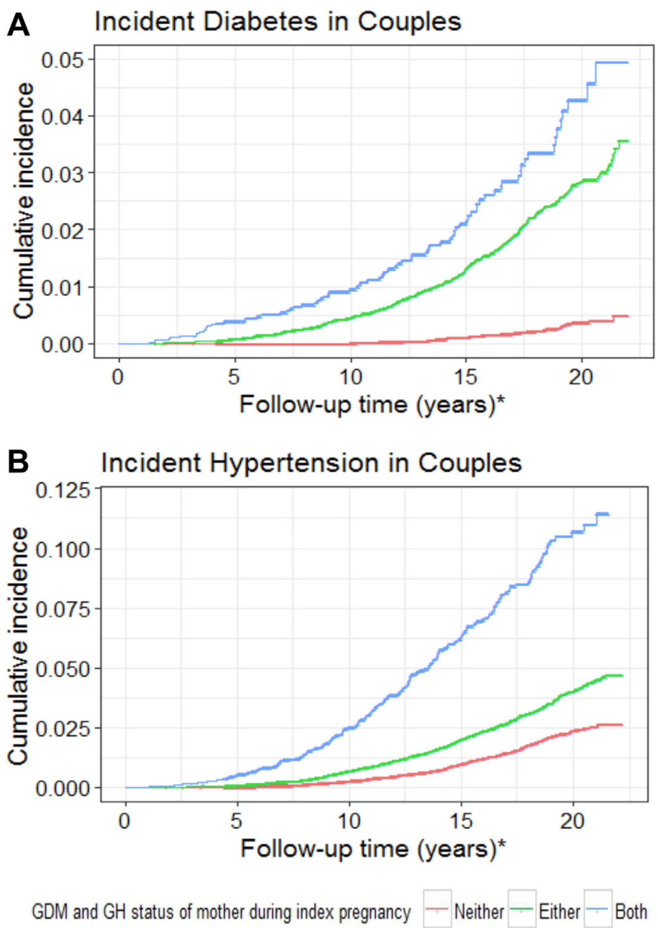

Fig. 2. Kaplan Meier curves for time to disease diagnosis of diabetes (A) and hypertension (B) in the couple-unit (both partners) stratified by gestational diabetes and gestational hypertension status of the mother. (Quebec, Canada; 1990–2012).

influenced by appreciating the shared risk in the couple as a unit, as illustrated in our study.

4.1. Limitations

We acknowledge limitations from the data available in our database. Our underlying hypothesis was that similarity in health behaviours, present either before union or emerging thereafter, would lead to an association between GDM/GH in mothers and incident diabetes and hypertension in the couple. We could not demonstrate such a mechanism because we did not have any data on physical activity, eating habits, smoking, or other health behaviours, nor did we have information on body mass index. However, prior studies have indicated concordance of health behaviours within couples [30]. Consistent with the impact of shared health behaviours, obesity, a known risk factor for diabetes, hypertension and CVD, is a characteristic that is often shared among spouses. Framingham cohort data also demonstrates that the development of obesity in one spouse increases the likelihood of its development in the other by 37% (95% CI 7–73) [31]. Additionally, results from the ARIC prospective cohort study showed that in couples married over 25 years, having a partner become obese nearly doubles a non-obese individual’s risk of also becoming obese in the future [32]. Further, as obesity likely lies along the causal pathway, it is not recommended to include it as a variable in our models examining the relationship between GDM/GH and incident diabetes and hypertension in the couple as a unit.

While we did not have data on maternal weight, we were able to account for the LGA offspring, which is driven by maternal pre-partum obesity and excess gestational weight gain [33]. The proportions of mothers with LGA offspring was lowest among those with neither GDM nor GH at 7.3%, higher among those with either GDM or GH at 12.2%, with a further increase to 14.3% among mothers with both conditions (Table 1). Accounting for LGA offspring in our analyses provided some indirect adjustment for maternal weight. In expectant couples, a Swedish cross-sectional study showed that a woman’s odds of being obese was more than six times higher (OR:6.2; 95%CI 4.2–9.3) if her partner was obese in comparison with a woman whose partner was non-obese. In univariate models, we found no significant association between LGA and hypertension (HR 1.17, 95%; CI 0.97, 1.42) and an increase in risk of incident diabetes (HR 1.69; 95% CI 1.33, 2.15) in the couple. The association between LGA and diabetes was attenuated in our multivariate analysis (HR 1.20; 95%CI 0.94, 1.53). Furthermore, the risk estimates for the GDM/GH variable were not significantly different in univariate models when compared to estimates adjusted for LGA.

As a diagnosis is only recorded in a health administrative database if an individual visits a physician or is admitted to a hospital, our use of administrative health data is subject to detection bias. A surveillance bias may be present as women with a history of GDM and/or GH compared to those without such a history may have more physician visits leading to more testing and diagnosis of diabetes and hypertension. Partners of women who have more frequent physician visits may also be more likely to interact with the healthcare system [5]. We also only had access to place of birth and first language to classify participants into ethnocultural groups which may have resulted in misclassification. Strengths of our study included alarge population-based cohort design and indicators of co-habitation status, size and gestational age of infant, socio-economic status and ethnicity that are not typically presented in administrative database studies.

5. Conclusions

In conclusion, GDM/GH status signals an increased risk of postpartum diabetes and postpartum hypertension in couples as a ‘unit’. This underscores the importance of considering GDM/GH history when assessing cardiovascular risk. Finally, this finding may be a powerful tool in promoting cardiovascular risk reduction by explicitly aiming for partner collaboration following a GDM/GH pregnancy to achieve behaviour change not only in the mother, but in the household as well.

Table 2
Incident diabetes rates per 1000 person-years, stratified Cox proportional hazards ratios and median time to diabetes diagnosis the couple stratified by gestational diabetes (GDM) and gestational hypertension (GH) status of the mother.

GDM and GH status of the mother	Incident diabetes (N)	Diabetes cases/1000 person-years [95%CI]	HR* [95%CI]	Median years to diagnosis [IQR]
Neither	0.14% (41)	0.10 [0.08,0.14]	1 (Reference)	15.1 [13.3,18.0]
Either	1.30% (395)	0.98 [0.88,1.08]	8.86 [6.41,12.23]	12.9 [9.0,16.3]
Both	2.04%(75)	1.61 [1.28,2.02]	15.99 [10.89,23.48]	11.6 [7.1,15.4]

* Adjusted for paternal age, gestational age and size of infants at birth, socioeconomic status, ethnicity, comorbidity, prior pregnancy and living together at delivery.

Table 3
Incident hypertension rates per 1000 person-years, stratified Cox proportional hazards ratios and median time to hypertension diagnosis in couple stratified by gestational diabetes (GDM) and gestational hypertension (GH) status of the mother.

GDM and GH status of the mother	Incident hypertension (N)	Hypertension cases/1000 person-years [95%CI]	HR* [95%CI]	Median years to diagnosis [IQR]
Neither	1.05% (310)	0.77 [0.69,0.86]	1 (Reference)	14.2 [10.6,16.8]
Either	1.93% (587)	1.43 [1.32,1.55]	1.77 [1.54,2.04]	12.7 [9.3,15.9]
Both	5.62% (198)	4.25 [3.70,4.88]	5.82 [4.86,6.98]	11.5 [8.2,15.0]

* Adjusted for paternal age, gestational age and size of infants at birth, socioeconomic status, ethnicity, comorbidity, prior pregnancy and living together at delivery.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.preghy.2019.02.004.

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