Birthweight and blood pressure among children in Harare, Zimbabwe

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Abstract

Aim—To determine whether poor uterine growth may be associated with increased blood pressure and subsequent hypertension in adulthood.

Methods—A retrospective cohort study of 756 schoolchildren (mean age 6.5 years) was carried out in six low income areas in Harare city, Zimbabwe. Indices of intrauterine growth and blood pressure were assessed.

Results—Adjusted for current weight, the children's systolic blood pressure was inversely related to their birthweight; for each decreasing kg of birthweight, systolic blood pressure rose by 1.73 mm Hg (95% CI; 0.181 to 3.28). After adjustment for current weight, systolic blood pressure was also inversely associated with occipito-frontal circumference, but not with birth length or gestational age. Diastolic blood pressure was not associated with any of the intrauterine indices.

Conclusion—Fetal size may be inversely related to systolic blood pressure in childhood in an African population.

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Keywords: intrauterine growth indices; blood pressure; Africa; adult health

In Africa ischemic heart disease is rare but cerebrovascular disorders are common.^{1 2} Estimates of the prevalence of hypertension in adults have ranged from 2% to 41%,³ with a recent study finding the prevalence in two West African countries to be between 15 and 23%.⁴ The epidemiology of hypertension in Africa seems to be different from that in industrialised countries. In Africa hypertension occurs at a younger age and it rapidly generates significant morbidity and mortality from cerebrovascular disease.⁵

Recent articles have suggested that low birthweight and intrauterine growth retardation may be risk factors for subsequent raised blood pressure and hypertension in adulthood.^{6–9} These findings and the hypothesis are of particular interest in Africa, as the prevalence of low birthweight is about 15%.¹⁰ Furthermore, almost all the studies on the birth weight–blood pressure association have been carried out in industrialised countries, and findings in this setting may not be applicable to other regions, and to Africa in particular. Hypertension in Africa has also become more prevalent over the past three decades,¹ associated with increased urbanisation and Westernisation.² Given that blood pressure

rises in an individual with age,¹¹ a study was developed to assess the relation of birthweight and other birth measures with blood pressure among children in their first year of school and their mothers in Harare, Zimbabwe.

Methods

In 1994 data were collected in all 42 government primary schools in six of the nine low income suburbs in Harare City, after permission had been obtained from the Ministry of Education and Culture, and from the school authorities. Meetings were called by the school authorities, at which the research team explained the study and invited parents of children in their first year of school (Grade 1) to participate. Those who agreed to do so (94%), signed consent forms.

Children who were born in Harare, and whose parents had consented, were assembled in a room, usually a classroom, to have their heights, weights, head circumferences, blood pressures and pulses measured. Before having their blood pressures taken, the children were made to sit quietly. The children's blood pressures were taken supine, with an appropriate child sized cuff on the right arm which covered 50% of the upper arm. Three blood pressure measurements were taken, each of them two minutes apart, using a Dinamap model 8100 portable blood pressure monitor. Systolic, diastolic, mean arterial pressures and pulse were recorded. Heights were measured in metres using a height measuring board, and weights in kilograms using a SECA model 770 portable electronic scale. The children were weighed in light clothing without shoes, standing squarely on the scale, not holding on to any object for support. The height measurements were taken in a standard way.¹² Head circumference was measured with a tape measure, ensuring that the longest part of the back of head was incorporated. The children who were absent at the time of the examination were included if the team returned to that school the next day. Blood pressures and anthropometric measurements took place mostly in the mornings, during normal school hours.

Birth data were abstracted from the birth registers at the various maternity centres where the study subjects had been born, and from the child health record cards which are kept by mothers. The child health card is prerequisite for school entry, as it has a record of the childhood immunisations. The following data were abstracted from these records on to a form designed for the purpose: birth date, child's sex, birthweight (kg), birth length (cm), occipito-frontal circumference (cm) and gestational age (weeks).

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Table 1 Children's blood pressure, pulse rate, age, birth and anthropometric data

	Boys mean (SD) [n]	Girls mean (SD) [n]	Total mean (SD) [n]
Age (years)	6.50 (0.62) [318]	6.40 (0.63) [318]	6.45 (0.63) [636]
Birthweight (g)	3065.29 (534.35) [288]	2985.29 (479.95) [295]	3024.81 (508.69) [583]
Birth length (cm)	49.09 (2.46) [131]	48.40 (2.77) [142]	48.73 (2.45) [273]
OFC (cm)	35.09 (1.87) [133]	34.56 (1.88) [144]	34.82 (1.89) [277]
Weight (kg)	20.41 (2.48) [384]	19.69 (2.86) [372]	20.06 (2.69) [756]
Height (cm)	115.94 (5.97) [383]	115.02 (5.63) [372]	115.49 (5.82) [755]
Head circumference (cm)	52.59 (1.44) [379]	51.51 (1.54) [371]	52.06 (1.58) [750]
BMI (wt/ht ²)	15.21 (1.50) [382]	14.83 (1.64) [372]	15.02 (1.58) [754]
Systolic blood pressure (mm Hg)	108.27 (9.08) [386]	108.39 (9.62) [370]	108.33 (9.34) [756]
Diastolic blood pressure (mm Hg)	61.57 (8.75) [386]	62.74 (9.08) [369]	62.14 (8.93) [755]
Pulse* (bpm)	87.63 (12.41) [386]	92.95 (12.73) [370]	90.24 (12.84) [756]

* $t = 5.824$, $p < 0.001$ between boys and girls.

OFC: occipito-frontal circumference; BMI: body mass index; SD: standard deviation.

The data were entered and analysed on Epi Info (version 6) and SPSS/PC+ computer software. Where there were differences in the data between the three types of records (the birth registers, the child health card, and the individual maternal record), the birth register was taken as the standard. Systolic, diastolic, and pulse measurements were averaged over the last two readings for the children. Birthweights were assessed from records, and where these were not available, from the mothers' reports. Eleven per cent of the birthweights were from the mothers' reports. When mothers' responses were compared with the recorded birthweights, 397 (75.3%) of the responses corresponded with the record. Among those that were discordant, there was a mean difference of -31.24 g (SD 319.3) on the mothers' birthweight responses, compared with the records.

Statistical analyses included analysis of variance and multiple linear regression techniques. Birthweight, birth length, current weight, height and gestational age were entered into the regression models as continuous variables. Twins were excluded from the analysis.

Results

Of 772 children sampled in 42 schools throughout Harare (including the 16 twins which have been excluded from this analysis), 583 (77.1%) had their birthweights ascertained (from either the records or the mothers' reports), and 636 (84.1%) had their ages recorded. Table 1 shows the children's blood pressure, age, pulse rates, birth and anthropometric data. Only about 36% of the children had their birth lengths and occipito-frontal circumferences ascertained, and only the records of 240 (31.7%) gestational ages were found.

BIRTH WEIGHT

Blood pressure

Table 2 shows mean systolic and diastolic pressures by 500 g intervals of birthweight, adjusted for current weight. The data are

pooled as there was no gender difference in the blood pressures. As current weight was so strongly positively associated with blood pressure, ($p < 0.001$), it was necessary to control for this to assess the birthweight–blood pressure correlation.

Children in the highest birthweight category had the lowest mean systolic and diastolic blood pressures, while those in the other three categories (2500–3499 g) had levels somewhat similar to one another. When analysed as a continuous variable, birthweight was significantly inversely associated with systolic blood pressure ($p = 0.0286$), adjusted for current weight. For each decreasing kg of birthweight, systolic blood pressure rose by 1.73 mm Hg (95% CI; 0.182 to 3.28). A formal test for interaction of current weight and birthweight, proved negative ($p = 0.15$). The sex and age of the child were not found to be confounders of the birth weight/blood pressure association. There was no association with diastolic blood pressure after adjustment for current weight, though the regression coefficients were also negative, -1.06 mm Hg/kg birthweight (95% CI; -2.573 to 0.452).

Pulse rate

The mean pulse rates by 500 g intervals of birthweight adjusted for sex are also shown in table 2. Pulse rate exhibited a similar trend to blood pressure; children whose birthweight was in the heaviest category had the lowest pulses, while those in the second lightest birthweight category had the highest pulse rates. The pulse rates of the heaviest children were, on average, 4.64 beats per minute slower than those in the second lightest category of birthweight.

When run as a continuous variable, and adjusted for sex, birthweight was significantly inversely associated with pulse rate ($p = 0.0015$). For each decreasing kg of birthweight, pulse rate rose by 3.2 beats per minute (95% CI; 1.24 to 5.23).

Table 2 Association between systolic (SBP) and diastolic (DBP) blood pressure (mm Hg), and birthweight (500 g intervals), adjusted for current weight (kg), and between pulse rate (bpm) and birth weight, adjusted for sex

Birthweight (g)	No of subjects	Mean SBP (mm Hg)	No of subjects	Mean DBP (mm Hg)	No of subjects	Mean pulse rate (bpm)
< 2500	73	94.49	73	52.69	71	83.84
2500-2999	168	95.29	167	55.29	159	84.20
3000-3499	231	94.06	231	53.44	224	81.97
3500+	104	91.87	104	52.53	96	79.56
Total	576	93.93 (SD 2.46)	575	53.48 (SD 0.77)	550	82.39 (SD 2.12)

Table 3 Association between means of blood pressure (mm Hg) and pulse rate, and tertiles of occipito-frontal circumference (cm) adjusted for current weight (kg) and height (cm), (blood pressure) and sex (pulse rate)

OFC (cm)	No of subjects	Mean SBP (mm Hg)	No of subjects	Mean DBP (mm Hg)	No of subjects	Mean pulse rate (bpm)
< 34	65	101.66	65	64.32	65	84.75
34-35	111	101.16	110	64.69	111	84.27
36+	100	99.29	100	63.70	100	83.02
Total	276	100.70 (SD 1.25)	275	64.23 (SD 0.49)	276	84.01 (SD 0.89)

BIRTH LENGTH

Blood pressure

There was no association between birth length and blood pressure, adjusted for current weight. Children in the highest tertile of birth length (50 or more cm) had the lowest mean systolic pressure of 92.46 mm Hg ($n=98$), compared with 93.76 mm Hg for birth lengths 48-49 cm ($n=136$), and 93.87 for birth lengths of less than 48 cm ($n=38$). The mean diastolic pressures were 58.87, 58.85 ($n=135$), and 58.37 mm Hg, respectively.

Pulse rate

The pulse rate, adjusted for sex, seemed to decrease by increasing tertile of birth length. Children in the lowest tertile of birth length (less than 48 cm) had the highest mean pulse rates of 86.51 beats per minute ($n=70$), compared with 85.12 beats per minute for birth lengths 48-49 cm ($n=104$), and 82.98 beats per minute for birth lengths of 50 or more cm ($n=98$). When analysed as a continuous variable, birth length was significantly inversely associated with pulse ($p=0.0104$), after adjustment for sex. For each 1 cm increase in birth length, mean pulse rate decreased by 0.78 beats per minute (95% CI; 0.18 to 1.37).

HEAD CIRCUMFERENCE AT BIRTH
(OCCIPITO-FRONTAL CIRCUMFERENCE)*Blood pressure*

Adjusted for current weight and height, the systolic and diastolic pressures were lowest in the highest tertile of OFC, with the mean systolic pressure decreasing with each increasing tertile of OFC (table 3). When entered into the model as a continuous variable, systolic blood pressure was inversely associated with head circumference at birth ($p=0.0245$), controlling for current height and weight. For each 1 cm increase in OFC, mean systolic blood pressure decreased by 0.66 mm Hg (95% CI; 0.09 to 1.24).

Pulse rate

There was no association between pulse rate and OFC, adjusted for sex, though the highest tertile of OFC had the lowest pulse, and the lowest tertile the highest (table 3).

GESTATIONAL AGE

Blood pressure

There was no association between the means of blood pressure by tertile of gestational age, adjusted for current weight. The mean systolic blood pressures were 91.98 mm Hg for the lowest tertile of gestational age of less than 38 weeks ($n=51$), 89.89 mm Hg for those between 38 and 39 weeks ($n=73$), and 89.93 mm Hg for gestational ages 40 to 44 weeks ($n=116$). The

mean diastolic pressures were 51.78 mm Hg, 51.713 mm Hg, and 50.629 mm Hg ($n=115$), respectively. An analysis was also made of pre-term (less than 37 weeks) and term babies. This showed a mean systolic pressure of 90.63 mm Hg for the preterm babies, and 90.90 mm Hg for those born at term. For the diastolic pressures, these levels were 49.75 mm Hg and 50.24 mm Hg, respectively. There were, however, only 27 preterm babies.

Pulse rate

There was no association between pulse rate and length of gestation, adjusted for sex. The mean pulse rates by tertile of gestational age were 85.73 beats per minute ($n=51$), 85.187 ($n=73$), and 85.264 ($n=116$), respectively.

Discussion

In summary, we found that birthweight was inversely associated slightly with systolic blood pressure, after adjustment for current weight. Unadjusted, systolic blood pressure rose by only 0.358 mm Hg (95% CI; -1.811 to 1.095), for each decreasing kg of birthweight. There was no clear association between birthweight and diastolic blood pressure. Current weight is strongly related to externally measured blood pressure, and controlling for current weight implies that we are evaluating the possible relation of birthweight to systolic blood pressure beyond the relation of birthweight to current weight. Birthweight and birth length were also inversely associated with pulse rate. Occipito-frontal circumference was inversely related to systolic blood pressure. Birth length was not associated with blood pressure. Gestational age was unrelated to blood pressure and pulse rate.

The use of a standardised protocol and the same calibrated automated (oscillometric) blood pressure machine throughout the study is likely to have minimised errors in blood pressure measurement. The oscillometric method is considered to be the most accurate and convenient method of indirectly measuring blood pressure.¹³ Birthweight recall bias was likely to have been minimal, as nearly 90% of birthweights were obtained from the birth records, and this error is likely to have been random, leading to an underestimate rather than an overestimate of the strength of the association with blood pressure. The birthweights and blood pressures were collected at different times, so that in most cases the observers had no knowledge of the birthweight in relation to the blood pressures of individual children. Much of the time, the functions of the records review and the blood pressure monitoring were also carried out by different people.

There is a potential for selection bias as the birthweights for 23% of the children were not

ascertained. The large amount of missing data on birth length, and gestational age particularly, is more problematic, not only affecting the power of the study, but potentially introducing bias. To our knowledge, this is the first published study of birthweight in relation to blood pressure in African children. The inverse association with systolic blood pressure is consistent with other studies in children,^{7 9 14 15} adolescents,¹⁶ and adults.^{6 8 9 17} The association, however, was not smoothly graded, though not quite the U shaped relation observed by Launer *et al.*¹⁸ The size of the association of -1.73 mm Hg/kg was similar to the -1.83 mm Hg/kg reported by Whincup, Cook and Shaper.¹⁵ While the strength of this relation is modest, this association may be progressively amplified in childhood¹⁴ and later life.¹⁷ In adults a 1 kg increase in birthweight is equivalent to a fall in systolic pressure of 5 mm Hg.¹⁹ The finding of a weak non-statistically significant association of birthweight with diastolic blood pressure was also consistent with other studies.⁹ This could be because the spread of the diastolic pressures was less than that of the systolic pressures and because of the greater error in measurement of this variable.

We found only two published reports on the association between pulse rate and birthweight among children of this age, one describing a weak inverse association,⁹ the other, no association.²⁰

The finding of the inverse association between head circumference at birth with systolic blood pressure is consistent with that found among children,⁷ and adults.⁶ The inverse association of blood pressure with birthweight and head circumference suggest that the birthweight–blood pressure relation is primarily due to total fetal growth rather than the rate of growth.

A hypothesis proposed to explain the inverse relation of birthweight and blood pressure is that of poor nutrition in pregnancy.¹⁹ This hypothesis is supported by animal experiments^{21 22} and a Jamaican study.¹⁶ Several mechanisms linking fetal growth retardation and increased blood pressure have been proposed. One is an increased concentration of plasma insulin-like growth factor-1 in childhood,²³ another is maternal iron deficiency anaemia.²⁴ It has been suggested that maternal protein deprivation may lead to higher concentrations of angiotensin converting enzyme.²¹ The higher activities of this enzyme result from the kidney due to intrauterine growth retardation. This hypothesis is similar to that of hypertension being inversely associated with the number of nephrons, and that low birthweight babies have fewer nephrons.^{25 26} Other proposed mechanisms have included impaired vascular structure, including loss of elasticity in vessel walls²⁷; suboptimal organ development²⁸; and increased exposure to blood pressure raising maternal glucocorticoid hormones.²⁹

We can only speculate about the findings on the pulse rate. Maternal stress (including under nutrition) may lead to decreased fetal placental circulation, consequent fetal growth retardation, and a faster fetal heart rate because of the stress of insufficient fetal placental circulation.

Further study is needed on the birthweight–pulse association, the extent to which it is an indicator of reduced fetal growth, and on whether pulse rate tracks in the same way as blood pressure.

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