

High-Meat, Low-Carbohydrate Diet in Pregnancy Relation to Adult Blood Pressure in the Offspring

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Abstract—To examine the hypothesis that a high-animal protein, low-carbohydrate diet in pregnancy is associated with raised blood pressure in the adult offspring, we performed a follow-up study of 626 men and women in Motherwell, Scotland, whose mothers' food intake had been recorded during pregnancy. The mothers had taken part in a dietary intervention in which they were advised to eat 1 lb (0.45 kg) of red meat per day and to avoid carbohydrate-rich foods during pregnancy. The offspring were followed up at age 27 to 30 years, and their systolic and diastolic blood pressures were measured. Women who reported greater consumption of meat and fish in the second half of pregnancy had offspring with higher systolic blood pressure in adult life (regression coefficient, 0.19 mm Hg per portion per week; 95% confidence interval, 0.04 to 0.35; $P=0.02$). High maternal consumption of fish, but not meat, was associated with higher diastolic blood pressure in the offspring (regression coefficient, 1.00 mm Hg per portion per week; 95% confidence interval, 0.18 to 1.82; $P=0.02$). These associations were independent of maternal blood pressure, body size, and smoking habits during pregnancy. Although we cannot exclude confounding by maternal saturated fat or salt intake, the findings support those of a study in Aberdeen showing higher blood pressure in men and women whose mothers had eaten a high-animal protein, low-carbohydrate diet in late pregnancy. These associations may reflect the metabolic stress imposed on the mother by an unbalanced diet in which high intakes of essential amino acids are not accompanied by the nutrients required to utilize them. (*Hypertension*. 2001;38:1282-1288.)

Key Words: nutrition ■ pregnancy ■ blood pressure ■ diet ■ young adults ■ epidemiology

An association between low birthweight and raised blood pressure in later life has been reported in >50 published studies.¹⁻³ The "fetal origins" hypothesis proposes that the association is a consequence of fetal adaptations to an inadequate or unbalanced supply of nutrients.⁴ Fetal nutrition depends on the concentrations of nutrients in the maternal circulation, on uteroplacental blood flow, and on transfer across the placenta.⁵ Nutrient concentrations in maternal blood are the product of the mother's body composition, metabolism, and diet. Low maternal weight, body mass index, and weight gain in pregnancy have been shown to be associated with cardiovascular disease and some of its biological risk factors, including insulin resistance, in the offspring.⁶⁻¹⁰ Little, however, is known about how maternal diet in pregnancy relates to the offspring's adult blood pressure.

A follow-up study in Aberdeen, Scotland, found associations between the mother's diet during pregnancy and the offspring's blood pressure in middle age.¹¹ The mothers' diets had been measured at ≈ 30 weeks of gestation as part of an observational study of maternal nutrition performed during 1948 to 1954. Imbalance in maternal animal protein and

carbohydrate intake, resulting in diets of either high or low protein density, was associated with raised systolic and diastolic blood pressures in the offspring. The offspring of 2 groups of women had raised blood pressure: those whose mothers had consumed >50 g animal protein per day but had low carbohydrate intakes and those whose mothers consumed <50 g protein per day but had high carbohydrate intakes. Maternal diets with high or low protein density have been shown to have adverse effects in humans and animals. High protein density supplements in humans are associated with reduced fetal growth,¹² whereas rats fed a low protein density diet during pregnancy have offspring with raised systolic blood pressure.¹³

The findings in Aberdeen need to be replicated. We therefore searched for records describing the diets of expectant women whose offspring are now adults. In Motherwell, Scotland, pregnant women attending the maternity hospital between 1952 to 1976 were advised to eat a high-meat, low-carbohydrate diet as a way of preventing preeclampsia. This advice was widely offered at the time because preeclampsia was thought to be a consequence of nutritional

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deficiency. The consultant obstetrician in Motherwell encouraged women to eat 1 lb (0.45 kg) of red meat per day; in a booklet given to all expectant women, he wrote "Quantity (of meat) is more important than quality. As it may be difficult to eat enough meat at meal times the use of cooked meat, especially corned beef, rather than fruit or biscuits, is advised to assuage hunger between meals." He discouraged carbohydrate-rich foods: "Do not eat potatoes or chips, bread—either white, brown, malted or toasted, rolls, scones, cakes or biscuits of any kind." He recommended the consumption of fish, eggs, and cheese in moderate quantities and of green vegetables twice daily. He advised that women consume no more than half a pint of milk a day. Provided his specific advice was followed, the women were allowed to eat to satiety. He warned, however, against excessive weight gain in pregnancy, which, at the time, was thought to induce preeclampsia. At the first and subsequent attendances at the antenatal clinic, each woman's food intake was recorded by trained clerical staff on a specially designed form.

Assessment of nutrient intakes in a sample of the women studied at the time showed that the advice given led to an increase in the mother's protein intake and to a reduction in energy intake: average daily intakes of total protein and energy were 88 g and 1443 kcal (6.04 MJ), respectively, compared with 71 g and 2089 kcal (8.74 MJ) daily in the usual Scottish diet eaten by pregnant women.¹⁴ As a result, the proportion of energy contributed by protein was 24.4% in Motherwell compared with 13.6% elsewhere. The low energy intakes in Motherwell were accompanied by low weight gain during pregnancy (0.25 kg/wk in Motherwell compared with 0.44 kg/wk elsewhere in Scotland) and reduced birthweight (0.51 SD lower).¹⁴

On the basis of the findings in the follow-up study in Aberdeen,¹¹ we predicted that the Motherwell women who followed advice to eat the high-meat, low-carbohydrate diet during late pregnancy would have offspring with raised blood pressure in later adult life. We report here on the blood pressures of 626 men and women age 27 to 30 years whose mothers attended the antenatal clinic during 1967 to 1968.

Methods

Obstetric records for Motherwell Maternity Hospital have been preserved since 1967. We abstracted maternal height, pregnancy weight gain, age, parity, social class, smoking, and highest blood pressure during pregnancy from 1967 to 1968, together with the baby's weight, placental weight, crown-heel length, and head circumference at birth; gestation was assessed using menstrual data. The Motherwell maternity unit frequently induced labor 2 weeks earlier than was usual, after 38 weeks' gestation. We also abstracted summaries of the women's dietary intakes in "early" (≤ 20 completed weeks) and "late" (> 20 weeks) pregnancy, recorded by staff at the antenatal clinic. These summaries described the number of portions eaten daily/weekly of 10 foods: meat, fish, eggs, cheese, green vegetables, potatoes, bread, cakes/scones/biscuits, sweets, and milk. The 24-hour urinary nitrogen excretion, a measure of total protein intake, had been determined in 10 women during pregnancy in an evaluation¹⁴ of the consequences of the dietary advice; to assess the validity of the intake data, we related urinary nitrogen excretion to the woman's reported meat and fish intakes.

There were 1432 records describing live born, singleton births with complete names, birth measurements, and ≥ 1 diet record. The offspring were traced using the National Health Service Central

Register (Scotland) and the records of Lanarkshire Health Board; 965 were alive and residing in Lanarkshire. We wrote to 957 persons, as 8 were thought unsuitable for the survey by their general practitioners; 94 had moved or could not be contacted and 179 declined to participate, leaving 684 (79%) who agreed to take part. Fifty-seven subjects were subsequently excluded because they had a dietary record only in early pregnancy, and 1 was excluded because blood pressure could not be measured because of obesity. Compared with the original sample of 1432, the 626 participants had similar birthweights.

Participants were visited by one of 4 trained fieldworkers who had not seen the obstetric records. Alcohol intake was classified as very low, low, moderate, or high (< 1 , 1 to 10, 11 to 21, and > 21 U/wk in men and < 1 , 1 to 7, 8 to 14, and > 15 U/wk in women, respectively). Height was measured with a portable stadiometer, weight with Seca scales, and blood pressure with an Omron HEM 711 automated recorder¹⁵ with the subject sitting. Three readings were taken on the left arm using the cuff size recommended for the arm circumference (adult, ≤ 31 cm; large adult, > 31 cm), and the average was used in the analysis. The study was approved by the Research Ethics Committee of Lanarkshire Health Board, and subjects gave informed consent.

Data were analyzed by multiple linear regression, correlation, and tabulation of mean and proportion values; tests for quadratic trends were not significant. Levels of significance refer to analyses of continuous variables by regression unless stated. Variables are grouped in the tables for clarity of presentation. For a given gender and body mass index, systolic and diastolic blood pressure were lower with use of the large cuff, and pressures increased progressively with higher alcohol intakes; we used linear regression to adjust blood pressures for gender, cuff size, alcohol intake, and body mass index.

An expanded Methods section can be found in an online data supplement available at <http://www.hypertensionaha.org>.

Results

Table 1 shows the characteristics of the 626 mothers and the 274 male and 352 female offspring followed up at a mean age of 29 years (range, 27 to 30 years). Of the offspring, 79% were born into families of manual workers (social class III, IV, or V): 54% were currently in the manual social classes. Mean gestation was 38.9 weeks because of the policy of induction of labor.

Mother's Diet

Table 2 shows the mothers' food intakes in late pregnancy, recorded at an average of 36 weeks' gestation, together with early pregnancy data for the 456 mothers in whom this was recorded. Between early and late pregnancy, meat consumption almost doubled. In the 10 pregnant women in whom 24-hour urinary nitrogen excretion had been measured, it correlated with the woman's reported meat and fish intake in late pregnancy ($r=0.66$, $P=0.04$). Consumption of potatoes, bread, and cakes/scones/biscuits, the carbohydrate-rich foods that were discouraged, fell to a third of their early pregnancy values. Mothers who consumed fewer portions of carbohydrate-rich foods in late pregnancy had a lower weight gain ($r=0.09$, $P=0.03$).

Mother's Diet and Offspring's Blood Pressure

Relating maternal food consumption in late pregnancy to the offspring's systolic and diastolic blood pressures, we found that higher maternal intakes of meat and fish were associated with higher systolic blood pressure in the offspring ($\beta=0.19$ mm Hg per portion per week; 95% confidence

TABLE 1. Characteristics of the 626 Mothers, Neonates, and Adults

Characteristic	Value	No. of Missing Values	
Mothers			
Age at delivery, y	27.1±6.0	0	
Height, cm	159.0±5.9	0	
Gestational week at first examination	17.2±6.1	0	
First antenatal weight,* kg	58.6±1.17	2	
First antenatal body mass index,* kg/m ²	23.2±1.16	2	
Weight gain in pregnancy, kg/wk	0.24±0.14	13	
Manual social class, %	78.8	6	
Smoked in pregnancy, %	52.2	0	
Primiparous, %	39.8	0	
Highest systolic pressure, mm Hg	129±10	0	
Highest diastolic pressure, mm Hg	83±8	0	
Neonates			
	Males (n=274)	Females (n=352)	
Birthweight, g	3083±406	3008±420	0
Length, cm	48.4±3.2	48.3±3.1	7
Ponderal index, kg/m ³	27.5±5.0	27.0±4.8	7
Head circumference, cm	33.9±1.9	33.4±2.0	8
Placental weight, g	620±104	616±108	0
Gestation, wk	38.8±1.4	39.0±1.5	0
Adults			
Age, y	28.8±0.6	28.8±0.6	0
Height, cm	175.8±6.4	161.0±5.9	0
Weight,* kg	81.3±1.18	65.0±1.23	0
Body mass index,* kg/m ²	26.4±1.15	25.1±1.22	0
Manual social class, %	59.5	50.3	56
Systolic blood pressure, mm Hg	129±12	113±11	0
Diastolic blood pressure, mm Hg	80±10	75±8	0

*Values are geometric mean±SD.

interval [CI], 0.04 to 0.35; $P=0.02$). The offspring's diastolic blood pressure was not related to maternal consumption of meat but rose with greater consumption of fish ($\beta=1.00$; 95% CI, 0.18 to 1.82; $P=0.02$). The effects of meat and fish on systolic, but not diastolic, blood pressure were strengthened

in a simultaneous analysis with green vegetable consumption, with high green vegetable consumption being associated with lower systolic blood pressure. Table 3 shows the effects of maternal consumption of meat, fish, and green vegetables on offspring's systolic and diastolic blood pressure, taking ac-

TABLE 2. Mean Food Consumption of the Mothers During Early and Late Pregnancy

Food	Early Pregnancy (≤20 wk) (n=456)	Late Pregnancy (>20 wk) (n=626)	Change Between Early and Late Pregnancy (n=456)
Meat, portions/wk	7.4±3.3	13.3±5.8	7.0±6.0
Fish, portions/wk	1.1±0.7	1.4±0.8	0.2±0.8
Eggs, n/wk	5.4±2.9	6.1±2.9	0.8±3.2
Cheese, oz/wk	3.9±3.3	4.2±3.0	0.4±3.5
Milk, pints/d	0.7±0.4	0.6±0.4	-0.1±0.4
Green vegetables, portions/wk	3.8±2.3	5.4±2.8	1.9±3.1
Potatoes, n/d	3.1±1.7	0.9±1.2	-2.6±1.8
Bread, slices/d	2.4±1.4	0.8±1.1	-1.9±1.6
Cakes/scones/biscuits, n/d	1.8±1.5	0.5±0.9	-1.4±1.5
Sweets, ¼ lb/wk	0.9±1.0	0.9±0.9	0.1±1.1

Values are mean±SD.

TABLE 3. Multiple Linear Regression Analysis of the Offspring's Blood Pressure on Mother's Consumption of Meat, Fish, and Green Vegetables in Late Pregnancy Adjusting for Offspring's Gender, Body Mass Index, Alcohol Consumption, and Cuff Size Used for Blood Pressure Measurement

Independent Variable	Regression Coefficient, mm Hg/Unit Change in Independent Variable	
	β (95% CI for β)	<i>P</i>
Systolic blood pressure		
Constant	143.2 (136.7 to 149.8)	<0.001
Mother's consumption (portions/wk) of meat	0.21 (0.04 to 0.37)	0.01
Fish	0.97 (−0.11 to 2.05)	0.08
Green vegetables	−0.29 (−0.62 to 0.05)	0.09
Gender		
Male	0.0 Baseline	
Female	−14.8 (−16.8 to −12.8)	<0.001
Body mass index (Z score of ln [kg/m ²])	2.5 (1.3 to 3.7)	<0.001
Alcohol consumption (units/wk)		
Very low (men and women, <1)	0.0 Baseline	
Low (men 1–10, women 1–7)	1.3 (−1.3 to 3.9)	0.3
Moderate (men 11–21, women 8–14)	2.9 (0.0 to 5.7)	0.05
High (men >21, women >14)	4.7 (1.7 to 7.7)	0.002
Cuff size		
Adult	0.0 Baseline	
Large adult	−3.7 (−6.6 to −0.8)	0.01
Diastolic blood pressure		
Constant	85.3 (80.3 to 90.3)	<0.001
Mother's consumption (portions/wk) of meat	0.00 (−0.12 to 0.13)	0.96
Fish	1.00 (0.18 to 1.82)	0.02
Green vegetables	−0.12 (−0.38 to 0.14)	0.4
Gender		
Male	0.0 Baseline	
Female	−4.7 (−6.2 to −3.1)	<0.001
Body mass index (Z score of ln [kg/m ²])	2.3 (1.4 to 3.3)	<0.001
Alcohol consumption (units/wk)		
Very low (men and women, <1)	0.0 Baseline	
Low (men 1–10, women 1–7)	−0.1 (−2.1 to 1.9)	0.9
Moderate (men 11–21, women 8–14)	1.1 (−1.1 to 3.3)	0.3
High (men >21, women >14)	2.1 (−0.2 to 4.4)	0.07
Cuff size		
Adult	0.0 Baseline	
Large adult	−1.9 (−4.1 to 0.4)	0.10

count of gender, body mass index, alcohol intake, and cuff size. Table 4 shows the observed effects of maternal meat and fish intake on the offspring's systolic blood pressure for those whose green vegetable consumption was above and below the median value of 7 portions per week. The greater effect of meat and fish was in the offspring of mothers who ate <7 portions per week. Table 4 shows that there was a 6 mm Hg difference in mean systolic blood pressure between participants whose mothers had high meat and fish but low green vegetable consumption and those whose mothers had low meat and fish but high green vegetable consumption. We

examined maternal consumption of the other foods shown in Table 2. Lower consumption of the carbohydrate-rich foods potatoes, bread, and cakes/scones/biscuits was weakly associated with higher systolic blood pressure in the offspring ($\beta = -0.31$ mm Hg per food item per day, $P = 0.09$). The corresponding regression coefficient for diastolic pressure was -0.17 mm Hg per food item per day ($P = 0.2$). Maternal consumption of the other foods in Table 2 was unrelated to the offspring's systolic or diastolic blood pressure.

In the 456 mothers whose intakes were also recorded in early pregnancy, we found no associations between maternal

TABLE 4. Mean Systolic Pressure of Men and Women, Adjusted for Gender, Body Mass Index, Alcohol Consumption, and Cuff Size According to Their Mother's Consumption of Meat, Fish, and Green Vegetables in Late Pregnancy

Green Vegetables, portions/wk	Meat and Fish, portions/wk					Regression Coefficient, mm Hg · portion ⁻¹ · wk ⁻¹		
	≤11	12–15	16–21	>21	All	β	(95% CI for β)	P
<7	120 (131)	120 (93)	123 (54)	124 (41)	121 (319)	0.26	0.03 to 0.50	0.03
≥7	118 (58)	120 (94)	120 (74)	121 (81)	120 (307)	0.16	−0.06 to 0.38	0.16
All	119 (189)	120 (187)	121 (128)	122 (122)	120* (626)	0.19	0.04 to 0.35	0.02

Number of subjects given in parentheses.

*Overall SD=11.5 mm Hg.

food consumption in early pregnancy and the offspring's systolic or diastolic blood pressure. An increase in meat and fish consumption between early and late pregnancy was, however, associated with raised systolic blood pressure ($P=0.04$), and an increase in fish consumption was associated with raised diastolic blood pressure ($P=0.006$). No other changes in food consumption between early and late pregnancy were related to systolic or diastolic blood pressure.

Mother's Blood Pressure, Body Composition, and Smoking

We examined the effects of the mothers' diets on their own blood pressure. An increase in meat and fish consumption between early and late pregnancy was associated with higher maternal systolic and diastolic blood pressures (both: $r=0.11$, $P=0.007$). Although maternal blood pressure was positively related to the offspring's blood pressure ($r=0.09$, $P=0.02$ for systolic blood pressure; $r=0.14$, $P<0.001$ for diastolic blood pressure), the effects of maternal meat and fish consumption on offspring's blood pressure were little changed by adjusting for maternal blood pressure in pregnancy. The mother's age, parity, weight, height, body mass index, and weight gain in pregnancy were not significantly related to the offspring's systolic or diastolic blood pressure. Fifty-two percent of the mothers smoked during pregnancy; the mean birthweight of their offspring was 184 g lower than that of mothers who did not smoke ($P<0.001$). Maternal smoking was not associated with the offspring's systolic blood pressure ($\beta=0.3$ mm Hg, $P=0.7$), but diastolic blood pressure tended to be higher in the offspring of mothers who smoked ($\beta=1.3$ mm Hg, $P=0.06$). Adjustment for maternal smoking had little effect on the relation between maternal meat and fish consumption and offspring's blood pressure. After adjustment for maternal blood pressure and smoking, together with the variables shown in Table 3, the regression coefficient for the effects of mothers' meat and fish consumption on systolic blood pressure was 0.20 mm Hg per portion per week ($P=0.01$), and the coefficient for the effect of fish on diastolic pressure was 1.01 mm Hg per portion per week ($P=0.02$).

Size at Birth and Adult Blood Pressure

Consumption of meat, fish, and carbohydrate-rich foods in late pregnancy was not related to birthweight, and taking account of birthweight had little effect on the relations between maternal diet and offspring's blood pressure. Although an increase in maternal meat and fish consumption between early and late pregnancy was unrelated to birth-

weight, a reduction in the mother's intake of carbohydrate-rich foods was associated with lower birthweight ($\beta=-11.3$ g per food item per day decrease, $P=0.03$, after allowing for gender, gestation, and maternal smoking). As expected, there was a progressive fall in blood pressure with increasing birthweight ($\beta=-2.2$ mm Hg/kg, $P=0.06$ for systolic blood pressure; -2.0 mm Hg/kg, $P=0.02$ for diastolic blood pressure). Blood pressure also fell with increasing ponderal index (birthweight per length³) ($\beta=-0.18$ mm Hg · kg⁻¹ · m⁻³, $P=0.06$ for systolic blood pressure; -0.21 mm Hg · kg⁻¹ · m⁻³, $P=0.005$ for diastolic blood pressure), but there were no trends with head circumference at birth, length at birth, placental weight, placental/birthweight ratio, or duration of gestation.

Discussion

A follow-up study in Aberdeen, Scotland, led us to hypothesize that the consumption of a high-meat, low-carbohydrate diet in late pregnancy would lead to raised adult blood pressure in the offspring.¹¹ To examine this hypothesis, we measured the blood pressure of 626 young adults in Motherwell whose mothers had been advised to eat 1 lb (0.45 kg) of red meat per day and to avoid the carbohydrate-rich foods such as potatoes, bread, scones, cakes, and biscuits as a way of preventing preeclampsia. We found that the offspring of mothers who reported eating more meat and fish had higher systolic blood pressure. This association was independent of the mother's blood pressure, body size, and smoking habits during pregnancy.

Our study was confined to persons born in Motherwell Maternity Hospital who still live in the area. Their birthweights and maternal body size and blood pressure were similar to those of persons born in the hospital who emigrated. Seventy percent of all births in the town occurred in the maternity hospital, and 79% of persons asked to take part in the study agreed to do so. Because our analyses depend on comparisons within the cohort, bias would only have been introduced if the associations between maternal diet and offspring's blood pressure differed in those who did or did not emigrate or take part.

By the standards of modern epidemiology, the dietary data in our study are crude, merely the numbers of portions of 10 different foods eaten daily or weekly, recorded at the antenatal clinic. Expectant mothers could have exaggerated their consumption of meat to please clinic staff. This would bias our findings if the tendency for mothers to exaggerate was in

some way linked to raised blood pressure in their offspring 30 years later. The association between high maternal meat intake and raised blood pressure in the offspring was, however, first suggested by the findings in Aberdeen, where dietary measurements were based on a 7-day weighed food diary not linked to any dietary advice.¹¹ The dietary advice given to pregnant women in Motherwell led to changes in eating habits, and in 10 women who had measurements of 24-hour urinary nitrogen excretion, these correlated with their reported meat and fish intakes in late pregnancy. Women who reported low consumption of carbohydrate-rich foods had low weight gain in pregnancy and offspring of lower birthweight. The reduction in birthweight in Motherwell is consistent with the conclusions from 16 published controlled trials of protein supplementation in pregnancy.^{12,16} Notwithstanding the measurement errors that must be associated with our dietary data, they predict 6 mm Hg differences in systolic blood pressure between groups (Table 4). Differences of this order could have large effects on death rates from cardiovascular disease; lowering the mean systolic blood pressure in a population by 10 mm Hg may correspond to a 30% reduction in total attributable mortality rates.¹⁷

We estimate that the meat and fish intakes of the Motherwell mothers would have given them mean daily animal protein intakes of ≈ 58 g, which is at the upper end of those recorded in Aberdeen. Associations between mother's meat and fish intakes and offspring's blood pressure occurred across the range of intakes, however, and were not confined to extreme values that would be unusual in the diets of pregnant women today. The diets of the Aberdeen mothers were recorded during the seventh month of pregnancy. It is therefore consistent that in Motherwell, it was diet in the second half of pregnancy rather than diet in the first half that was associated with the offspring's blood pressure. These observations are further evidence that the effects of women's diets differ at different stages of pregnancy.^{18,19}

As expected, small birth size was associated with raised adult blood pressure: as in Aberdeen, however, the effect of maternal diet on offspring's blood pressure was independent of size at birth. There is other evidence that the physiology of the human fetus can be programmed by changes in the mother's diet independent of effects on size at birth.^{8,20,21} In the wartime famine in Holland, birth size was only slightly reduced, but there were long-term alterations in the glucose-insulin metabolism of persons who were in utero at the time.⁸

One explanation for the adverse effect of high meat consumption is that it is a consequence of high intake of essential amino acids, which must be either used for protein synthesis or oxidized.²² The latter process consumes nonessential amino acids, the synthesis of which requires cofactors, including folate and vitamin B6. The natural sources of these cofactors include bread and potatoes, which the pregnant women in Motherwell were specifically advised to avoid. We found that low intake of green vegetables, a source of folate, accentuated the effect of high meat and fish consumption on systolic blood pressure (Table 4). High meat and fish consumption was associated with an increase in the blood pressure of the mother as well as that of the offspring. High intakes of essential amino acids could impose a metabolic

stress to which both mother and fetus respond by elevation of blood pressure. One possible mechanism for this is release of maternal cortisol; women who consume protein-rich meals increase their salivary cortisol concentrations.²³ Other possible explanations for the adverse effects of high meat consumption are that they reflect an effect of high saturated fat intake or of the high salt content of the tinned meats the mothers were advised to eat. We have no quantitative data to elucidate this. It is also possible that the change in meat intake between early and late pregnancy, as opposed to the absolute amounts eaten, is important. We found that diastolic blood pressure was higher in offspring whose mothers reported greater consumption of fish in late pregnancy but was not related to the mother's meat consumption. There was no a priori hypothesis for this finding and it needs replication in other studies. The offspring of mothers who smoked in pregnancy also tended to have raised diastolic blood pressure. This association has not been reported previously in persons born at term.²⁴

The women's remarkably low intakes of carbohydrate-rich foods and their consequent low energy intakes may also have contributed to the offspring's raised blood pressure. Low weight gain in pregnancy, which is associated with low energy intake, has been related to raised blood pressure in the offspring during childhood in other studies.^{9,10,25} The low energy intakes and maternal weight gain in our study were in part the direct result of advice given to the mothers but would also have resulted from the loss of appetite that accompanies an increase in consumption of animal protein.²⁶

We conclude that a dietary intervention in which pregnant women increased their consumption of meat and reduced their consumption of carbohydrate-rich foods resulted in elevation of their offspring's blood pressure during adult life. This replicates findings from the study in Aberdeen. Because blood pressure tracks from childhood into adult life, this association can now be examined in more detail in today's mothers and children, and the mechanisms underlying it can be explored.

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