Prepregnancy dietary patterns and risk of developing hypertensive disorders of pregnancy: results from the Australian Longitudinal Study on Women’s Health

Danielle AJM Schoenaker, Sabita S Soedamah-Muthu, Leonie K Callaway, and Gita D Mishra

Schools of Public Health and Medicine, University of Queensland, Brisbane, Australia; Division of Human Nutrition, Wageningen University, Wageningen, The Netherlands; and Departments of Obstetric and Internal Medicine, Royal Brisbane and Women’s Hospital, Brisbane, Australia

ABSTRACT
Background: Hypertensive disorders of pregnancy (HDPs), including gestational hypertension and pre-eclampsia, are common obstetric complications associated with adverse health outcomes for the mother and child. It remains unclear how dietary intake can influence HDP risk.

Objective: We investigated associations between prepregnancy dietary patterns and risk of HDPs.

Design: We selected 3582 women participating in the Australian Longitudinal Study on Women’s Health, which is an observational population-based study. Women were not pregnant at baseline in 2003 and reported at least one live birth between 2003 and 2012. Diet was assessed by using a validated 101-item food-frequency questionnaire in 2003, and factor analysis was used to identify dietary patterns. HDP were assessed by using the question, “Were you diagnosed or treated for hypertension during pregnancy?” Generalized estimating equation models were used to estimate RRs (95% CIs) adjusted for dietary, reproductive, sociodemographic, and lifestyle factors.

Results: During 9 y of follow-up of 3582 women, 305 women (8.5%) reported a first diagnosis of HDPs in 6149 pregnancies. We identified 4 dietary patterns labeled as meat, high-fat, and sugar; Mediterranean-style; fruit and low-fat dairy; and cooked vegetables. In the adjusted model, the meat, high-fat, and sugar, fruit and low-fat dairy, and cooked vegetable dietary patterns were not associated with HDP risk. The Mediterranean-style dietary pattern (characterized by vegetables, legumes, nuts, tofu, rice, pasta, rye bread, red wine, and fish) was inversely associated with risk of developing HDPs (quartile 4 compared with quartile 1: RR, 0.58; 95% CI, 0.42, 0.81).

Conclusions: In this population-based study of Australian women, we observed an independent protective dose-response association between prepregnancy consumption of a Mediterranean-style dietary pattern and HDP risk. Additional studies are recommended to confirm our findings by prospectively examining whether the implementation of the Mediterranean-style dietary pattern before pregnancy has a role in the prevention of HDPs.

Keywords: dietary patterns, hypertensive disorders of pregnancy, nutrition, pregnancy, diet, Mediterranean diet

INTRODUCTION
Hypertensive disorders of pregnancy (HDPs) are common complications encountered in pregnancy that affect between 5% and 15% of pregnancies on the basis of population data from developed countries (1, 2). The prevalence of HDPs is expected to increase as a result of, e.g., the trend toward higher maternal age and the obesity epidemic (1, 3). HDPs are associated with significant adverse maternal, fetal, and neonatal outcomes (4, 5). Women who develop HDPs are more likely to experience complications during pregnancy and delivery, and HDPs account for 10–15% of all direct maternal deaths (6). Babies born to mothers with HDPs often have a low birth weight and are at increased risk of fetal growth restriction (1, 7). Long-term consequences include significant increased risk of future development of cardiovascular disease and type 2 diabetes for both the mother and child (8–11).

These lifelong and intergenerational adverse health consequences highlight the need for the identification of modifiable risk factors that may contribute to the prevention of HDPs. Endothelial dysfunction, inflammation, oxidative stress, insulin resistance, and dyslipidemia are characteristics of HDPs, even though the exact cause remains largely unclear (1, 12). Dietary intake during pregnancy was proposed to play a role in the etiology of HDPs (13, 14), but current evidence on the relation between diet and the prevention of HDPs remains inconclusive. Systematic reviews of results from intervention trials in pregnant women did not support nutrient supplementation to reduce HDP risk with the exception of calcium supplementation in women with low dietary calcium intake and for those at high risk (15–20). Meta-analyses of intervention studies that examined the overall...
diet during pregnancy showed conflicting findings. Lower risk of HDPs was shown for dietary interventions including a balanced diet during pregnancy (21) but not for dietary counseling during pregnancy (22). Current evidence from observational studies on the association between maternal dietary intake and HDPs is limited (23). Findings from our recent systematic review and meta-analyses of cohort studies indicated that pregnant women with higher calcium intake were less likely to be diagnosed with HDPs. The few studies that examined foods and dietary patterns during pregnancy suggested a protective association between a diet rich in fruit and vegetables and pre-eclampsia even though results were not all significant (23).

Thus far, the majority of studies focused on examining single nutrients and foods. However, foods are consumed together in an overall diet. Evidence that links overall dietary patterns with HDPs will provide a stronger scientific basis for new intervention strategies and enable a better formulation of dietary recommendations. Furthermore, prepregnancy nutrition was suggested to be crucial for an optimal onset and development of pregnancy because early pregnancy is a critical period for placental development and cardiovascular adaptations related to blood pressure development (24–26). However, to our knowledge, no studies to date prospectively examined prepregnancy dietary factors in relation to HDPs. This study aims to examine the associations between prepregnancy dietary patterns and risk of developing HDPs in a population-based study of reproductive-aged Australian women.

**METHODS**

**Study design and participants**

The ALSWH (Australian Longitudinal Study on Women’s Health) is an ongoing population-based cohort study examining factors associated with the health and well-being of Australian women in 3 age cohorts. Full details on the study design, recruitment methods, and responses were published previously (27, 28). Women were randomly selected from the national Medicare health insurance database, including all Australian citizens and permanent residents. Women from rural and remote areas were intentionally oversampled. The ALSWH collects self-reported data by using mailed surveys every 2–4 y on a rolling basis. In addition, the FFQ included 21 items on the number of servings and types of milk, bread, fat spread, sugar, eggs, and cheese consumed. The consumption of 101 food items (in g/d) and nutrient intakes were computed from the national government food composition database of Australian foods, the NUTTAB95 (32).

**Assessment of HDPs**

Physician-diagnosed HDPs were ascertained from self-reported responses to the following question at surveys 5 (2009) and 6 (2012): “Were you diagnosed or treated for hypertension (high blood pressure) during pregnancy?” (answered separately for each pregnancy that resulted in a live birth). With the use of the reported child dates of birth and dates when surveys were returned, HDPs were assigned to each 3-y survey interval. If data for questions at surveys 5 and 6 were missing, the following survey 2–4 question was used: “In the last 3 years, have you been diagnosed or treated for hypertension (high blood pressure) during pregnancy?” (answered for each survey interval). Women who reported HDPs before survey 3 were excluded because they may have reported HDPs before survey 3 were excluded because they may have been diagnosed or treated for hypertension.

**Dietary assessment**

Diet was assessed at survey 3 by using the Dietary Questionnaire for Epidemiologic Studies version 2. The development of this 101-item food-frequency questionnaire (FFQ) has been described elsewhere (30). The FFQ was validated for 63 women against 7-d food diaries (31). Energy-adjusted correlation coefficients for nutrient intake ranged between 0.28 for vitamin A and 0.78 for carbohydrates, which indicated that the FFQ performed reasonably well for the assessment of habitual intake. Participants were asked to report their usual frequency of consumption of 74 food items and 6 alcoholic beverage items over the previous 12 mo by using a 10-point scale that ranged from never to ≥3 times/d. Portion-size photographs were used to adjust serving sizes for vegetables, meat, and casseroles. In addition, the FFQ included 21 items on the number of servings and types of milk, bread, fat spread, sugar, eggs, and cheese consumed. The consumption of 101 food items (in g/d) and nutrient intakes were computed from the national government food composition database of Australian foods, the NUTTAB95 (32).
have changed their diet and lifestyle habits to prevent recurrence. Incidence of HDPs was defined as first cases between surveys 3 (2003) and 6 (2012). At each survey, women were asked the following separate question: “In the last 3 years, have you been diagnosed or treated for hypertension (high blood pressure) other than during pregnancy?” Women with a positive response to this question on pre-existing hypertension before pregnancy were excluded from our analyses. A reliability study in a subgroup of women (n = 1914) showed high agreement of 87% between self-reported HDP diagnoses in our study and administrative data records (E Gresham, P Forder, C Chojenta, J Byles, D Loxton, A Hure, Research Centre for Gender, Health and Ageing, School of Medicine and Public Health, University of Newcastle, Newcastle, Australia, personal communication, 2015).

Assessment of socioeconomic, reproductive, and lifestyle factors

Women reported on a range of socioeconomic, reproductive, and lifestyle factors at each survey, including the highest qualification completed, nulliparity, multiple births, gestational diabetes mellitus (GDM), preterm birth (<36 wk of gestation), low birth weight (<2500 g), vitamin and mineral supplement use, smoking, physical activity, and BMI. Responses for the highest qualification completed were categorized as a “high school degree or less”, “some college or associate’s degree”, and “graduate degree”; for nulliparity, multiple births, GDM, preterm birth, and low birth weight, responses were categorized as “yes” or “no”; for vitamin and mineral supplement use, responses were categorized as “never or rarely”, “sometimes”, and “often”; and for smoking, responses were categorized as “never smoked”, “ex-smoker”, and “current smoker”. Physical activity scores obtained were derived from self-reported frequency and duration of walking (for recreation or transport) and from moderate- and vigorous-intensity activity in the past week. The total metabolic equivalent (MET; in min/wk) was calculated as

(Walking minutes × 3.5) + (moderate minutes × 4) +

(vigorous minutes × 7.5)

Physical activity was categorized as “sedentary or low” (<600 MET minutes per week), “moderate” (600 to <1200 MET minutes per week), or “high” (≥1200 MET minutes per week). Validation of the self-reported physical activity questions was published previously (33). BMI was computed as weight divided by the square of height and categorized according to WHO classifications as “underweight” [BMI (in kg/m²) <18.5], “healthy weight” (BMI from 18.5 to <25), “overweight” (BMI from 25 to <30), or “obese” (BMI ≥30) (34). Because only a limited number of women (n = 150; 42%) were classified as “underweight”, they were combined and classified as “healthy weight” (BMI <25).

Statistical analysis

Baseline characteristics for women who did and did not develop HDP during follow-up were described as mean (±SD) or percentages and compared by using t or chi-square tests. Descriptive statistics were weighted by the area of residence to account for the oversampling of women from rural and remote areas.

Prepregnancy dietary patterns were identified by using exploratory factor analysis with factor loadings extracted by using the principal component method and varimax/orthogonal rotation. The number of dietary patterns that best-represented the data were based on eigenvalues ≧1.25, the identification of a break point in the screeplot, and interpretability (35). Factor loadings represented the correlation between foods and a particular pattern. Factors were labeled according to those food items that most heavily contributed to the pattern (factor loading ≧20). Dietary pattern scores were used to rank women according to the degree to which they conformed to each dietary pattern by dividing dietary pattern scores into quartiles.

Generalized estimating equation (GEE) analyses, which accounted for correlations in repeated pregnancies contributed by a single woman (36), were used to examine the associations between quartiles of dietary patterns (survey 3) and incidence of HDPs (surveys 4–6). Log-binomial models (37) or log-Poisson models (38) (when log-binomial models did not converge) were used to estimate RRAs (95% CIs). Models were adjusted for time-varying covariates as follows: we adjusted for sociodemographic characteristics (area of residence and highest qualification completed) and lifestyle factors (vitamin and mineral supplement use, smoking, physical activity, and BMI) reported at the survey before the index pregnancy and for reproductive characteristics (GDM, nulliparity, and multiple birth) reported at the same survey as the index pregnancy. All models were adjusted for energy intake (kJ/d) reported at survey 3. Risk factors for HDPs including country of birth and ethnicity, polycystic ovary syndrome, type 1 or 2 diabetes, interpregnancy intervals, and alcohol consumption were not included in the models because they were not significant confounders.

To test the robustness of our results, we performed a range of sensitivity analyses as follows: 1) we tested whether associations between significant dietary patterns and HDP risk were modified by risk factors of HDPs (including age, GDM, nulliparity, multiple births, highest qualification completed, smoking, and BMI) by evaluating interaction terms in the multivariable models; 2) dietary pattern scores were, in addition to quartiles, divided into more-broad (i.e., tertiles) and -refined (i.e., quintiles) categories; 3) to minimize the potential effect of any changes in diet over time and reduce measurement error (39), we calculated the average long-term diet of nonpregnant women on the basis of data from FFQs at surveys 3 and 5, and we examined associations between average long-term prepregnancy dietary patterns and HDP risk; 4) to assess the influence of participant exclusions that resulted from missing covariate data (n = 305), a multiple-imputation analysis was used (40). The following SAS procedures (SAS Software Version 9.4; SAS Institute Inc.) were performed: 1) PROC MI was used to create 20 imputed data sets; all covariates described were included in the model and imputed; 2) GEE analyses were performed on each of the imputed data sets; and 3) these results were analyzed by using MIANALYZE to create combined estimates and CIs that appropriately accounted for the variance within and between imputed data sets.

Additional analyses were conducted to identify potential dietary components responsible for associations between significant prepregnancy dietary patterns and HDP. We performed GEE analyses for associations between main contributors to the dietary pattern (food items with factor loading ≧20) (survey 3) and...
incidence of HDPs (surveys 4–6). Food items significantly associated with HDPs were removed from the dietary pattern to examine whether the association between the dietary pattern and incidence of HDPs persisted. Models were adjusted for time-varying covariates as previously described.

We also performed analyses to explore whether associations between significant prepregnancy dietary patterns and HDPs differed according to subtypes of HDPs including gestational hypertension and pre-eclampsia. Pre-eclampsia, but not gestational hypertension, is associated with placental dysfunction and intrauterine growth restriction that result in preterm birth and low birth weight of the offspring (1). Women in our study did not report on these subtypes of HDPs separately. Therefore, we conducted subgroup analyses for associations of prepregnancy dietary patterns with incidence of HDPs with inclusion of all reported HDPs, 2) HDPs in pregnancies that resulted in preterm birth or low birth weight (likely to reflect pre-eclampsia), and 3) HDPs in pregnancies with no preterm birth or low birth weight (less likely to reflect severe early onset pre-eclampsia and more likely to include women with term pre-eclampsia or gestational hypertension) (41). To retain statistical power, we examined associations between continuous prepregnancy dietary patterns (per one score increase) and HDP incidence.

Statistical analyses were conducted with SAS Software (Version 9.4). P < 0.05 was considered statistically significant.

RESULTS

During 9 y of follow-up of 3582 women who reported at least one live birth, 305 women (8.5%) reported a first diagnosis of HDPs in 6149 pregnancies. HDPs were more likely to occur in nulliparous women, women with lower education, and women who were overweight or obese at baseline (Table 1).

### Dietary patterns

Four dietary patterns were identified by using factor analysis (Table 2). The meat, high-fat, and sugar pattern was characterized by high consumption of meat, processed meat, cakes, sweet biscuits, chocolate, meat pies, and pizza. The Mediterranean-style pattern positively correlated with vegetables, legumes, nuts, tofu, rice, pasta, rye bread, red wine, and fish. The fruit and low-fat dairy pattern showed high factor loadings for fruit, yogurt, low-fat cheese, and skim milk. The cooked vegetable pattern was characterized by high consumption of carrots, peas, cooked potatoes, cauliflower, and pumpkin. Women in the highest quartile of each dietary pattern generally reported higher intakes of energy and nutrients (Supplemental Table 1). The Mediterranean-style and fruit and low-fat dietary patterns were inversely associated with the glycemic index.

### Associations between prepregnancy dietary patterns and HDPs

After adjustments for total energy intake, vitamin and mineral use, GDM, nulliparity, multiple births, area of residence, highest qualification completed, smoking, physical activity, and BMI, the Mediterranean-style dietary pattern was linearly inversely associated with HDP risk, whereas no significant associations were shown for the other dietary patterns (Table 3). Adjusted RRs (95% CIs) of HDP risk across lowest to the highest quartiles of Mediterranean-style dietary pattern scores were 1.00 (reference), 0.85 (0.65, 1.11), 0.70 (0.50, 0.97), and 0.58 (0.42, 0.81).

<table>
<thead>
<tr>
<th>Prepregnancy characteristic</th>
<th>HDPs (n = 305)</th>
<th>No HDPs (n = 3277)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>28 ± 1.5†</td>
<td>28 ± 1.4</td>
<td>0.93</td>
</tr>
<tr>
<td>Nulliparity, %</td>
<td>90.3</td>
<td>76.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Area of residence, %</td>
<td></td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>Urban</td>
<td>70.6</td>
<td>72.8</td>
<td></td>
</tr>
<tr>
<td>Rural/remote</td>
<td>29.4</td>
<td>27.2</td>
<td></td>
</tr>
<tr>
<td>Highest qualification completed, %</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school degree or less</td>
<td>22.5</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>Some college or associate’s degree</td>
<td>28.7</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>Graduate degree</td>
<td>48.8</td>
<td>58.5</td>
<td></td>
</tr>
<tr>
<td>Total energy intake, kJ/d</td>
<td>6539 ± 2112</td>
<td>6621 ± 2205</td>
<td>0.53</td>
</tr>
<tr>
<td>Vitamin/mineral use, %</td>
<td></td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>Never/rarely</td>
<td>13.7</td>
<td>15.1</td>
<td></td>
</tr>
<tr>
<td>Sometime</td>
<td>44.7</td>
<td>39.8</td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>41.6</td>
<td>45.2</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²), %</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Healthy weight (&lt;25)</td>
<td>56.1</td>
<td>73.5</td>
<td></td>
</tr>
<tr>
<td>Overweight (25 to &lt;30)</td>
<td>28.3</td>
<td>18.2</td>
<td></td>
</tr>
<tr>
<td>Obese (≥30)</td>
<td>15.6</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>Physical activity (MET min/wk), %</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary/low (&lt;600)</td>
<td>41.5</td>
<td>41.5</td>
<td></td>
</tr>
<tr>
<td>Moderate (600 to &lt;1200)</td>
<td>22.0</td>
<td>25.2</td>
<td></td>
</tr>
<tr>
<td>High (≥1200)</td>
<td>36.5</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td>Smoking, %</td>
<td></td>
<td></td>
<td>0.20</td>
</tr>
<tr>
<td>Never smoked</td>
<td>61.9</td>
<td>62.5</td>
<td></td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>15.0</td>
<td>18.0</td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>23.1</td>
<td>19.5</td>
<td></td>
</tr>
</tbody>
</table>

†Values were weighted by area of residence. P values were determined by using chi-square or t tests. HDPs, hypertensive disorders of pregnancy; MET, total metabolic equivalent.

*Mean ± SD (all such values).*

Associations between prepregnancy dietary patterns and HDP risk were robust in multiple sensitivity analyses (data not shown). Associations were not significantly modified by age, GDM, nulliparity, multiple births, highest qualification completed, smoking, or BMI. We observed similar results in a sensitivity analysis in which dietary pattern scores were divided into more-broad (i.e., tertiles) and -refined (i.e., quintiles) categories as well as for the associations between average long-term prepregnancy dietary and HDP risk. In addition, a sensitivity analysis in which missing covariate data were imputed yielded similar findings.

We examined associations of food items highly correlated with the Mediterranean-style dietary pattern with HDP incidence. Nuts, red wine, and rye bread, which are important contributing food items to the Mediterranean-style dietary pattern, were significantly associated with HDP incidence. Higher consumption of 5 g/d of nuts (RR 0.85; 95% CI: 0.72, 0.99), 5 g/d of red wine (RR: 0.98; 95% CI: 0.97, 0.99), and 5 g/d of rye bread (RR: 0.95; 95% CI: 0.90, 0.99) was significantly associated with reduced risk of HDPs. The elimination of these food items from the Mediterranean-style dietary pattern attenuated estimates but did not remove the significant association between the Mediterranean-style dietary pattern and incidence of HDPs.

No differences were shown in associations of prepregnancy consumption of the Mediterranean-style dietary pattern with HDPs reported in pregnancies that did and did not result in preterm
delivery or delivery of a low birth weight baby; in the adjusted model, the RRs (95% CIs) for each increase of one dietary pattern score were 0.79 (0.69, 0.91) for all HDPs (305 cases), 0.73 (0.58, 0.87) for HDPs in pregnancies with preterm delivery or low birth weight (68 cases), and 0.81 (0.69, 0.95) for HDPs in pregnancies that did not result in preterm delivery or a low birth weight baby (237 cases).

DISCUSSION

In this population-based study of Australian women, we observed an independent dose-response association between pre-pregnancy consumption of a Mediterranean-style dietary pattern and reduced HDP risk during 9 y of follow-up. Women in the highest quartile of Mediterranean-style dietary pattern scores had 42% lower risk of developing HDPs compared with women in the lowest quartile. No associations were observed for the following dietary patterns: meat, high-fat, and sugar; fruit and low-fat dairy; and cooked vegetables.

To our knowledge, associations between prepregnancy dietary patterns and the prospective development of HDPs have not been previously investigated. Our findings extend results from studies on dietary factors during pregnancy and HDPs. In line with our findings, results from the Norwegian Mother and Child Cohort study showed that pregnant women (n = 23,423) consuming a vegetable dietary pattern rich in vegetables, plant foods, vegetable oils, and rice (comparable to our Mediterranean-style dietary pattern) were less likely to be diagnosed with HDPs [top tertile (n cases = 495) compared with bottom tertile (n cases = 357): OR, 0.72; 95% CI, 0.62, 0.85] (42). Moreover, the processed food dietary pattern rich in processed meat, salty snacks, and sugar-sweetened drinks was positively associated with HDPs (OR: 1.21; 95% CI: 1.03, 1.42) (24). In our study, we did not find an association for the meat, high-fat, and sugar dietary pattern. Women in the highest quartile of our meat, high-fat, and sugar dietary pattern also reported high consumption of fish, vegetables (including potatoes), and fruit, which may have resulted in the overall null association. In the US cohort study Project Viva, overall diet quality as measured by the Alternate Healthy Eating Index slightly modified for pregnancy was not associated with pre-eclampsia when assessed in the first trimester but slightly lowered the odds of developing pre-eclampsia when assessed in the second trimester of pregnancy (per 5-point increase: OR, 0.87; 95% CI, 0.76, 1.00) (43). In the Generation R study, Timmermans et al. (44) showed that low adherence to a Mediterranean-style dietary pattern and high adherence to a traditional dietary pattern during pregnancy were associated with higher blood pressure during pregnancy, but these patterns were not associated with gestational hypertension or pre-eclampsia outcomes.

Several mechanisms for a biological effect of the Mediterranean-style dietary pattern on HDP risk may explain the observed association. The overall Mediterranean-style diet has consistently been shown to be beneficial in the prevention of a range of

| TABLE 2 |
| Prepregnancy dietary patterns and factor loadings (n = 3582) |

<table>
<thead>
<tr>
<th>Factor loading</th>
<th>Mediterranean-style factor loading</th>
<th>Fruit and low-fat dairy factor loading</th>
<th>Cooked vegetables factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>Beef</td>
<td>Pears</td>
<td>Carrots</td>
</tr>
<tr>
<td>Sausage</td>
<td>Sausage</td>
<td>Melon</td>
<td>Cauliflower</td>
</tr>
<tr>
<td>Chicken</td>
<td>Chicken</td>
<td>Peaches</td>
<td>Peas</td>
</tr>
<tr>
<td>Cakes</td>
<td>Cakes</td>
<td>Apples</td>
<td>Broccoli</td>
</tr>
<tr>
<td>Crisps</td>
<td>Crisps</td>
<td>Yogurt</td>
<td>Pumpkin</td>
</tr>
<tr>
<td>Pizza</td>
<td>Pizza</td>
<td>Apricots</td>
<td>Potatoes</td>
</tr>
<tr>
<td>Lamb</td>
<td>Lamb</td>
<td>Strawberries</td>
<td>Green beans</td>
</tr>
<tr>
<td>Fried fish</td>
<td>Fried fish</td>
<td>Pineapple</td>
<td>Cabbage</td>
</tr>
<tr>
<td>Meat pies</td>
<td>Meat pies</td>
<td>Mango</td>
<td></td>
</tr>
<tr>
<td>Ice cream</td>
<td>Ice cream</td>
<td>Pasta</td>
<td></td>
</tr>
<tr>
<td>Bacon</td>
<td>Bacon</td>
<td>Avocado</td>
<td></td>
</tr>
<tr>
<td>Sweet biscuits</td>
<td>Sweet biscuits</td>
<td>Soya milk</td>
<td></td>
</tr>
<tr>
<td>Salami</td>
<td>Salami</td>
<td>Nuts</td>
<td></td>
</tr>
<tr>
<td>Chips</td>
<td>Chips</td>
<td>Tomatoes</td>
<td></td>
</tr>
<tr>
<td>Pork</td>
<td>Pork</td>
<td>Red wine</td>
<td></td>
</tr>
<tr>
<td>Vegemite</td>
<td>Vegemite</td>
<td>Hard cheese</td>
<td></td>
</tr>
<tr>
<td>Chocolate</td>
<td>Chocolate</td>
<td>Bean sprouts</td>
<td></td>
</tr>
<tr>
<td>Crackers</td>
<td>Crackers</td>
<td>Ricotta or cottage cheese</td>
<td></td>
</tr>
<tr>
<td>Hamburger</td>
<td>Hamburger</td>
<td>Heavy beer</td>
<td></td>
</tr>
<tr>
<td>Tomato sauce</td>
<td>Tomato sauce</td>
<td>Fish</td>
<td></td>
</tr>
<tr>
<td>Ham</td>
<td>Ham</td>
<td>Rye bread</td>
<td></td>
</tr>
<tr>
<td>Fruit juice</td>
<td>Fruit juice</td>
<td>White wine</td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>White bread</td>
<td>Porridge</td>
<td></td>
</tr>
<tr>
<td>Firm cheese</td>
<td>Firm cheese</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jam</td>
<td>Jam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veal</td>
<td>Veal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavored milk drink</td>
<td>Flavored milk drink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peanut butter</td>
<td>Peanut butter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Rotated factor loadings ≥20. Dietary patterns were identified by using factor analysis with factor loadings extracted by using the principal component method and Varimax/orthogonal rotation.

DIET AND HYPERTENSIVE DISORDERS OF PREGNANCY 5 of 8
Prepregnancy dietary pattern | Women/pregnancies, n (percentage of pregnancies) | Model 1 | Model 2 | Model 3 | Model 4
--- | --- | --- | --- | --- | ---
Meat, high-fat, and sugar  
Quartile 1 | 895/1547 | 78 (5.0) | Reference | Reference | Reference | Reference  
Quartile 2 | 896/1598 | 72 (4.5) | 0.91 (0.66, 1.26) | 0.95 (0.69, 1.30) | 0.91 (0.66, 1.25) | 0.89 (0.64, 1.22)  
Quartile 3 | 896/1516 | 77 (5.1) | 1.12 (0.78, 1.61) | 1.15 (0.81, 1.64) | 1.08 (0.76, 1.54) | 1.04 (0.73, 1.48)  
Quartile 4 | 895/1488 | 78 (5.2) | 1.27 (0.78, 2.07) | 1.20 (0.74, 1.95) | 1.06 (0.66, 1.72) | 0.94 (0.57, 1.55)  
Median | 0.44 | 0.59 | 0.73 | 0.77  
Mediterranean-style  
Quartile 1 | 895/1470 | 99 (6.7) | Reference | Reference | Reference | Reference  
Quartile 2 | 896/1539 | 84 (5.5) | 0.82 (0.62, 1.08) | 0.76 (0.58, 1.00) | 0.77 (0.59, 1.01) | 0.85 (0.65, 1.11)  
Quartile 3 | 896/1599 | 64 (4.0) | 0.63 (0.47, 0.86) | 0.58 (0.42, 0.81) | 0.61 (0.44, 0.84) | 0.70 (0.50, 0.97)  
Quartile 4 | 895/1541 | 58 (3.8) | 0.60 (0.43, 0.82) | 0.47 (0.34, 0.64) | 0.51 (0.37, 0.70) | 0.58 (0.42, 0.81)  
Median | 0.004 | <0.0001 | 0.0005 | 0.0008  
Fruit and low-fat dairy  
Quartile 1 | 895/1463 | 75 (5.1) | Reference | Reference | Reference | Reference  
Quartile 2 | 896/1530 | 83 (5.4) | 1.05 (0.78, 1.41) | 1.06 (0.79, 1.43) | 1.13 (0.83, 1.54) | 1.08 (0.80, 1.46)  
Quartile 3 | 896/1574 | 72 (4.6) | 0.89 (0.65, 1.21) | 0.95 (0.69, 1.31) | 1.03 (0.74, 1.42) | 0.98 (0.70, 1.37)  
Quartile 4 | 895/1582 | 75 (4.7) | 0.94 (0.69, 1.28) | 0.94 (0.69, 1.27) | 1.04 (0.76, 1.43) | 0.97 (0.71, 1.32)  
Median | 0.72 | 0.84 | 0.87 | 0.89  
Cooked vegetables  
Quartile 1 | 895/1568 | 75 (4.8) | Reference | Reference | Reference | Reference  
Quartile 2 | 896/1567 | 73 (4.7) | 0.94 (0.69, 1.29) | 1.04 (0.76, 1.41) | 1.00 (0.74, 1.37) | 0.97 (0.71, 1.32)  
Quartile 3 | 896/1558 | 87 (5.6) | 1.09 (0.81, 1.47) | 1.29 (0.96, 1.73) | 1.23 (0.91, 1.65) | 1.15 (0.86, 1.54)  
Quartile 4 | 895/1456 | 70 (4.8) | 0.95 (0.69, 1.30) | 1.20 (0.87, 1.65) | 1.08 (0.77, 1.51) | 1.04 (0.73, 1.48)  
Median | 0.76 | 0.31 | 0.51 | 0.70

A number of limitations of the study should be considered. First, misclassification of dietary intake was inevitable. However, the dietary data could not have been influenced by the subsequent development of HDPs because of the prospective design of the study. We observed similar results when we examined associations of HDP incidence with average long-term prepregnancy dietary patterns, which reduced the influence of random errors. Moreover, the FFQ has been validated against 7-d food diaries and shown to be a valuable tool for the assessment of habitual dietary intake. Second, in our study, we were not able to take diet during pregnancy into account. Women may have changed their dietary patterns from before to during pregnancy that may have had a direct effect on HDP risk or that may have modified the effect of prepregnancy dietary patterns on risk of developing HDPs. However, evidence from prospective cohort studies suggested minimal change in diet from before to during pregnancy (53, 54), from early to late pregnancy (53, 55, 56), and even postpartum (54). Third, the use of self-reported HDPs may have introduced bias. In Australia, a diagnosis of gestational hypertension is defined as new-onset hypertension (\( \geq 140 \) mm Hg systolic blood pressure or \( \geq 90 \) mm Hg diastolic blood pressure) arising after 20 wk of gestation, and a diagnosis of pre-eclampsia is defined as gestational hypertension with the involvement of one or more other organ systems and/or the fetus (57). Our survey questions did not distinguish between a diagnosis of hypertension before or after 20 wk of gestation; therefore, women who were diagnosed with hypertension <20 wk of gestation may have been included in our definition of HDPs. The incidence rate of HDPs reported in our study may differ slightly across populations. In our study, women in the highest quartile of the Mediterranean-style dietary pattern consumed, on average, 2.5 servings vegetables/d, 1.5 servings whole fruit/d, 2 servings dairy/d (mainly low-fat), 2 servings pasta and rice/d, 2 servings high-fiber grain foods/d (such as whole-meal bread, rye bread, and muesli), 1.5 servings meat/d, 1.5 alcoholic beverages/d, 1.5 servings nuts/wk (45 g), and 2–3 servings fish/wk. Our study had several unique strengths. To our knowledge, this is the first study to examine prepregnancy dietary factors prospectively in relation with HDPs. The repeated surveys provided the opportunity to follow women for multiple subsequent pregnancies. Furthermore, the ALSWH is a nationally representative population-based study and results are generalizable to the Australian population of reproductive-aged women (27, 29).
population (8.5%) was comparable to those reported in population data (birth or hospital records) from Australia (8.8% and 9.1% for New South Wales and Western Australia, respectively, accounting for 43% of births in Australia) (2). Moreover, the reliability of the self-reported HDPs in our study population showed high agreement with administrative records. Women with chronic hypertension before pregnancy on the basis of a self-reported diagnosis or treatment were excluded from our analyses; however, we were unable to formally distinguish between subtypes of HDPs including gestational hypertension and mild and severe pre-eclampsia. Previous studies on dietary factors during pregnancy and subtypes of HDPs suggested more-pronounced risk of severe compared with mild pre-eclampsia for lower intakes of calcium (58), vitamin C (59), and probiotics (6) and higher consumption of tea (61). However, our results did not suggest a difference in the association between the Mediterranean-style dietary pattern and risk of HDPs in pregnancies that did or did not result in preterm delivery or delivery of a low birth weight baby. The similar magnitude and direction of associations between dietary factors and gestational hypertension and pre-eclampsia may have indicated overlapping pathophysiologic mechanisms for the influence of dietary factors on subtypes of HDPs. Last, in our observational study, we were not able to prove causality of observed associations. We could not rule out that unmeasured or imprecisely measured factors may have confounded associations. Although we controlled for a variety of known risk factors for HDPs, no information was collected on chronic conditions such as kidney disease and endometriosis, family history of hypertension or HDPs, and gestational and interpregnancy weight gain.

In conclusion, our findings indicate that prepregnancy consumption of a Mediterranean-style dietary pattern is associated with lower risk of developing HDPs. No individual dietary component could fully explain this association, suggesting that the combination and interaction of foods and nutrients of the Mediterranean-style dietary pattern are important and responsible for the observed association with reduced HDP risk. Diet is a modifiable factor, and the promotion of a healthy diet represents an ideal strategy to optimize HDP outcomes. Reproductive-aged women should be encouraged to consume a healthy diet rich in vegetables, legumes, nuts, tofu, rice, pasta, rye bread, red wine, and fish. Although a causal link between prepregnancy consumption of a Mediterranean-style diet and reduced HDP risk cannot be confirmed, our results indicate a clear dose-response for this relation. Additional studies are recommended to confirm our findings by prospectively examining whether the implementation of the Mediterranean-style dietary pattern before pregnancy has a role in the prevention of HDPs.

We thank Graham Giles of the Cancer Epidemiology Centre of The Cancer Council Victoria for permission to use the Dietary Questionnaire for Epidemiological Studies, version 2; Melbourne (Australia); The Cancer Council Victoria; 1996. We also thank Ellie Gresham, Pete Forder, Catherine Chojenta, Julie Byles, Deborah Loxton, and Alexis Hure for contributing unpublished results on the validation of the self-reported HDP outcome used in this study.

The authors’ responsibilities were as follows—DAJMS: designed the research, performed the statistical analysis, wrote the manuscript, and had primary responsibility for the final content of the manuscript; SSS-M and GDM: contributed to the design of the research, interpretation of results, and critical revision of the manuscript for important intellectual content; and LKC: contributed to the interpretation of results and critical revision of the manuscript for important intellectual content. The ALSWH was conceived and developed at the Universities of Newcastle and Queensland. None of the authors reported a conflict of interest related to the study.

REFERENCES