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Title page

Title: DASH (Dietary Approaches to Stop Hypertension) dietary pattern and maternal blood pressure in pregnancy

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Author’s contributions to the manuscript

AC, EOB, RC, and FMcA designed the research. All authors conducted the research. All authors helped with data analysis. All authors were involved with writing the paper. FMcA had primary responsibility for the final paper.

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Abbreviations List;

BMI – Body Mass Index

BMR – Basal Metabolic Rate

BP – Blood Pressure

DASH – Dietary Approaches to Stop Hypertension

DBP – Diastolic Blood Pressure

GI – Glycemic Index

GTT – Glucose Tolerance Test

GWG – Gestational Weight Gain

HDP – Hypertensive Disorders of Pregnancy

HTN – Hypertension

IOM – Institute of Medicine

IQR – Interquartile Range

Kcal – Kilocalorie

MAP – Mean Arterial Pressure

MET – Metabolic Equivalent

mm Hg – Millimeters Mercury (measurement of blood pressure)

NMH – National Maternity Hospital

RCT – Randomized Control Trial

ROLO – Randomized control trial of low glycemic index diet for the prevention of recurrence of macrosomia

SBP – Systolic Blood Pressure

SD – Standard Deviation

SSB – Sugar Sweetened Beverages

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Abstract

Background: High blood pressure (BP) in pregnancy is associated with significant adverse outcomes. In non-pregnant populations, the DASH (Dietary Approaches to Stop Hypertension) diet is associated with reductions in blood pressure. This study investigated the relationship between the DASH dietary pattern and maternal BP in pregnancy.

Methods: This is an observational study of 511 women who participated in the ROLO study (Randomized cOntrol trial of LOw glycemic index diet for the prevention of recurrence of macrosomia), 2007-2011, Dublin, Ireland. Auscultatory blood pressure, systolic (SBP) and diastolic (DBP) blood pressure measurements were taken. Mean Arterial Pressure (MAP) was calculated. Dietary intakes were recorded using 3-day food diaries in each trimester. DASH scoring criteria were used to score and rank participants from low to high intakes of foods recommended in the DASH diet. Statistical analysis using ANOVA and multiple linear regression were used to determine the relationship between maternal BP and DASH scores.

Results: Dietary intake more closely resembling the DASH dietary recommendations throughout pregnancy were associated with lower DBP (mmHg) in trimesters 1 (B:-0.70, 95%CI:-1.21, -0.18), and 3 (B:-0.68, 95%CI:-1.19, -0.17), and lower MAP (mm Hg) in trimesters 1 (B:-0.78, 95%CI:-1.33, -0.25), and 3 (B:-0.54, 95%CI:-1.04, -0.04) controlling for BMI, age, education, energy intake and intervention grouping.

Conclusions: The DASH dietary pattern was associated with lower maternal BP in pregnancy among healthy women without hypertensive disorders of pregnancy. Despite the observational nature of these findings, the results demonstrate the potential for healthcare professionals to intervene to promote cardiovascular health in pregnancy.

Introduction

Physiological changes within the cardiovascular system in normal pregnancy are significant, as systolic, diastolic, and mean arterial pressure (MAP) decrease in the first trimester, increasing back to the pre-pregnancy values towards delivery ¹⁻⁴. Blood pressure can be used as a clinical health marker in the prediction of hypertensive disorders of pregnancy (HDP); chronic hypertension, gestational hypertension, pre-eclampsia and white coat hypertension ^{5,6}. Hypertension (HTN) occurs in 6% of pregnancies ⁷, and increases the risk of hypertension in subsequent pregnancies ⁸.

In non-pregnant populations, weight reduction and DASH (Dietary Approaches to Stop Hypertension) dietary intakes are lifestyle modifications with the greatest reduction in systolic blood pressure (SBP) ⁹. As weight reduction during pregnancy is not recommended ⁹, the DASH diet appears to be the most suitable modifiable factor to target, as a method of controlling blood pressure in a pregnant population ⁹. The DASH diet is high in fruit, vegetables, nuts, seeds, legumes, low-fat dairy products, wholegrains, lean meat, and fish, with reduced intakes of saturated fat, and total fat, with sodium restricted to 2300 mg per day ^{10,11}. Previous studies suggest dietary interventions using the DASH diet, as a complement to weight loss ¹²⁻¹⁴, and reduced daily intake of sodium <2,300mg ^{15,16}, lowers blood pressure in healthy, non-pregnant populations. However, many of these studies have been limited by small sample size, and food provision, which may not be generalizable to a normal population.

It is well known that blood pressure disorders during pregnancy can have significant adverse effects on both the mother and the fetus ^{6,17,18}. However, only one study to date has examined the DASH dietary pattern and blood pressure during pregnancy, with null findings for risk of

HDP or third trimester blood pressure¹⁹. Further examination of detailed maternal dietary intakes using food diaries and repeated blood pressure measurements throughout pregnancy is required.

Since pregnancy is a time when women are in regular contact with healthcare professionals and are motivated to make dietary changes for the benefit of their infant²⁰, it is an ideal time for dietitians and healthcare professionals to intervene to improve cardiovascular health. An understanding of the effect of dietary patterns on blood pressure in pregnancy could identify potential future maternity and public health strategies. Given the potential for the DASH diet to improve outcomes, and the relative dearth of knowledge in pregnancy, compared to non-pregnant populations, an examination of the DASH diet and maternal blood pressure is warranted. Thus, the primary aim of this study is to describe the diet in a sample of healthy pregnant women and compare it to DASH recommendations. The secondary aim is to investigate the relationship between the DASH dietary pattern and maternal blood pressure at multiple time points in pregnancy, among healthy women without HDP.

Subjects (or Materials) and Methods

Study Design

This was an observational study of 511 women who participated in the ROLO (Randomized cOntrol trial of LOw glycemic index diet for the prevention of recurrence of macrosomia) study, in the National Maternity Hospital, Dublin, Ireland, 2007 to 2011²¹. The ROLO study originally focused on reduced consumption of high glycemic index foods, aimed at preventing fetal macrosomia, reducing gestational weight gain and improving maternal glucose tolerance²¹. Detailed methods and descriptions of the study have been outlined elsewhere^{21,22}. Participants were recruited during their second pregnancy, and were included

115 based on previous macrosomia (infant birth weight >4kg)²¹. Women were excluded if they
116 had any underlying medical disorders, history of gestational diabetes, on medication, unable
117 to give full consent, under 18 years old, greater than 18 weeks' gestation, or multiple
118 pregnancies²¹. Inclusion criteria for this analysis were completed and returned 3-food diaries,
119 food diaries with plausible dietary reporting (between 500 and 3500 kcal/day), available
120 blood pressure measurements, and women without HDP (**Figure 1**).

121
122 Ethical approval was granted by the National Maternity Hospital ethics committee, Dublin,
123 Ireland. The exposure of interest in this analysis was the DASH dietary pattern, using a
124 DASH score as an index of dietary quality. The outcome of interest was maternal blood
125 pressure (systolic, diastolic, and MAP) across the three trimesters of pregnancy.

126 127 Data Collection

128 Body weight and blood pressure were obtained at booking (week 13), week 28, and 34
129 weeks' gestation. Each participant had their height and weight measured using standardized
130 protocols and instruments; body weight was measured using a calibrated SECA weighing
131 scales (SECA GmbH & CO. KG., Hamburg, Germany), to the nearest 0.1kg without shoes,
132 in minimal clothing; height was measured, without shoes, on first hospital visit, using a wall
133 mounted stadiometer to the nearest 0.1cm. Body mass index (BMI) was calculated using the
134 equation weight in kilograms divided by height in meters squared (kg/m^2). All
135 anthropometric measures were performed by a midwife or researcher. Primary outcome
136 variables were maternal blood pressure; SBP and DBP, measured in early (week-13), mid
137 (week-28), and late (week-34) pregnancy. Auscultatory blood pressure measurements (mm
138 Hg) were obtained by the doctors and/or midwife, using a mobile Trimline aneroid
139 sphygmomanometer as per institutional protocol for routine antenatal care. After the

participant had rested, sitting with arm at heart level, the observer measured blood pressure in the right arm, using an appropriately sized cuff (according to mid-arm circumference). Mean arterial pressure (MAP) was calculated as $[DBP + 1/3 \times (SBP-DBP)]$ ²³. Dietary intakes were assessed at trimester 1 (pre-low glycemic index diet intervention), trimester 2 and trimester 3, using 3-day food diaries²¹. Women were asked to include the type and amount of all foods and drinks consumed over three consecutive days²¹. The dietary data from the food diaries were entered into NetWISP food composition database version 3.0 (Tinuviel Software, Llanfechell, Anglesey, UK), derived from the McCance and Widdowson food composition tables (6th Edition)²⁴. Implausible mean dietary energy intakes (<500 kcal/day, or >3500 kcal/day), which could be a result of misreporting, or measurement errors, were excluded from the analysis (n=1)²⁵. These cut-off values were previously reported in a pregnant population²⁶. Questionnaires distributed during pregnancy assessed patient's activity, smoking status, education, well-being, alcohol and supplement intakes. Other maternal characteristics (age and race) were self-reported in pregnancy.

DASH Adherence Score

Adherence to the DASH diet was examined using a modified version of Fung and colleagues'²⁵ DASH scoring criteria (8 components); fruit, vegetables, nuts/seeds/legumes, wholegrains, low fat dairy, red lean/red processed meat, sweet snacks and sodium. An additional 9th food group; salty snacks was included, previously used in a non-pregnant Irish cohort¹⁶. 3-day food diaries assessed maternal dietary intakes during pregnancy. The 1,730 foods reported in the food diaries were; (a) grouped into 1 of 9 food groups as per DASH recommendations (n=1,079), or (b) not grouped (n= 651) foods which fall outside DASH food groups e.g. white bread. A portion size (grams) was assigned to each food using the Food Pyramid food portion sizes e.g. 200mls milk, 75g lean meat²⁷. However, some foods were not specifically

represented as a serving size in grams e.g. 1 medium apple. These foods were assigned a median gram weight using the “*Irish Food Portion Sizes Database*”²⁸. Additional foods were sourced from Nutritics (Nutritics Software 2018, Dublin, Ireland). To calculate the number of servings of each food group consumed, each participant’s food intakes (grams reported in 3-day food diary), were divided by serving size (grams weight). Servings consumed = reported gram weight of food eaten (mean of 3-day food diary)/ serving size (in grams). Example: Serving of nuts = 45 grams as per food diary (mean of 3 days)/ 40g serving size as per Food Pyramid = 1.13 servings. Foods that fall into more than one food group e.g. lasagna, were assigned into all appropriate food groups (meat, vegetable), with the proportion contributed and the serving size, in grams, of the allocated food group. All 9 food groups were ranked into quintiles (1 to 5). 5 of the 9 food groups; fruits, vegetables, nuts/seeds/legumes, wholegrains, and low-fat dairy products were positively scored from 1 to 5, based on participants’ intakes. The higher the score, the more frequent the consumption (quintile 1, the lowest consumption received a score of 1; quintile 5, the highest consumption received a score of 5). The remaining 4 components; sodium, red meat, sweet snacks and salty snacks were scored in reverse, as a lower consumption of these foods is recommended (quintile 1 received a score of 5, and quintile 5 received a score of 1). The scores were totaled across the 9 food groups to yield the DASH diet adherence score of minimum 9 and maximum 45 points.

Statistical Analysis

Data was assessed for normality using the Kolmogorov-Smirnov tests and through visual inspection of histograms. One-way ANOVA and independent-samples *t*-tests were used to compare mean DASH scores and demographic, lifestyle and behavioral characteristics. Bivariate analysis was carried out to examine correlations between maternal characteristics

and blood pressure at Trimester 1, 2, and 3. One-way ANOVA tests compared maternal characteristics with DASH quintile across all three measures of blood pressure (SBP, DBP, and MAP). *Post hoc* (Tukey's test) allowed for comparison between DASH quintiles. Independent-samples *t*-tests were used to identify differences between the participants assigned the ROLO intervention and the control diet. Variables in the bivariate analysis, or ANOVA, with an association with blood pressure ($P < 0.1$) were selected for further analysis. These values were included in the multivariate linear regression models to determine the associations between maternal blood pressure (SBP, DBP, MAP) with (i) the categorical variable DASH quintiles (quintile 1 served as the referent), and (ii) DASH as a continuous variable, examining the change in blood pressure for every 5-unit increase in DASH score. Unadjusted and adjusted models of regression were carried out, with and without confounders, based on earlier literature, and determined *a priori*¹⁶; adjusted for BMI (kg/m^2), age (years), education (greater or less than tertiary), grouping (intervention or control) and energy intake (kcal/day). Although confounders were decided *a priori*, as most of the women were Caucasian and we had a very low smoking rate of circa 3%, neither were included as confounders. Data analysis was conducted using IBM SPSS Statistics 24.0 statistical software for Mac (IBM, Armonk, NY). To reduce bias, all food group allocation, DASH scoring, and statistical analysis were conducted blind to the participants' ROLO intervention grouping.

Results

Maternal Characteristics

511 women from the ROLO study were included in this analysis. **Table 1** summarizes the baseline characteristics and demographics of the population. The sample was comprised of healthy pregnant women 32.2 ± 4.0 years of age, mostly Caucasian (97.7%), with body mass index (BMI) of $26.3 \pm 4.4 \text{ kg}/\text{m}^2$. Mean $\pm$ standard deviation (SD) for blood pressures in

trimesters 1 to 3 were: SBP (112.7 ± 11.5 mm Hg, 112.4 ± 11.2 mm Hg, 112.7 ± 10.3 mm Hg, respectively); DBP (68.0 ± 7.1 mm Hg, 66.6 ± 7.3 mm Hg, 68.1 ± 7.3 mm Hg, respectively); and MAP (82.9 ± 7.6 mm Hg, 81.9 ± 7.6 mm Hg, 82.9 ± 7.2 mm Hg, respectively). For analysis, overall participants' DASH score represented as quintiles ranged as follows: Q1 (11-22); Q2 (23-25); Q3 (26-28); Q4 (29-32); Q5 (33-42). Mean $\pm$ SD DASH score in trimesters 1, 2, 3 were 26.7 ± 5.2 , 26.7 ± 5.3 , 26.8 ± 5.2 , respectively.

Positive significant associations (bivariate correlations) were identified between blood pressures (systolic, diastolic and MAP) for weight (kilograms) at booking, and BMR (Henry-Oxford) and BMI at booking (kg/m^2) across all trimesters of pregnancy. Negative significant associations between blood pressures were identified for maternal age (years) in trimester 2 for SBP and MAP, and physical activity (METs) for DBP in trimester 1.

Maternal Dietary Pattern

Table 2 displays the number of servings of each DASH component (2,000 kcal energy level) by quintiles (of maternal dietary intake ranked according to the DASH dietary guidelines), for trimester 1, trimester 2, trimester 3 and on average during pregnancy (trimester 1, trimester 2, trimester 3 summed and divided by 3). It was noted that those in the highest quintile (quintile 5) did not meet the recommended servings for the majority of components within the DASH diet. Consumption of two food groups (red lean/red processed meats, and salty snacks) met the daily DASH recommendations of less than 2.3 and less than 0.7 servings respectively. A higher DASH score was positively associated with other health promoting behaviors; micronutrient supplementation, non-smoker, healthy BMI, older age, adequate gestational weight gain (GWG), and tertiary education attainment (**Table 3**). The ROLO intervention group had significantly higher mean DASH score than the control group.

When independent-samples *t*-tests compared maternal blood pressure (systolic, diastolic and MAP) among those in the intervention and control, no differences were observed.

DASH Diet Score and Maternal Blood Pressure

Figure 2 displays the difference in SBP, DBP and MAP between the lowest DASH quintile (quintile 1) and the highest DASH quintile (quintile 5) across the three trimesters; SBP differed by 4.0 mm Hg, 1.8 mm Hg and 1.6 mm Hg; DBP differed by 2.1 mm Hg, 1.6 mm Hg, and 1.9 mm Hg; and MAP by 2.7 mm Hg, 1.7 mm Hg, and 1.8 mm Hg, respectively. Greater dietary intake resembling the DASH diet guidelines (higher DASH score) throughout pregnancy was associated with lower DBP in trimesters 1 (B: -0.70 95%CI: -1.21, -0.18) (P=0.008), and trimester 3 (B: -0.68 95%CI: -1.19, -0.17) (P=0.010), and lower MAP in trimesters 1 (B: -0.78 95%CI: -1.33, -0.25) (P=0.004), and trimester 3 (B: -0.54 95%CI: -1.04, -0.04) (P=0.033) controlling for BMI, age, education, energy intakes, and grouping (**Table 4**). Lower SBP was observed with greater DASH score, in trimester 1 (B: -0.94 95%CI: -1.75, -0.12) (P=0.000) but not across trimester 2 or 3. Each 5-unit increase in overall DASH score was significantly associated with 0.8 mm Hg lower DBP in trimester 1 (P=0.001), 0.76 mm Hg lower DBP in trimester 3 (P=0.05), and 0.74 mm Hg lower MAP trimester 1 (P=0.024), adjusting for the same cofounders (Table 4).

Discussion

Among a cohort of healthy, normotensive, pregnant women recruited in early pregnancy, a higher DASH score was significantly associated with lower blood pressure across the three trimesters. A higher DASH score associated with higher education, non-smokers, and normal BMI. For each 5-unit increase in DASH score, participants had 1 mm Hg lower DBP and MAP.

This is a novel study, there is only one such known study examining the effect of the DASH diet on blood pressure during pregnancy ¹⁹. The positive findings from this analysis differ in many aspects to the research carried out in the USA in 2018 ¹⁹, that reported null findings for dietary adherence to the DASH diet during pregnancy on 3rd trimester BP and HDP. The differences between this ROLO cohort and the study by Project Viva lie within the study design. First, the population; data from a cohort of healthy pregnant women (n=800), compared to pregnant women (n=1760) with disorders including hypertensive disorders of pregnancy and gestational diabetes ¹⁹. Second, the data collection; in the ROLO study 3-day food diaries were used at each trimester to capture specific foods and allow thorough categorization into DASH food groups, Project Viva used a semi-quantitative food frequency questionnaire in trimester 1 ¹⁹. Third, BP measurements; BP in ROLO was measured at 3 time-points (13, 28, and 34 weeks' gestation) during pregnancy, compared to one time-point in trimester 1 ¹⁹. Finally, the outcomes of interest differed; DASH dietary score and measures of BP (SPB, DBP, MAP) were the primary outcomes in this study, compared to DASH dietary score and occurrence of GDM, HDP and 3rd trimester BP.

This is not the first study to question the adherence to the DASH diet ^{11,25,29-31}. Various methods used to assess DASH compliance include construction of DASH score based on dietary intake ^{10,25,30,32-35}, self-reported adherence from participant FFQ or 3-day food record charts ^{10,25,30,32-35}, observation during on-site meal times ^{10,32} or urinalysis of potassium and sodium to reflect high levels of DASH dietary adherence ^{10,32,33,36}. Previous studies have admitted that participant dietary adherence is poor ³⁰ – DASH scores ranged from 4.9 out of 8 (61%) ³⁷, 1.4 to 2.9 out of 9 (16%-32%) ^{29,38,39}, and 3.9 to 6 out of 10 (40-60%) ¹⁴. Troyer defined adherence to the DASH dietary recommendations as a DASH score of >4.5/9 or

290 >50% adherence. The mean DASH score in our study of 5.3/9 (60%) indicates that our
291 participants, in terms defined by Troyer et al were compliant, although not meeting the
292 National Institutes of Health National Heart, Lung, and Blood Institute portion requirements
293 ⁴⁰. Our Mean DASH score 26.7 out of 45 (59%) compared almost exactly to the Pregnancy
294 Infection Nutrition (PIN) Study DASH score 24.3 out of 40 (58.5%) a larger (n = 4227)
295 American prospective study without intensive feeding, dietary education on the DASH diet,
296 or meal provision ³⁷.
297
298 Similar to our findings, a higher DASH score was associated with older age, higher
299 education, non-smokers, and normal BMI, in accordance with previous research in a non-
300 pregnant population ⁴¹. Although >75% of the women in this study were aged over 30, which
301 may be considered a higher age than the general population, the mean age of participants was
302 32.2 years. This is comparable across recent similar studies including project VIVA 31.8
303 years ⁴², 32.2 years ¹⁹, and 33.2 years ⁴³. Higher DASH score was previously inversely
304 associated with blood pressure in a non-pregnant population ¹⁶. In our unadjusted model, a
305 higher DASH score in each trimester, and overall during pregnancy, was associated with
306 lower maternal blood pressure (systolic, diastolic and MAP). Those in the highest DASH
307 group (quintile 5) differed in SBP by 1.6-4.0 mm Hg, DBP by 1.6-2.0 mm Hg, and MAP by
308 1.7-2.7 mm Hg, to those in the lowest DASH group (quintile 1). This concurs with evidence
309 in non-pregnant populations as the DASH diet is known to reduce blood pressure by 4.5 mm
310 Hg (systolic) and 2.7 mm Hg (diastolic) ¹². Similarly, the Joint National Committee
311 guidelines on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure
312 suggest that the DASH diet can reduce SBP by 3 mm Hg, in normotensive individuals ⁴⁴. As
313 pregnancy is a stressed state, women's response to the DASH diet may be exaggerated.

A small, yet significant, decrease in blood pressure, as low as 2 mm Hg SBP, reduced the risk of cardiovascular death rates by 4-5%, a 4% reduction in coronary heart disease and 6% reduction for stroke ⁴⁵. The DASH diet compared on par with pharmacologic mono-therapy in individuals with clinical HTN, those following the DASH diet had greater BP reductions among those with clinical HTN than those with normal BP ³². Thus, DASH dietary compliance may potentially obviate the need for anti-hypertensive medications and suggests the potential application of DASH dietary recommendations for both the treatment and primary preventative measures within the general population. ³²

Challenges arise in the attainment of low sodium dietary intakes, as many foods are high in sodium, with the daily recommended salt allowance of 6g/day ⁴⁶. Ongoing dietary counselling and support measures may be required to sustain long term dietary adherence to the DASH diet ⁴⁷. Previous studies randomized participants into DASH diet vs control and examined dietary patterns with blood pressure within the general, non-pregnant population, or observed health outcomes of adherence to the DASH diet using a scoring scheme in pregnant, and non-pregnant, populations. Although we cannot ascertain cause and effect from this observational study, these results support the hypothesis that a diet resembling the DASH diet during pregnancy could reduce maternal blood pressure. During pregnancy, women are more receptive to lifestyle changes ²⁰, so, a better understanding of how diet during pregnancy impacts on gestational outcomes could have measurable impacts on population health, and combat hypertension, and other diseases that arise from unhealthy dietary patterns. In our adjusted model, a 5-unit increase in DASH score, decreasing DBP and MAP by approximately 1 mm Hg, has been previously cited to reduce SBP by 1.9 mm Hg in a non-pregnant population ¹⁶. Potentially, a small adjustment in maternal diet to increase overall DASH score by 5, could potentially reduce blood pressure by 1 mm Hg, important for those

on the cusp of pre-hypertension. Pregnancy is thought to act as a stress test for life, and these women may only be diagnosed with hypertension when their blood pressure fails to normalize at delivery ⁴⁸. As one of the first studies to examine the DASH diet and blood pressure in pregnancy, further research in this area is needed to confirm these results.

The strengths of this study include the use of food diaries captured at three time points during pregnancy, which allowed for repeated measurements to obtain long-term overall dietary intakes and, therefore, reduced measurement error. Unlike FFQs, food diaries do not rely on memory or recall, as they are filled out daily. The ROLO study is a RCT, with a large sample size (n=511), results should be applicable to pregnant women. The Fung et al. ²⁵ scoring system was previously validated as a method to assess adherence to dietary patterns in relation to health outcomes in pregnant ¹⁹ and non-pregnant populations ¹⁶. The DASH diet is a low cost, low risk, simple to follow diet which uses foods that are easily accessible and accepted ³². This is a clinically relevant study and will help to drive research in this area and potentially lead to an RCT in women with HTN in pregnancy. Limitations include the observational study design, predominately white, educated, non-smoking population and the health-conscious nature of women who volunteer to take part in a study. The generalizability of the results may be limited due to the specific population studied; previous history of macrosomia, recruited on their second pregnancy, without gestational diabetes or HDP. As participants were recruited at approx. 13 weeks' gestation, pre-pregnancy blood pressure measurements were unavailable, and it is not clear whether blood pressure was high for some women before pregnancy, though this is unlikely. This is similar to the Generation R study ³, which only included pregnancy blood pressure values, and not baseline values, as women were recruited during pregnancy. The DASH score does not measure adherence to the DASH diet per se, but ranks participants according to their

364 dietary intakes in comparison to the DASH diet. The allocation of the same weight to each
365 dietary component, may dilute the effectiveness of certain components, such as sodium's
366 effect on blood pressure. Although these women were not prescribed the DASH diet per se,
367 the retrospective examination of their usual dietary pattern and the ROLO intervention of
368 low glycemic diet allowed for dietary intake and comparison to the DASH dietary
369 guidelines. The DASH score does, however, reflect how closely an individual's diet
370 represents the DASH recommendations ⁴⁰.

371
372 The DASH dietary pattern was associated with lower maternal blood pressure in pregnancy
373 among healthy women without HDP. Despite the observational nature of these novel
374 findings, the results demonstrate the potential for dietitians and healthcare professionals to
375 intervene, to promote cardiovascular health, using the DASH diet to reduce blood pressure
376 during pregnancy.

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Figure 1: Flow diagram of the step by step participant randomization, selection, and inclusion for analysis within this study.

Figure 2: The difference in blood pressure (systolic, diastolic and mean arterial pressure) between the participants in quintile 5 (highest DASH score) and quintile 1 (lowest DASH score) across the three trimesters of pregnancy (One-way ANOVA).

Table 1: Maternal characteristics of the ROLO (Randomized cOntrol trial of LOw glyemic index diet versus no dietary intervention in the prevention of recurrence of macrosomia) participants with blood pressures measurements and returned completed 3-day food diaries (n=511)

Demographics	N		
Age at booking (years) ^a	509	32.2	4.0
Age at childbirth (years) ^a	511	32.7	4.0
Age Groups ^b	511		
- Less than 30 years ^b	121	23.7%	
- Greater than 30 years ^b	390	76.3%	
Race/ethnicity:	511		
- Caucasian ^b	499	97.7%	
- Other ^b	12	2.3%	
Education attainment:	511		
- Less than third level education ^b	209	42.8%	
- Completed third level education ^b	279	57.2%	
Smoking habits at baseline:	511		
- Yes ^b	14	2.7%	
- No ^b	497	97.3%	
Supplementation (not specified):	489		
- Yes ^b	287	58.7%	
- No ^b	202	41.3%	
Alcohol intakes (ml/day) ^c	494	1.4	5.3
Alcohol intakes (ml/week) ^c	494	9.5	37.0
Alcohol intakes (units/week) ^c	494	1.0	3.7
Energy Intakes (mean overall pregnancy) ^a	511	1879.8	375.9
- Trimester 1 ^a	511	1855.2	436.1
- Trimester 2 ^a	511	1886.6	450.9
- Trimester 3 ^a	511	1897.7	443.6
Anthropometry			
Weight at booking (kg) ^a	510	72.2	12.4
Height (cm) ^a	509	165.8	6.1
Body Mass Index (BMI) in early pregnancy ^a	509	26.3	4.3
Body Mass Index Classification:	509		
- Underweight (BMI <18.5kg/m ²) ^b	2	0.4%	
- Normal weight (BMI 18.49-25kg/m ²) ^b	229	45.0%	
- Overweight (BMI 25-29.99kg/m ²) ^b	194	38.1%	
- Obese (BMI >30kg/m ²) ^b	84	16.5%	
Gestational Weight Gain (kg) ^a	429	13.2	4.2
Gestational weight gain (GWG) IOM categories	511		
- Inadequate weight gain ^b	65	15.2%	

- Adequate weight gain ^b	154	36.0%	
- Excessive weight gain ^b	209	48.8%	
Basal Metabolic Rate (Henry Oxford) ^a	510	1423.0	142.9
Blood Pressure			
Trimester 1			
- Systolic (mm Hg) ^a	468	112.7	11.5
- Diastolic (mm Hg) ^a	468	68.0	7.1
- Mean Arterial Pressure (MAP) ^a	468	82.9	7.6
Trimester 2			
- Systolic (mm Hg) ^a	489	112.4	11.3
- Diastolic (mm Hg) ^a	489	66.6	7.3
- Mean Arterial Pressure (MAP) ^a	489	81.9	7.7
Trimester 3			
- Systolic (mm Hg) ^a	503	112.7	10.3
- Diastolic (mm Hg) ^a	503	68.1	7.3
- Mean Arterial Pressure (MAP) ^a	503	82.9	7.2
Gestational Diabetes			
GTT Carpenter-Coustan			
- Yes (diagnosed) ^b	11	2.2%	
Physical Activity			
METs ^a	443	450.8	295.1
Time spent sitting (minutes/day):			
- Total over week day ^a	443	385.2	180.2
- Total over weekend day ^a	439	300.5	139.8
Grouping (Low GI Diet in ROLO Study vs Control)			
- Intervention ^b	225	44.0%	
- Control ^b	286	56.0%	

Data is presented as ^a mean (SD), ^b n (%), ^c median (IQR), MET (Metabolic Equivalent); N, number of participants; Supplement not specified within lifestyle questionnaire; ml, milliliter, unit, unit of alcohol; energy intakes; mean kilocalorie intakes as reported in 3-day food diaries; kg, kilograms; BMI, Body Mass Index classification per World Health Organization cut-offs; GWG, Gestational Weight Gain per IOM guidelines of weight gain in pregnancy (Underweight 12.5-18 kg, Normal weight 11.5-16 kg, Overweight 7-11.5 kg, Obese 5-9 kg); GTT, Glucose Tolerance Test 50g glucose tolerance test. 10ml alcohol = 1 unit of alcohol; * P-value <0.05, **P-value <0.001

Table 2: Comparison of DASH (Dietary Approaches to Stop Hypertension) score with DASH diet recommendations: mean number of daily servings of food groups consumed during pregnancy according to overall total DASH score quintile

Food Group	DASH Score (quintile)					DASH diet	Meeting DASH?
	Q1	Q2	Q3	Q4	Q5		Yes/No
Overall Pregnancy	(n=108)	(n=93)	(n=98)	(n=126)	(n=86)		
Fruit and Fruit Juice	1.1	1.6	2.0	2.4	2.8	4-6 servings/day	No
Vegetables excluding potatoes & legumes	1.4	1.6	1.9	2.2	2.6	4-6 servings/day	No
Nuts, seeds, legumes	0.2	0.2	0.2	0.4	0.5	0.57-0.71 servings/day	No
Wholegrains	0.8	1.1	1.3	1.6	1.8	3 servings/day	No
Low fat dairy	0.5	0.7	0.8	1.1	1.3	2-4 servings/day	No
Sodium (mg/day)	2902.2	2690.9	2619.8	2631.1	2439.1	<2300mg/day	No
Red and red processed meat	1.2	1.0	0.9	0.8	0.6	<2.26 servings/day	Yes
Sweet snacks, SSB, desserts	2.7	2.2	2.1	2.0	1.4	<0.71 servings/day	No
Salty snacks	0.5	0.3	0.2	0.2	0.1	<0.71 servings/day	Yes
Trimester 1	Q1	Q2	Q3	Q4	Q5		Yes/No
	(n=93)	(n=112)	(n=119)	(n=92)	(n=95)		
Fruit and Fruit Juice	1.1	1.5	2.1	2.8	3.0	4-6 servings/day	No
Vegetables excluding potatoes & legumes	1.2	1.7	2.0	2.3	2.6	4-6 servings/day	No
Nuts, seeds, legumes	0.2	0.2	0.3	0.4	0.5	0.57-0.71 servings/day	No
Wholegrains	0.7	1.0	1.2	1.5	1.8	3 servings /day	No
Low fat dairy	0.4	0.6	0.8	1.0	1.5	2-4 servings/day	No
Sodium (mg/day)	2944.1	2591.1	2747.0	2620.8	2389.7	<2300mg/day	No
Red and red processed meat	1.2	1.0	0.8	0.8	0.5	<2.26 servings/day	Yes
Sweet snacks, SSB, desserts	2.7	2.0	2.0	1.6	1.3	<0.71 servings/day	No
Salty snacks	0.6	0.3	0.2	0.2	0.1	<0.71 servings/day	Yes

Trimester 2	DASH Score (quintile)					DASH diet	Meeting DASH?
	Q1	Q2	Q3	Q4	Q5		
	(n=114)	(n=84)	(n=126)	(n=93)	(n=94)		
Fruit and Fruit Juice	0.8	1.5	2.1	2.3	2.2	4-6 servings/day	No
Vegetables excluding potatoes & legumes	1.4	1.6	2.0	2.1	2.6	4-6 servings/day	No
Nuts, seeds, legumes	0.2	0.2	0.2	0.4	0.5	0.57-0.71 servings/day	No
Wholegrains	0.8	1.1	1.5	1.7	2.0	3 servings /day	No
Low fat dairy	0.4	0.7	0.8	1.1	1.3	2-4 servings/day	No
Sodium (mg/day)	2954.6	2710.3	2584.3	2610.1	2395.1	<2300mg/day	No
Red and red processed meat	1.2	1.1	0.9	0.7	0.6	<2.26 servings/day	Yes
Sweet snacks, SSB, desserts	2.8	2.3	2.3	1.8	1.3	<0.71 servings/day	No
Salty snacks	0.5	0.4	0.3	0.2	0.1	<0.71 servings/day	Yes
Trimester 3	Q1	Q2	Q3	Q4	Q5		
	(n=111)	(n=82)	(n=123)	(n=95)	(n=100)		
Fruit and Fruit Juice	0.9	1.6	2.0	2.4	2.8	4-6 servings/day	No
Vegetables excluding potatoes & legumes	1.4	1.7	1.8	1.9	2.6	4-6 servings/day	No
Nuts, seeds, legumes	0.1	0.2	0.2	0.4	0.6	0.57-0.71 servings/day	Yes
Wholegrains	0.7	1.2	1.2	1.7	1.9	3 servings /day	No
Low fat dairy	0.4	0.6	1.0	1.1	1.4	2-4 servings/day	No
Sodium (mg/day)	2966.3	2703.0	2623.9	2568.4	2505.2	<2300mg/day	No
Red and red processed meat	1.2	1.1	1.0	0.8	0.6	<2.26 servings/day	Yes
Sweet snacks, SSB, desserts	3.0	2.3	2.0	2.2	1.5	<0.71 servings/day	No
Salty snacks	0.5	0.2	0.3	0.3	0.1	<0.71 servings/day	Yes

DASH, Dietary Approaches to Stop Hypertension; Q1-Q5, quintile 1 to quintile 5; mg, milligrams; SSB, sugar sweetened beverages; 6 servings of 1 oz. cooked meat, 75g 1 serving as per food pyramid 6oz=170g 170/75=2.26 servings; Salty snacks and sweet snacks <5servings/week were divided by 7 = 0.71servings/day; Nuts and seeds 4-5 servings/week were divided by 7 to get 0.57- 0.71/day, and averaged = 0.64 servings/day

Table 3: The unadjusted mean DASH (Dietary Approaches to Stop Hypertension) score for key maternal demographic and lifestyle factors of the n=511 women during pregnancy

Demographic and Lifestyle Factors	DASH Score			
	N	Mean	SD	P-value
Race/ethnicity:				
- Caucasian	499	27.1	5.7	0.464
- Other	12	25.9	5.3	
Education attainment:				
- Less than third level education	209	25.6	5.8	0.000**
- Completed third level education	279	28.2	5.2	
Smoking habits at baseline:				
- Yes	14	23.6	4.7	0.020**
- No	497	27.2	5.6	
Supplementation*:				
- Yes	287	28.1	5.5	0.000**
- No	202	25.8	5.5	
Age Groups:				
- <30 years	121	25.0	6.2	0.000**
- >30 years	390	27.7	5.3	
Body Mass Index Classification:				
- Underweight (BMI <18.5kg/m ²)	2	26.0	1.4	0.000**
- Normal weight (BMI 18.5-25kg/m ²)	229	28.1	5.4	
- Overweight (BMI 25-29.99kg/m ²)	194	26.9	5.5	
- Obese (BMI >30kg/m ²)	84	24.9	6.2	
Grouping				
- Intervention	225	28.4	5.4	0.000**
- Control	286	26.1	5.7	

BMI, Body Mass Index classification as per World Health Organization cut-offs;
 Supplement not specified in supplement question within lifestyle questionnaire; Grouping,
 Participants within the ROLO study randomized into either the intervention low glycemic
 index diet or the control diet); *P-value <0.05, **P-value <0.001

Table 4: Adjusted multiple linear regression model for association between (A) an increase in DASH quintile and reduced blood pressure and (B) each 5-unit increase in DASH score and reduced blood pressure during the three trimesters of pregnancy

(A) 1-Increase in DASH score							
Blood Pressure	N	B	95% CI		R ² Adj	P-value	Model P
Systolic Blood Pressure							
Trimester 1	445	-0.968	-1.788	-0.147	0.075	0.021*	0.000**
Trimester 2	465	-0.169	-0.961	0.622	0.041	0.675	0.000**
Trimester 3	478	-0.268	-0.987	0.451	0.042	0.465	0.000**
Diastolic Blood Pressure							
Trimester 1	445	-0.696	-1.211	-0.181	0.043	0.008*	0.000**
Trimester 2	465	-0.439	-0.953	0.075	0.053	0.094	0.000**
Trimester 3	478	-0.680	-1.194	-0.166	0.023	0.010*	0.009*
Mean Arterial Pressure							
Trimester 1	445	-0.787	-1.326	-0.247	0.071	0.004*	0.000**
Trimester 2	465	-0.349	-0.883	0.184	0.062	0.199	0.000**
Trimester 3	478	-0.543	-1.043	-0.043	0.040	0.033*	0.000**
(B) 5-unit increase in DASH score							
	N	B			P-value	Model P-value	
Systolic Blood Pressure							
Trimester 1	445	-0.880			0.092	0.000**	
Trimester 2	465	+0.005			0.990	0.000**	
Trimester 3	478	-0.330			0.471	0.000**	
Diastolic Blood Pressure							
Trimester 1	445	-0.804			0.041*	0.001**	
Trimester 2	465	-0.385			0.236	0.000**	
Trimester 3	478	-0.755			0.022*	0.015*	
Mean Arterial Pressure							
Trimester 1	445	-0.740			0.032*	0.000**	
Trimester 2	465	-0.255			0.451	0.000**	
Trimester 3	478	-0.615			0.055	0.000**	

B, DASH Score Coefficient; R² Adj, R squared adjusted; Variables adjusted for age (years), education (greater than/less than tertiary), BMI (kg/m²), grouping (ROLO Low GI intervention vs control) and energy intake (kcal/day); * P-value <0.05, **P-value <0.001

■ Systolic Blood Pressure

▨ Diastolic Blood Pressure

▤ Mean Arterial Pressure

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