PAPERS

Early influences on blood pressure: a study of children aged 5-7 years

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Abstract

Objective—To examine factors that influence blood pressure in children.

Design—Cross sectional study of children aged 5·0-7·0 years who had blood pressure measurements and for whom parental questionnaires were completed.

Setting—School based survey.

Subjects—3591 Children aged 5·0-7·5 years selected by stratified random sampling of primary schools in nine British towns (response rate 72%); 3591 were examined and their parental questionnaires were completed. Data were complete for birth rank in 3559, maternal age in 3542, maternal history of hypertension in 3524, and paternal history in 2633.

Results—Birth weight was inversely related to mean systolic blood pressure but only when standardised for current weight (weight standardised regression coefficient −1·83 mm Hg/kg (95% confidence interval −1·31 to −2·35). Mean diastolic pressure was similarly related to birth weight. Maternal age, birth rank, and a parental history of hypertension were all related to blood pressure. After standardisation for current weight a 10 year increase in maternal age was associated with a 1·0 mm Hg (0·4 to 1·6) rise in systolic pressure; first born children had systolic blood pressure on average 2·53 mm Hg (0·81 to 4·25) higher than those whose birth rank was ≥4; and a maternal history of hypertension was associated with a systolic pressure on average 0·96 mm Hg (0·41 to 1·51) higher than in those with no such history. The effects described were largely independent of one another and of age and social class. The relation for birth rank was, however, closely related to that for family size.

Conclusions—Influences acting in early life may be important determinants of blood pressure in the first decade. The relation between birth weight and blood pressure may reflect the rate of weight gain in infancy. The reasons for the relation with birth rank and maternal age are unknown; if confirmed they imply that delayed motherhood and smaller family size may be associated with higher blood pressure in offspring.

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Introduction

A growing body of evidence suggests that influences acting in the first years of life may influence blood pressure in adulthood. This includes observations that blood pressure rank in individual subjects is established at an early age[1 2] and that familial influences on blood pressure are apparent in the first decade.[3] Some studies have suggested that differences in blood pressure among populations may be established at an early age[4 5] and that environmental factors (including diet) may act in the same way in infancy as in adulthood.[6 7] Barker and Osmond reported a relation between infant mortality and adult mortality from stroke, which they suggested may be mediated by differences in blood pressure.[8] For these reasons there has been a considerable interest in factors that influence blood pressure early in life; many studies, however, have been handicapped by limitations in measuring blood pressure[9 10] or have focused on children whose mothers were hypertensive in pregnancy.[11] We have measured the blood pressures of 3591 children aged 5-7 years from nine British towns with particular attention to standardising measurements.[5] We report the relation between blood pressure and birth weight, infant feeding, maternal age, birth rank, and a parental history of hypertension.

Subjects and methods

Full details of the nine towns study of blood pressure in children have been described.[5] The study took place in nine British towns selected to give a wide range of mean blood pressures in adults living in towns.[12] Within each town a sample of 10 primary schools stratified by size, location within the town, and religious denomination gave a sample of children that was socially representative of each.

All blood pressure measurements and over 96% of other measurements were carried out by two research nurses, who had been trained in all measurement procedures and whose procedures had been standardised.

Blood pressure was measured in triplicate at one minute intervals with a Dinamap 1846 SX P automatic oscillometric blood pressure recorder, with the child seated and the arm supported at chest level. The size of the cuff was chosen according to the circumference of the arm (measured at the midpoint of the right arm) following recommendations based on those of the American Heart Association.[13] Two sizes of cuff (bladder dimensions 15×9 cm (child cuff) and 22×12 cm (adult cuff) were used. A systematic difference in blood pressure measurement between the two cuff sizes was observed. Accordingly, all measurements were standardised to the child cuff with correction factors derived from a study of 497 children not included in this study population.[14]

Current weight was measured to the nearest 0·1 kg with a Soehnle digital electronic weighing scale.

A self administered questionnaire was sent to the parents of all participating children to give information on:

Birth weight—Mothers were asked to record the child's birth weight as accurately as possible. The reliability of maternal recall after a five to seven year interval has previously been shown.[15]

Birth rank—The number of living siblings older than the child in question aged ≤16 years was used to give a measure of birth rank; first born children were assigned a value of 1, second born children a value of 2, and so on.

Younger siblings—The number of living siblings younger than the child in question.

Maternal age—The age of the mother when the child was born.

Feeding in infancy—Mothers were asked to specify the method of feeding in the first three months of the child's life: breast feeding, bottle feeding, or both. The duration of breast feeding in months (when applicable) was also recorded.

Maternal history of high blood pressure—Mothers were asked whether they had ever had their blood pressure measured and, if so, whether it had been high at any time. Mothers who answered yes were asked to specify whether this had been in pregnancy, at other times, or both.

Paternal history of high blood pressure—Fathers were asked whether they had ever had their blood pressure measured and, if so, whether it had been high at any time.

Social class—Both parents were asked for their longest held occupation. This was classified according to the registrar general's six social classes with the 1980 manual of the Office of Population Censuses and Surveys. The analyses presented relate to the occupation of the head of the household (male in 89%) as defined in the classification of social class for children by the Office of Population Censuses and Surveys.[16]

Statistical analysis

Weight, birth weight, and maternal age were treated as continuous variables in the analysis. All standardisation procedures were carried out by linear regression techniques. When appropriate data were standardised for weight, which in the study population also provided standardisation for age and body build. A family history of high blood pressure was treated as a 0/1 variable and birth rank as a class variable. Standardisation for differences in blood pressure among towns described earlier[5] had no effect on the results and was therefore not used.

Results

Results are presented here for 3591 children (72%) who attended for examination and for whom parental questionnaires were completed. Analyses of birth rank were restricted to 3559 children for whom data were complete and those of maternal age were restricted to 3542 subjects for whom the information had been given. Analyses including parental history of high blood pressure were restricted to those children whose parents reported having had their blood pressure measured at some time (3524 for maternal history and 2633 for paternal history).

TABLE I—*Mean systolic blood pressure (mm Hg) according to birth weight and current weight as fifths of their distributions in boys and girls*

	Current weight (kg)					
	Boys (n=1789)					
Birth weight (g)	13·1-18·8	18·9-20·4	20·5-21·7	21·8-23·7	23·8-47·8	Mean (SD)
1190-2999	96·5	100·6	100·8	103·1	108·6	100·2 (9·0)
3000-3289	97·3	99·9	100·4	103·6	106·5	101·0 (8·6)
3290-3529	94·8	98·9	100·5	102·6	106·8	101·1 (9·2)
3530-3799	96·0	99·7	100·3	102·3	104·3	101·1 (8·5)
3800-5469	96·4	98·0	99·7	100·8	104·4	101·0 (8·0)
Mean (SD)	96·4 (8·3)	99·6 (7·6)	100·2 (7·7)	102·3 (8·2)	105·4 (8·7)	
	Girls (n=1802)					
	13·3-18·1	18·2-20·0	20·1-21·4	21·5-23·6	23·7-47·0	Mean (SD)
1040-2819	97·7	99·7	102·6	105·3	105·5	101·1 (9·4)
2820-3169	97·7	100·1	100·8	102·0	107·8	101·0 (9·2)
3170-3389	94·5	97·7	100·6	103·2	103·7	100·0 (8·8)
3390-3659	96·6	99·0	99·7	102·4	105·8	101·0 (8·0)
3690-5299	95·6	97·9	98·9	99·5	104·5	100·4 (8·9)
Mean (SD)	96·8 (9·0)	98·9 (8·2)	100·4 (7·6)	102·1 (8·4)	105·2 (8·8)	

Birth weight and current weight

Univariate analysis showed no evidence of a relation between birth weight and systolic or diastolic blood pressure in either sex (systolic pressure r=0·003 in boys, r=0·035 in girls). Adjustment for age made no difference to this finding. Current weight, however, was positively associated with birth weight (r=0·27) as well as with systolic blood pressure (r=0·35) and diastolic pressure (r=0·21). The relation between birth weight and blood pressure was therefore examined taking current weight into account. Table I shows the mean systolic blood pressures at different birth weight intervals within each fifth of the distribution of current weight in boys and girls separately. In both sexes birth weight and blood pressure were inversely related within each fifth of the current weight. The overall magnitude of the effect seemed to be similar in boys and girls, with weight standardised regression coefficients (representing change in blood pressure/kg change in birth weight) of −1·58 mm Hg/kg in boys (95% confidence interval −2·33 to −0·83) and −2·03 mm Hg/kg in girls (−2·76 to −1·30). A similar pattern of associations was observed for diastolic blood pressure (not shown). The regression slopes relating birth weight and systolic blood pressure within each fifth of current weight are presented in the figure. In boys the relation between birth weight and mean systolic blood pressure was apparently stronger in those with higher current weights; this was confirmed by a formal test for interaction (p=0·002). No such difference, however, was apparent in girls.

Maternal age

Table II shows the univariate relation between maternal age and mean systolic blood pressure in boys and girls combined. With increasing maternal age both the mean systolic and the mean diastolic pressure increased. The regression coefficients for blood pressure associated with maternal age controlling for current weight were 0·10 mm Hg/year for systolic pressure (p=0·0002) and 0·05 mm Hg/year for diastolic pressure (p=0·005), implying an increase of 1·0 mm Hg in systolic pressure and 0·5 mm Hg in diastolic pressure for each 10 year increase in maternal age. For systolic pressure this relation seemed to be similar in boys and girls; for diastolic pressure the effect seemed to be stronger in girls (p=0·004).

TABLE II—*Relation between maternal age and mean (standard error) blood pressure (mm Hg) in boys and girls*

Maternal age (years)	No of children	Systolic blood pressure	Diastolic blood pressure
15·0-22·4	787	99·8 (0·3)	58·2 (0·2)
22·5-25·4	720	100·7 (0·3)	58·9 (0·2)
25·5-27·4	567	100·5 (0·4)	58·9 (0·2)
27·5-30·4	679	101·1 (0·3)	59·1 (0·2)
≥30·5	789	101·8 (0·3)	59·3 (0·2)

Birth rank and number of younger siblings

Table III shows the univariate relation between birth rank and blood pressure. A stepwise fall in both mean systolic and mean diastolic blood pressures was observed with increasing birth rank, with a mean difference of 2·3 mm Hg in systolic blood pressure and 1·9 mm Hg in mean diastolic blood pressure between birth rank 1 (that is, first born children) and birth rank ≥4. When adjusted for current weight the effect of birth rank was slightly more apparent and remained highly significant for both systolic (p=0·0007) and diastolic (p <0·0001) pressures. To examine whether any other aspect of family size might be important the

TABLE III—*Relation between birth rank and mean (standard error) blood pressure (mm Hg) in boys and girls*

Birth rank	No of children	Systolic blood pressure	Diastolic blood pressure
1	1653	101·4 (0·2)	59·4 (0·2)
2	1390	100·4 (0·2)	58·5 (0·2)
3	424	100·0 (0·4)	58·3 (0·3)
≥4	92	99·1 (0·9)	57·5 (0·6)

TABLE IV—*Mean (standard error) systolic blood pressure (mm Hg) by birth rank and number of younger siblings in boys and girls**

No of younger siblings	Birth rank 1	2	3	≥4
0	102·1 (0·4) (n=450)	100·9 (0·3) (n=969)	100·3 (0·5) (n=328)	99·0 (1·0) (n=58)
1	101·3 (0·3) (n=944)	99·2 (0·5) (n=347)	99·0 (1·0) (n=83)	
≥2	100·4 (0·5) (n=259)	99·2 (1·0) (n=74)		

*Categories based on fewer than 25 subjects were excluded.

association of birth rank and number of younger siblings with blood pressure was examined; table IV shows the results for mean systolic pressure. The inverse association between birth rank and blood pressure was observed for each number of younger siblings. An increasing number of younger siblings, however, was associated with a fall in mean systolic pressure even after birth rank had been taken into account.

Infant feeding

Blood pressures of children who had been fed exclusively with either breast milk or bottled milk were compared. Both systolic and diastolic blood pressures were identical in the two groups (mean systolic pressure 100·7 mm Hg, mean diastolic pressure 58·8 mm Hg; 95% confidence interval for difference −0·62 mm Hg to 0·62 mm Hg systolic pressure, −0·25 mm Hg to 0·25 mm Hg diastolic pressure).

Maternal and paternal history of high blood pressure

The mean systolic and diastolic blood pressures of children whose mothers or fathers had reported a history of high blood pressure were compared with

TABLE V—*Relation between parental history of hypertension and mean blood pressure (mm Hg) in boys and girls*

	Maternal history: Present	Maternal history: Absent	Paternal history: Present	Paternal history: Absent
No of children	1409	2115	257	2376
Mean (SE) blood pressure:				
Systolic	101·6 (0·2)	100·3 (0·2)	101·8 (0·5)	100·7 (0·2)
Diastolic	59·3 (0·2)	58·6 (0·1)	60·1 (0·4)	58·9 (0·1)

TABLE VI—*Multiple regression analysis of current weight, birth-weight, maternal age, birth order, and maternal history of hypertension and systolic blood pressure in childhood*

Variable	Adjusted for current weight alone: Regression coefficient	Standard error	p Value	Adjusted for all factors: Regression coefficient	Standard error	p Value
Current weight (mm Hg/kg)*	0·89	0·04	<0·0005	0·91	0·04	<0·0005
Birth weight (mm Hg/kg)	−1·83	0·26	<0·0005	−1·73	0·27	<0·0005
Maternal age (mm Hg/kg)	0·10	0·03	<0·0005	0·15	0·03	<0·0005
Birth rank 1	0·00		<0·005	0·00		<0·0005
2	−0·86	0·30		−0·94	0·31	
3	−1·16	0·44		−1·34	0·46	
≥4	−2·53	0·88		−2·70	0·89	
Maternal history of hypertension:						
Absent	0·00		<0·005	0·00		<0·005
Present	0·96	0·28		0·90	0·28	

*Excluded from current weight adjustment.

those subjects in whom no such history had been reported (table V). The children in whom both parents had a history of high blood pressure constituted too small a group to be treated separately. The results seemed to be similar for boys and girls. Children in whom either parent had reported a history of high blood pressure had systolic blood pressures that were on average >1·0 mm Hg higher than those whose parents had not and diastolic pressures on average ≥0·7 mm Hg higher. These differences were significant in analyses of both paternal and maternal history. Adjustment for current weight reduced the magnitude of the effects slightly, but the effect in maternal history remained highly significant in both systolic ($p=0·0007$) and diastolic ($p=0·009$) pressures.

Interrelations of factors

The independent contributions of maternal age, birth rank, birth weight, and maternal history of high blood pressure to childhood blood pressure were examined in a multiple regression analysis, which took all these variables and current weight into account. Paternal history of high blood pressure was excluded because it would have considerably restricted the number of children that could be included in the analysis. Table VI shows the results for systolic pressure. Regression coefficients are given for the relation between each variable and systolic pressure adjusted for current weight alone and then for current weight and all other factors in a simultaneous regression model. The effects of current weight, birth weight, maternal age, birth rank, and maternal history of hypertension remained significant in the multiple regression model and were little affected by the addition of the other factors. The strengths of relations between maternal age and blood pressure and between birth rank and blood pressure were increased by taking the other factors into account; this resulted from the association between maternal age and birth rank (greater maternal age being associated with high birth rank), which has opposing effects on blood pressure. A similar pattern was observed for diastolic pressure (results not shown). Because adjustment for a maternal history of high blood pressure as a 0/1 variable is unlikely to take the factor into account completely, the relation of birth weight, maternal age, and birth rank with blood pressure were re-examined in children with a maternal history of high blood pressure and those without. The results suggested that the relations were similar in both groups.

Discussion

The data examined in this report have two important strengths; firstly, they are based on a sample of children from nine British towns (six in England, two in Scotland, and one in Wales) carefully selected to represent all social classes in each town, and, secondly, measurement of blood pressure was standardised by using the same observers and procedures and the same calibrated automated instrument throughout. Errors introduced by the retrospective collection of data on potential blood pressure determinants are likely to be random, leading to underestimation rather than overestimation of the strength of associations with blood pressure. The absence of appreciable differences in blood pressure based on social class and the lack of awareness about blood pressure measurements in the parents make major recall bias unlikely.

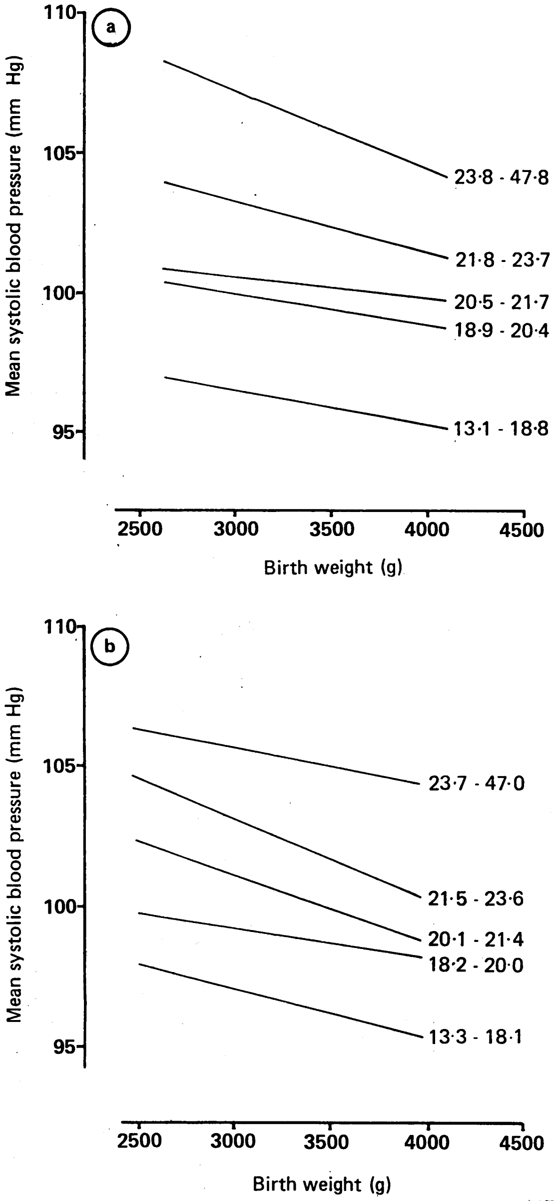
Negative associations between birth weight and blood pressure have been described in two studies of 7 year olds[11 17] and in two populations of 10 year olds.[10 18] In our study population the relation was observed only when the effect of current weight was taken into account. This presumably reflects the strong association between birth weight and current weight in the early years of life, which becomes increasingly attenuated with age. When compared with the effect of current weight the magnitude of the association between birth weight and blood pressure is small; the change in systolic blood pressure for a change of one standard deviation in current weight is 3·11 mm Hg compared with −0·98 mm Hg for birth weight. The importance of the relation between birth weight and blood pressure depends on whether it persists into adult life; earlier reports have suggested that this may be the case.[9 10 19] The basis of the association remains unknown, although unspecified intrauterine factors have been suggested to be important.[10] The negative relation between birth weight and blood pressure, however, does not seem to be present at birth. Studies examining this relation in full term infants found either a positive association[20 21] or no association.[22] Studies of infants of low birth weight have found a consistently positive association between birth weight and blood pressure at birth.[23-25] These findings imply that the relation between birth weight and blood pressure develops in infancy or early childhood. One factor that may be important in its development is weight gain, which is particularly pronounced in infants of low birth weight,[26] particularly during the first year of life.[27] The indication from our data, at least in boys, that blood pressures are highest in those who have gained most weight since birth (figure) is consistent with this hypothesis.[11]

Maternal age and birth rank

We could not identify previous descriptions of the relation between maternal age and blood pressure and between birth rank and blood pressure. These relations are in opposing directions; by taking both factors into account the strengths of the individual associations with blood pressure are increased. The magnitude of the effects are comparable with those of birth weight; the change in systolic blood pressure for a change of one standard deviation in maternal age is 0·51 mm Hg, compared with −0·98 mm Hg for birth weight. These relations seem to be independent of birth weight, current weight, and social class. The causality and mechanisms underlying these associations, however, remain to be established. For birth rank the relation may be particularly complex; the finding that the number of younger siblings is related to blood pressure after birth rank has been taken into account suggests that family size or factors related to it may be aetiologically important. The extent to which maternal age and birth rank are related to blood pressure at birth is of considerable interest. Assessment of the public health importance of these relations must, however, wait until they have been shown to persist into adult life. If this is confirmed it implies that the tendency towards smaller families and rising maternal age in pregnancy in Britain during the past two decades[28 29] may be associated with higher blood pressure in children.

Infant feeding methods

The relation of feeding method to blood pressure is particularly interesting because of the differing sodium content of breast milk and bottle milk, which is considerably higher in bottled preparations.[30] The feeding methods used in the first months of life did not seem to influence blood pressure at age 5-7 years. This remained the case even when adjustment was made (unpublished data) for slight differences in current weight observed between breast fed and bottle fed groups (in agreement with a previous report[31]). Our results are consistent with the findings of other retrospective studies, which observed no relation between blood pressure in infancy or childhood and previous



Regression analysis of birth weight and mean systolic blood pressure by fifths of current weight (kg) in boys (top) and girls (bottom). Numbers are ranges in each fifth of distribution

feeding methods.[17 32] They are, however, challenged by the results of a randomised controlled trial of sodium restriction in neonates, in which a difference of 2 mm Hg in systolic blood pressure was observed after a six month intervention period.[7] In our observational study the differences in sodium intake between the groups may well have been much less than those under trial conditions. If a difference of even half the magnitude reported,[7] however, persisted to age 5-7 years we should have been able to detect it without difficulty. This inconsistency may imply that the results of the previous study were incorrect; alternatively, it may indicate that the influence of sodium intake in infancy on blood pressure is not sustained after the restriction is withdrawn or that the effect is small when compared with the influence of other factors, particularly weight gain.

Influence of parental history of hypertension

A parental history of high blood pressure was associated with higher blood pressure in childhood. Self reported assessments are a crude index of blood pressure, and the strength of the familial relationship is probably being underestimated; better estimates of the strength of relations in blood pressure in parents and children can be obtained from studies in which parental blood pressure has been measured.[3] It is interesting, however, that the relation between birth weight, maternal age, and birth rank and blood pressure were largely unaffected by adjustment for reported parental history of high blood pressure and seemed to be similar in children with and without a maternal history of hypertension. These findings suggest that the means by which familial influences on blood pressure are mediated are quite separate from those of the other factors discussed.

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Motor vehicle driving among diabetics taking insulin and non-diabetics

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Abstract

Objective—To determine whether rates of road traffic accidents were higher in diabetics treated with insulin than in non-diabetic subjects.

Design—Controlled, five year retrospective survey.

Setting—Diabetic, dermatology, and gastroenterology outpatient clinics.

Patients—596 Diabetics treated with insulin (354 drivers) aged 18-65 attending two clinics and 476 non-diabetic outpatients (302 drivers).

Main outcome measures—Rates of accidents in diabetic and non-diabetic subjects.

Results—A self completed questionnaire was used to record age, sex, driving state, and rates of accidents and convictions for motoring offences among diabetic and non-diabetic volunteers. For the diabetic volunteers further information was obtained on treatment, experience of hypoglycaemia, and declaration of disability to the Driving and Vehicle Licensing Centre and their insurance company. Accident rates were similar (81 (23%) diabetic and 76 (25%) non-diabetic drivers had had accidents in the previous five years). A total of 103 diabetic drivers had recognised hypoglycaemic symptoms while driving during the previous year. Only 12 reported that hypoglycaemia had ever caused an accident. Overall, 249 had declared their diabetes to an insurance company. Of these, 107 had been required to pay an increased premium, but there was no excess of accidents in this group.

Conclusions—Diabetic drivers treated with insulin and attending clinics have no more accidents than non-diabetic subjects and may be penalised unfairly by insurance companies.

Introduction

Diabetes mellitus in drivers of motor vehicles is assumed to be a potential danger both to the driver and to other road users. This belief stems from both the immediate disabling effects of hypoglycaemia and the long term implications of the disease, particularly retinopathy. With these problems diabetics might be expected to have more road traffic accidents than the general population, but available evidence is conflicting. Early studies from the United States have consistently shown higher accident rates for diabetic