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Maternal verbally aggressive behavior in early infancy is associated with blood pressure at age 5–6

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Abstract

Early life stress has been shown to contribute to alterations in biobehavioral regulation. Whereas many different forms of childhood adversities have been studied in relation to cardiovascular outcomes, very little is known about potential associations between caregivers' verbally aggressive behavior and heart rate and blood pressure in the child. This prospective study examined whether maternal verbally aggressive behavior in early infancy is associated with heart rate or blood pressure at age 5–6. In the Amsterdam Born Children and their Development study, a large prospective, population-based birth cohort, maternal verbally aggressive behavior was assessed by questionnaire in the 13th week after birth. The child's blood pressure and heart rate were measured during rest at age 5–6 ($n = 2553$ included). Maternal verbally aggressive behavior in infancy was associated with a higher systolic blood pressure (SBP) both in supine and sitting position after adjustment for sex, height and age (SBP supine B = 1.01 mmHg; 95% CI [0.06; 1.95] and SPB sitting B = 1.29 mmHg; 95% CI [0.12; 2.46]). Adjustment for potential confounding variables, such as other mother–infant dyad aspects, family hypertension and child's BMI, only slightly attenuated the associations (SBP supine B = 0.99 mmHg; 95% CI [0.06; 1.93] and SPB sitting B = 1.11 mmHg; 95% CI [− 0.06; 2.27]). Maternal verbally aggressive behavior was not associated with diastolic blood pressure or heart rate at age 5–6. Maternal verbally aggressive behavior might be an important early life stressor with negative impact on blood pressure later in life, which should be further investigated. Possible underlying mechanisms are discussed.

Introduction

Increasing evidence indicates that early life stress such as adverse childhood experiences may have long-term consequences for cardiovascular health, possibly by altering the sensitivity of stress-related physiological systems predisposing to adverse cardiovascular outcomes.[1,2] Exposure to parental aggression in childhood is sadly common.[3] Various kinds of aggression such as child physical abuse and family violence have been shown to be associated with altered biobehavioral regulation in adults, and blood pressure (BP) or hypertension in particular.[4,5] Adults who experienced multiple adverse childhood experiences, including abuse, neglect and household dysfunction, showed a faster rise in BP levels after 30 years of age, than those without those experiences.[6] In addition, accumulation of four or more childhood adversities was positively associated with resting heart rate (HR) in adolescents.[7] Consequences of infant's exposure to parental aggressive behavior for later cardiovascular outcomes are largely unknown. Also, very little is known about potential associations between verbally aggressive behavior to the young infant and BP and HR in the child.

The prevalence of maternal verbally aggressive behavior is unknown. Interestingly, high 'expressed emotion' (criticism, hostility and emotional over involvement) has been shown to appear in 6% of pregnant women.[8] Maternal verbally aggressive behavior to the very young infant can be considered a profound early life stressor, as soothing maternal behavior would be more appropriate at this young age. Vocalizations have been shown to be highly important in neuroendocrine regulation of bonding, equally as important as touch.[9] The quality of mother–infant interaction influences the development of the child's self-regulation capacities[10] and disturbances might affect biobehavioral pathways.

Indeed, maternal sensitivity or attunement is vital for mother–infant communication, and the quality of the mother–infant dyad can be a source of stress reduction or distress to the

infant. Maternal verbally aggressive behavior has been regarded as a kind of emotional abuse. Maternal–child interactions of emotionally abusing mothers are characterized by poor sensitivity, hostility and criticism or disinterest.[11] Other factors that may influence the quality of the mother–infant dyad are maternal depression and low levels of pleasure in taking care of the infant. Depressed mothers often show less sensitivity and more harsh or disrupted parenting behaviors.[12] Most mothers, both depressed and not, enjoy taking care of their infant, but some do not. Mothers experiencing low levels of pleasure in infant care could be less sensitive to the infant's needs,[13] possibly enabling less positive interactions similar to depressed mothers.

Based on the evidence demonstrating adverse cardiovascular outcomes in people who had been exposed to parental physically aggressive behavior in childhood, we hypothesized that children exposed to maternal verbally aggressive behavior in early infancy would have a higher resting BP and HR already at age 5–6, compared with children not exposed to maternal verbally aggressive behavior in early infancy, regardless of other important mother–infant dyad aspects.

Method

Participants and research design

The study sample is part of a large prospective population-based multiethnic birth cohort, the Amsterdam Born Children and their Development (ABCD) study, which started in 2003. Extensive information about the cohort and procedures regarding data collection has been published elsewhere.[14] Approval of the ABCD study was obtained from local ethical committee (Institution name XXX, approval number MEC 02/39#02.17.392). All participating mothers gave written informed consent for themselves and their children.

The flow chart of participants included is presented in Fig. 1. Between January 2003 and March 2004, all pregnant women living in Amsterdam were asked to participate in the ABCD study during their first prenatal visit to an obstetric care provider. Of the 12,373 women approached, 8266 women filled out the pregnancy questionnaire [mean gestational age: 15.7 weeks (SD 3.5)(response rate: 67%)]. A total of 6735 women gave permission for follow-up. Three months after birth, 5131 women filled out the infancy

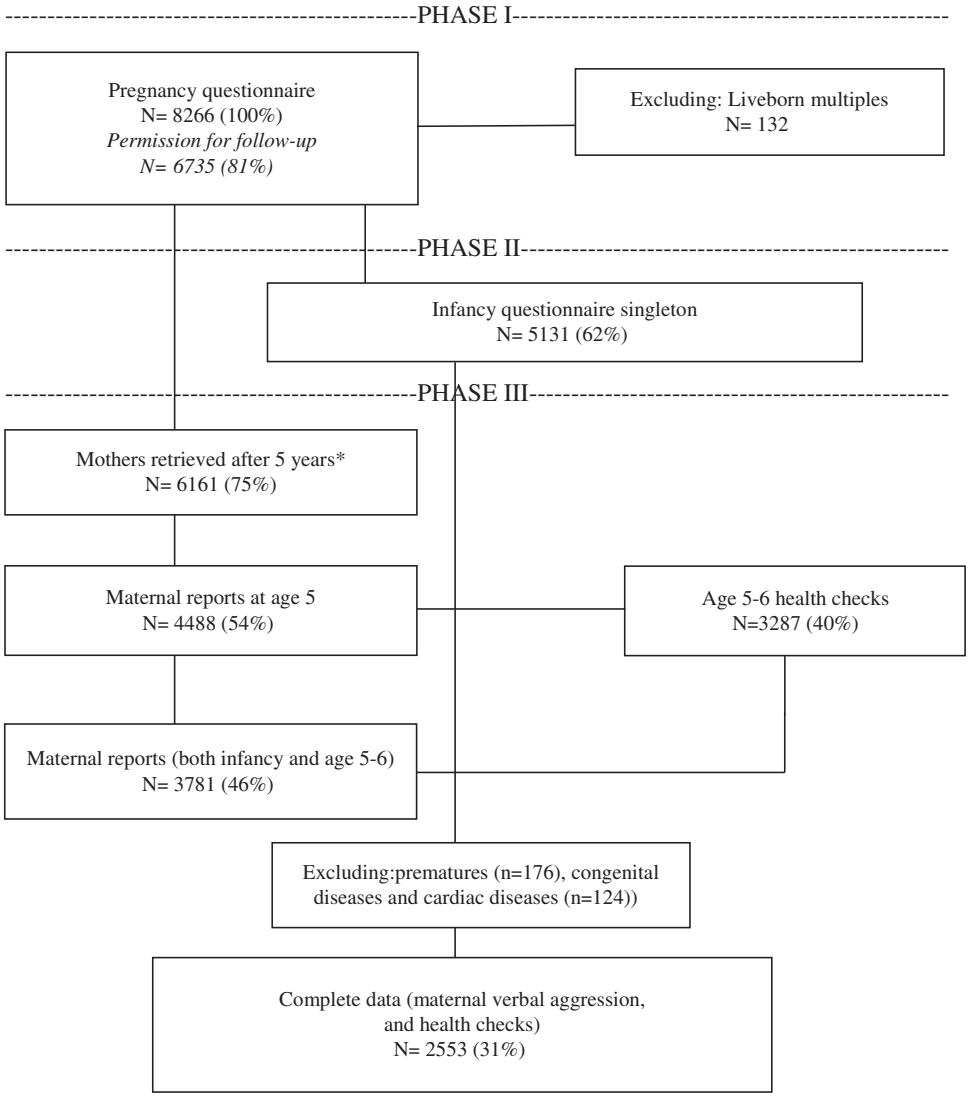

Fig. 1. Flow chart of participants included for analysis. *Attrition at this stage due to withdrawal, infant or maternal death, and unknown address or emigration.

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questionnaire. For the questionnaire at the child's age of 5–6 years, addresses of 6161 mothers were retrieved and 4488 mothers returned the questionnaire. Data on all three measurements (pregnancy, infancy and early childhood) had to be available to be included in the present study. Children who were twins, born prematurely (gestational age <37 weeks) or had congenital diseases or cardiac diseases were excluded ($n = 2553$ included).

Maternal verbal aggressive behavior in infancy

Maternal verbally aggressive behavior was assessed by a maternal self-report questionnaire completed in the 13th week after birth (range 11–25 weeks, SD 2 weeks), using a question on frequency of speaking angrily to the infant on a six-point scale: 'Have you ever spoken angrily to your baby in order to diminish the crying?.' The score was dichotomized [speaking angrily (frequency $\leqslant 1$ or $\geqslant 2$)]. Maternal verbally aggressive behavior was considered present if speaking angrily to the infant had been present twice or more. This cut-off was chosen in order to make a distinction between speaking angrily to the infant infrequently, for example by accident, *v.* twice or more often.

Children's cardiovascular outcomes at age 5–6

Children's BP was measured twice both in supine and sitting position after a test reading and 5 min of rest with the automatic oscillometric method, using an automatic device with a small cuff (arm circumference 17–22 cm) on the non-dominant arm. When either the systolic (SBP) or diastolic pressure (DBP) differed more than 10 mmHg between the two measurements, a third measurement was taken ($n = 502$: 17%). The average of the two supine position measurements closest together was used. HR was measured using the VU University Ambulatory Monitoring System (VU-AMS-version-5fs, TD-FPP, Amsterdam, the Netherlands). Reliability and validity aspects and recording methodology of the VU-AMS have been described previously.[15,16] To obtain the mean value of HR, mean HR across all supine conditions was used, excluding the period during which BP was measured.

Potential confounders

The following child characteristics during infancy were assessed: sex, birth weight, gestational age, and excessive crying. Excessive infant crying was considered present if mothers estimated their infant to cry for three or more hours per 24 h/day on average in the past week (best approximation of the Wessel's criteria).[17,18] The following maternal characteristics during pregnancy were included: age, parity (0 or $\geqslant 1$), ethnicity (European origin or non-European origin), cohabitation status (single or living together with partner), and level of education (years after primary school). During infancy maternal postnatal depressive symptoms, maternal physically aggressive behavior and maternal smoking at home were included. Maternal postnatal depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale (CES-D).[19] The summed scores were dichotomized (<16 or $\geqslant 16$), using the cut-off for potential cases. Pleasure in infant care was measured using five questions on a four-point scale (very true, true, not true, not true at all): 'Do I feel very good taking care of my baby?'; Do I feel very satisfied taking care of my baby?; Do I feel happy taking care of my baby?; Am I fed up taking care of my baby?; Do I really enjoy taking care of my baby?.' The summed score were analyzed continuously. A higher score corresponded with lower levels of pleasure in infant care. Maternal physically aggressive behavior consisted of three behaviors, which were dichotomized [cloth on mouth (frequency 0 or $\geqslant 1$), slapping (frequency 0 or $\geqslant 1$), shaking baby (frequency 0 or $\geqslant 1$)]. These three behaviors were scored as maternal physically aggressive behavior, if one out of three was present (yes or no). Maternal smoking at home during infancy was either present or absent (yes or no).

In addition, the following characteristics were included: maternal pre-pregnancy BMI (kg/m^2) and preexistent hypertension (yes or no). Pregnancy-induced hypertension (yes or no) was available by combining patient records and the Dutch Perinatal Registration and classified in accordance with the guidelines of the International Society for the Study of Hypertension in Pregnancy (www.isshp.com). Paternal hypertension and family (maternal or paternal) hypertension were derived from a questionnaire previously described elsewhere.[20]

Covariates at age 5 included the exact age of the child at the 5–6 years health check. Height and weight of the child were measured from which BMI was calculated. Authoritarian parenting style was measured by the 12-items subscale of the short version of the Parenting Styles and Dimensions Questionnaire[21] and analyzed continuously. Maternal parenting stress was measured by a 9-items subscale on attachment of the 123-items of the 'Nijmeegse Ouderlijke Stress Index'[22] and analyzed continuously. Maternal depressive symptoms at age 5 were measured continuously by the depression severity subscale of the Depression Anxiety Stress Scales (DASS 21).[23]

Statistical analysis

Analyses were conducted using SPSS 19.0 (SPSS inc, Chicago, IL, USA). Descriptive statistics were used to describe maternal and child characteristics. Associations between these characteristics and maternal verbally aggressive behavior were tested using analysis of variance for continuous variables and χ^2 tests for categorical variables. The associations of maternal verbally aggressive behavior and BP and HR were analyzed by means of multivariable linear regression analysis. Potential confounders were selected *a priori* and included in the regression model by using a forced-entry method. In the first model, associations were tested in a standardized model for sex, age and height of the child. Subsequently, the potential confounders birth weight, maternal pre-pregnancy BMI, pregnancy related hypertension, family hypertension, child's BMI at age 5, maternal postnatal depressive symptoms, pleasure in infant care, and maternal physically aggressive behavior were added to a second model. In addition, in order to correct for possible stressful parenting behavior at age 5–6, authoritarian parenting style, maternal parenting stress and depressive symptoms at that age were added to a third model. The significance level we used in the study was 5%.

Results

Subjects characteristics

The characteristics of both mothers and children are presented in Table 1. Of the 2553 included children, 246 (9.6%) had been exposed to maternal verbally aggressive behavior in early infancy. Compared with children without exposure to maternal verbally aggressive behavior, exposed children more often had been excessive crying babies, had mothers who reported more postnatal depressive symptoms, lower levels of pleasure in

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Table 1. Characteristics of 2553 women and their children according to maternal verbal aggressive behavior in early infancy

	$n = 2553$	% or mean (SD)	No maternal verbal aggression to infant [$n = 2307$ (90.4%)]	Maternal verbal aggression to infant [$n = 246$ (9.6%)]	P
Child characteristics					
Gender: female (%)	1277	50.0	49.9	51.2	0.692
Birth weight (g)	2544	3540 (489)	3538 (486)	3555 (512)	0.594
Gestational age (weeks)	2553	39.7 (1.2)	39.7 (1.2)	39.8 (1.2)	0.550
Excessive crying (%)	73	2.9	2.5	6.1	0.001
Maternal characteristics					
Pre-pregnancy BMI (kg/m^2)	2553	22.8 (3.6)	22.9 (3.7)	22.6 (3.3)	0.254
Pre-pregnancy hypertension (%)	68	2.7	2.6	3.3	0.550
Pregnancy-related hypertension (%)	236	9.3	9.1	11.4	0.228
Primiparous (%)	1436	56.2	56.0	58.5	0.446
Maternal age (years)	2553	32.1 (4.4)	32.2 (4.4)	31.6 (4.4)	0.074
Cohabitancy: living with partner (%)	2317	90.9	90.9	91.8	0.578
Education, years after primary school	2541	10.0 (3.5)	10.0 (3.5)	10.3 (3.3)	0.308
Ethnic background					0.774
European (%)	2154	84.4	84.4	83.7	
Non-European (%)	399	15.6	15.6	16.3	
Maternal factors in infancy					
Pleasure in infant care	2526	5.9 (1.5)	5.9 (1.4)	6.5 (1.7)	<0.001
Depression (CES-D) (%)	334	13.1	12.2	22.1	<0.001
Smoking at home (%)	95	3.7	3.9	2.4	0.264
Physical aggression (%)	62	2.4	1.4	12.2	<0.001
Child characteristics at 5–6 years					
Age of the child (years)	2542	5.15 (0.26)	5.15 (0.26)	5.15 (0.30)	0.862
Height (cm)	2553	116.6 (5.7)	116.5 (5.7)	116.9 (5.5)	0.313
BMI (kg/m^2)	2553	15.5 (1.4)	15.4 (1.4)	15.6 (1.5)	0.244
Family hypertension					
Paternal hypertension (%)	118	4.6	4.7	4.1	0.651
Family (M or P family) hypertension (%)	154	6.4	6.1	8.7	0.125
Maternal characteristics at the child's age 5–6					
Authoritarian Parenting Style	2416	5.1 (3.0)	5.1 (3.0)	5.5 (2.8)	0.021
Parenting stress (NOSI-K)	2388	11.7 (3.0)	11.6 (2.9)	12.4 (3.2)	<0.001
Depressive symptoms	2412	1.0 (1.9)	1.0 (1.9)	1.4 (2.4)	0.001

M, maternal; P, paternal; CES-D, Centre for Epidemiologic Studies Depression Scale; NOSI-K, 'Nijmeegse Ouderlijke Stress Index' for children.

infant care, and more often behaved physically aggressively to the infant. At age 5–6, mothers who had been verbally aggressive in infancy more often used an authoritarian parenting style, reported more parenting stress and more depressive symptoms, compared with mothers who had not been verbally aggressive in infancy.

Association of verbal maternal aggressive behavior with HR and BP at age 5–6

Maternal verbally aggressive behavior in infancy was associated with a higher SBP both in supine and sitting position after adjustment for sex, height and age (Model 1) (SBP supine

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Table 2. Heart rate and blood pressure at age 5–6 years according to maternal verbal aggressive behavior in early infancy

	Maternal verbal aggressive behavior in infancy: No		Maternal verbal aggressive behavior in infancy: Yes		Difference	Model 1	Model 2	Model 3
	n	Mean (SD)	*n*	Mean (SD)	(95% CI)	Adjusted difference (95% CI)	Adjusted difference (95% CI)	Adjusted difference (95% CI)
SBP (mmHg)								
Supine	2307	99.1 ± 7.1	246	100.2 ± 7.6	1.04 (0.10; 1.98)	1.01 (0.06; 1.95)	1.03 (0.10; 1.96)	0.99 (0.06; 1.93)
Sitting	2263	97.5 ± 8.6	243	98.7 ± 8.8	1.21 (0.07; 2.35)	1.29 (0.12; 2.46)	1.13 (−0.03; 2.30)	1.11 (−0.06; 2.27)
DBP (mmHg)								
Supine	2299	57.0 ± 5.7	245	57.6 ± 5.9	0.63 (−0.12; 1.39)	0.35 (−0.42; 1.12)	0.34 (−0.43; 1.12)	0.31 (−0.46; 1.09)
Sitting	2268	58.0 ± 8.0	243	58.4 ± 7.9	0.41 (−0.64; 1.47)	0.15 (−0.96; 1.26)	−0.09 (−1.22; 1.03)	−0.16 (−1.29; 0.97)
HR (bpm)								
Supine	2080	85.5 ± 9.7	230	84.9 ± 10.1	−0.55 (−1.89; 0.78)	−0.83 (−2.17; 0.52)	−0.96 (−2.34; 0.42)	−1.00 (−2.38; 0.38)
Sitting	2041	90.8 ± 10.2	223	90.1 ± 10.4	−0.75 (−2.17; 0.66)	−1.09 (−2.50; 0.39)	−0.90 (−2.38; 0.59)	−0.92 (−2.40; 0.57)

SBP, systolic blood pressure; DBP, diastolic blood pressure; Model 1: adjusted for sex, height and age of the child; Model 2: additionally adjusted for birth weight, pregnancy related hypertension, family hypertension, maternal BMI, child's BMI, maternal depression in infancy, pleasure in infant care, maternal physical aggression; Model 3: additionally adjusted for authoritarian parenting style, maternal depressive symptoms and parenting stress (NOSI-K) at the child's age of 5–6.

B = 1.01 mmHg; 95% CI [0.06; 1.95] and SPB sitting B = 1.29 mmHg; 95% CI [0.12; 2.46]). Adjustment for potential confounding factors (Model 3) only slightly attenuated the associations between maternal verbally aggressive behavior in infancy and SBP in supine position at age 5–6 (B = 0.99 mmHg; 95% CI [0.06; 1.93], $R^2 = 0.16$) and SPB sitting B = 1.11 mmHg; 95% CI [−0.06; 2.27], $R^2 = 0.14$). Maternal verbally aggressive behavior was not associated with DBP nor HR (Table 2).

Discussion

Our study showed that children exposed to maternal verbally aggressive behavior during early infancy had higher SBP at the age of 5–6, compared with those unexposed to maternal verbally aggressive behavior in early infancy. These prospective findings are in line with literature showing increased cardiovascular risk after early life stress exposure and in particular retrospective studies showing increased BP and hypertension after parental aggression.[4,5,24] Adding to this, we have now shown that infant's exposure to maternal verbally aggressive behavior is an early life stressor which might have long-term consequences for cardiovascular health. The effects on SBP were small at age 5–6, but as childhood BP has been shown to track into adulthood,[25,26] we can expect our reported increased SBP to persist and possibly become more pronounced in later life.

In contrast to our hypothesis, and contrasting with literature on physical abuse and DBP and HR in adults,[5] we found no associations between maternal verbally aggressive behavior and DBP or HR at age 5–6. An association might start showing after multiple early life stressors, comparable with the study of Pretty *et al.*,[7] in which four or more ACEs were positively associated with resting HR or might only show in stressful circumstances.

Strengths and limitations

Strengths of this study were the large, population-based, multiethnic birth cohort with prospective design, extensive data collection from early infancy onwards and BP measurements according to a standardized protocol. Importantly, we were able to control for a large number of potentially confounding factors, for example maternal physical aggression and maternal postnatal depressive symptoms, authoritarian parenting style at age 5–6 and factors known to be related to BP, such as birth weight, pre-pregnancy BMI, family hypertension, and BMI child. The response rate of the study (initial participation, phase I) was 67%. In an era where response rates to large epidemiological studies are decreasing,[27] our response rate can be considered adequate. However, selective loss to follow-up was present as in most cohort studies. Our responders were slightly healthier compared with the total study population, but our responders did not differ in the prevalence of maternal verbally aggressive behavior in infancy, compared with our non-responders at age 5–6 (9.6% *v.* 9.3%, $P = 0.335$). We specifically excluded previously known physiological variables of influence on BP such as congenital disorders and preterm birth.[28] BP was assessed by an automatic oscillometric device which may have eliminated potential inter-observer differences.

Maternal verbally aggressive behavior was considered present if angry speaking had been present more than once, at the infant's age of 3 months, according to maternal self-report. It may be difficult to ask mothers to self-report their verbally aggressive behavior to their infant. Possible social desirability in answering this question could lead to underestimation of the true frequency of maternal verbally aggressive behavior. However, it is the only way to measure this, as it is impossible to ask the infant itself, and continuous observation of the mother–infant dyad is not feasible. Also, the definition of maternal verbally aggressive behavior seems quite narrow, but, at the same time, encloses all from only twice to frequent exposure to maternal verbally aggressive behavior in the first 3 months. The associations in our study might differ between children having experienced maternal verbally aggressive behavior only twice and children having experienced this behavior frequently during the first 3 months of life, or even ongoing until the age of 5–6. The distinction between temporary and persistent maternal verbally aggressive behavior to the infant, thus creating chronic stress, could not be made based on

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our data. Due to small numbers we were not able to investigate a possible dose–response relationship.

Another limitation included the inability to assess the contribution of possible paternal aggressive behavior. However, even in the absence of additional data on abuse and neglect in early childhood, maternal verbally aggressive behavior in early infancy was associated with an increased SBP. We suspect that, in line with studies in adults,[6] the experience of simultaneous other adverse events will probably increase this association.

Potential underlying mechanisms

Our results suggest that presence of maternal verbal aggression is an experience of unpredictable intense or chronic stress to the very young infant. Exposure to frequent interactions with a frightening parent motivates infants' defense system to flee, while the parent embodies the solution for infants' needs.[29,30] This exposure could be a relational trauma influencing the stress-coping system.[31]

Possible pathophysiological mechanisms explaining the positive association between maternal verbally aggressive behavior to the infant and SBP at age 5–6, could be programming effects of the hypothalamic–pituitary–adrenal axis (HPA axis)[32–34] and the sympathetic nervous system (ANS). The experience of maternal verbally aggressive behavior could potentially lead to increased levels of stress in the infant with consequent programming alterations in the HPA axis, such as elevated cortisol levels and altered glucocorticoid feedback sensitivity, which, after frequent exposure, ultimately impacts BP regulation. Indeed, cortisol concentrations have been positively associated with BP in children cross-sectionally.[35,36] Likewise, alterations of the sympathetic nervous system, such as resetting of the baroreflex function or possibly oxidative stress[2,37] may mediate the effect of early life stress on dysregulation of BP. Programming effects of cerebral function have been reported recently. Emotional abuse in early life, as reported in retrospect by adults, has been shown to reduce resting state functional connectivity (rs-FC) between the amygdala and the pregenual anterior cingulate cortex in later life,[38] affecting connectivity in brain areas related to stress responsiveness. Furthermore, stress conditions have been shown to be associated with upregulated amygdalar activity[39,40] and resting amygdalar activity has been shown to be predictive of cardiovascular disease events.[41] A final explanation may be a genetic profiling by maternal hypertension. Importantly, in our study maternal pre-pregnancy hypertension was not associated with maternal verbally aggressive behavior, hereby eliminating the possibility of adding profiling risk in the child.

Conclusion

Exposure to maternal verbally aggressive behavior in early infancy was associated with a higher SBP at age 5–6 compared with unexposed children. Maternal verbally aggressive behavior may be an important early life stressor with negative impact on cardiovascular health later in life, which should be further investigated.

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Conflicts of Interest. None.

References

1. Loria AS, Ho DH, Pollock JS. A mechanistic look at the effects of adversity early in life on cardiovascular disease risk during adulthood. *Acta Physiol (Oxf)*. 2014; 210, 277–287.
2. Murphy MO, Cohn DM, Loria AS. Developmental origins of cardiovascular disease: Impact of early life stress in humans and rodents. *Neurosci Biobehav Rev*. 2017; 74, 453–465.
3. Theodore AD, Chang JJ, Runyan DK, *et al.* Epidemiologic features of the physical and sexual maltreatment of children in the Carolinas. *Pediatrics*. 2005; 115, e331–e337.
4. Parrish C, Surkan PJ, Martins SS, *et al.* Childhood adversity and adult onset of hypertension and heart disease in São Paulo, Brazil. *Prev Chronic Dis*. 2013; 10, E205.
5. Slopen N, Non A, Williams DR, Roberts AL, Albert MA. Childhood adversity, adult neighborhood context, and cumulative biological risk for chronic diseases in adulthood. *Psychosom Med*. 2014; 76, 481–489.
6. Su S, Wang X, Pollock JS, *et al.* Adverse childhood experiences and blood pressure trajectories from childhood to young adulthood: the Georgia stress and Heart study. *Circulation*. 2015; 131, 1674–1681.
7. Pretty C, O'Leary DD, Cairney J, Wade TJ. Adverse childhood experiences and the cardiovascular health of children: a cross-sectional study. *BMC Pediatr*. 2013; 17, 208.
8. Lambregtse-van den Berg MP, Lucassen N, Kuipers-Nap MF, *et al.* Assessing expressed emotion during pregnancy. *Psychiatry Res*. 2013; 205, 285–288.
9. Seltzer LJ, Ziegler TE, Pollak SD. Social vocalizations can release oxytocin in humans. *Procedings. Biological Sciences*. 2010; 277, 2661–2666.
10. MacLean PC, Rynes KN, Aragón C, *et al.* Mother-infant mutual eye gaze supports emotion regulation in infancy during the Still-Face paradigm. *Infant Behav Dev*. 2014; 37, 512–522.
11. Naughton AM, Maguire SA, Mann MK, *et al.* Emotional, behavioral, and developmental features indicative of neglect or emotional abuse in preschool children: a systematic review. *JAMA Pediatr*. 2013; 167, 769–775.
12. Brummelte S, Galea LA. Postpartum depression: etiology, treatment and consequences for maternal care. *Horm Behav*. 2016; 77, 153–166.
13. Dollberg D, Feldman R, Keren M. Maternal representations, infant psychiatric status, and mother-child relationship in clinic-referred and non-referred infants. *Eur Child Adolesc Psychiatry*. 2010; 19, 25–36.
14. Van Eijsden E, Vrijkotte TGM, Gemke RJBJ, van der Wal MF. Cohort profile: The Amsterdam Born Children and their Development (ABCD) study. *Int J Epidemiol*. 2011; 40, 1176–1186.
15. de Geus EJ, Willemsen GH, Klaver CH, van Doornen LJ. Ambulatory measurement of respiratory sinus arrhythmia and respiration rate. *Biol Psychol*. 1995; 41, 205–227.
16. Van Dijk AE, van Lien R, van Eijsden M, *et al.* Measuring cardiac autonomic nervous system (ANS) activity in children. *J Vis Exp*. 2013; 74, e50073.
17. Van der Wal MF, van Eijsden M, Bonsel GJ. Stress and emotional problems during pregnancy and excessive infant crying. *J Dev Behav Paediatr*. 2007; 28, 431–437.
18. Smarius LJ, Strieder TG, Loomans EM, *et al.* Excessive infant crying doubles the risk of mood and behavioral problems at age 5: evidence for mediation by maternal characteristics. *Eur Child Adolesc Psychiatry*. 2017; 26, 293–302.
19. Knight RG, Williams S, McGee R, Olaman S. Psychometric properties of the Centre for Epidemiologic Studies Depression Scale (CES-D) in a sample of women in middle life. *Behav Res Ther*. 1997; 35, 373–380.
20. van Dijk A E, van Eijsden M, Stronks K, Gemke R J, Vrijkotte TG. The association between prenatal psychosocial stress and blood pressure in the child at age 5-7 years. *PLoS One*. 2012; 7, e43548.
21. Robinson CC, Mandleco B, Olsen SF, Hart CH. The Parenting Styles and Dimensions Questionnaire (PSDQ). In: *Handbook of Family Measurement Techniques* (eds. Perlmutter BF, Touliatos J, Holden GW), 2001; pp. 319–321. Sage: Thousand Oaks.
22. de Brock AJ, Vermulst AA, Gerris JR, Abidin RR. NOSI, handleiding experimentele versie [NOSI, manual experimental version in Dutch]/ Parenting Stress Index. 1992. Pearson: Amsterdam.

https://doi.org/10.1017/S2040174418000041

23. Henry JD, Crawford JR. The short-form version of the Depression Anxiety Stress Scales (DASS-21): construct validity and normative data in a large non-clinical sample. *Br J Clin Psychol*. 2005; 44, 227–239.
24. Gooding HC, Milliren CE, Austin SB, Sheridan MA, McLaughlin KA. Child abuse, resting blood pressure, and blood pressure reactivity to psychosocial stress. *J Pediatr Psychol*. 2016; 41, 5–14.
25. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation*. 2008; 117, 3171–3180.
26. Toschke AM, Kohl L, Mansmann U, von Kries R. Meta-analysis of blood pressure tracking from childhood to adulthood and implications for the design of intervention trials. *Acta Paediatr*. 2010; 99, 24–29.
27. Galea S, Tracy M. Participation rates in epidemiological studies. *Ann Epidemiol*. 2007; 17, 643–653.
28. Johansson S, Norman M, Legnevall L, *et al*. Increased catecholamines and heart rate in children with low birth weight: perinatal contributions to sympathoadrenal overactivity. *J Intern Med*. 2007; 261, 480–487.
29. Cassidy J, Mohr JJ. Unsolvable fear, trauma and psychopathology; theory, research and clinical considerations related to disorganized attachment across the live cycle. *Clin Psychol*. 2001; 8, 275–298.
30. Liotti G. Trauma, dissociation and disorganized attachment: three stands of a single braid. *Psychotherapy*. 2004; 41, 472–486.
31. Schore AN. Affect Dysregulation and the Disorders of the Self. 2003. Norton: New York.
32. Pesonen AK, Räikkönen K, Feldt K, *et al*. Childhood separation experience predicts HPA axis hormonal responses in late adulthood: a natural experiment of World War II. *Psychoneuroendocrinology*. 2010; 35, 758–767.
33. Danese A, McEwen BS. Adverse childhood experiences, allostasis, allostatic load, and age-related disease. *Physiol Behav*. 2012; 106, 29–39.
34. Pervanidou P, Chrousos GP. Metabolic consequences of stress during childhood and adolescence. *Metabolism*. 2012; 61, 611–619.
35. Boyne MS, Woollard A, Phillips DI, *et al*. The association of hypothalamic-pituitary-adrenal axis activity and blood pressure in an Afro-Caribbean population. *Psychoneuroendocrinology*. 2009; 34, 736–742.
36. Krishnaveni GV, Veena SR, Dhube A, *et al*. Size at birth, morning cortisol and cardiometabolic risk markers in healthy Indian children. *Clin Endocrinol (Oxf)*. 2014; 80, 73–79.
37. Nuyt AM, Alexander BT. Developmental programming and hypertension. *Curr Opin Nephrol Hypertens*. 2009; 18, 144–152.
38. Fan Y, Herrera-Melendez AL, Pestke K, *et al*. Early life stress modulates amygdala-prefrontal functional connectivity: implications for oxytocin effects. *Hum Brain Mapp*. 2014; 35, 5328–5339.
39. Shin LM, Wright CI, Cannistraro PA, *et al*. A functional magnetic resonance imaging study of amygdala and medial prefrontal cortex responses to overtly presented fearful faces in posttraumatic stress disorder. *Arch Gen Psychiatry*. 2005; 62, 273–281.
40. Bremner JD, Vermetten E, Schmahl C, *et al*. Positron emission tomographic imaging of neural correlates of a fear acquisition and extinction paradigm in women with childhood sexual-abuse-related post-traumatic stress disorder. *Psychol Med*. 2005; 35, 791–806.
41. Tawakol A, Ishai A, Takx RA, *et al*. Relation between resting amygdalar activity and cardiovascular events: a longitudinal and cohort study. *Lancet*. 2017; 389, 834–845.

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