Prenatal Exposure to Cell Phone Use and Neurodevelopment at 14 Months

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Background: Recently, an association was reported between prenatal and postnatal exposure to cell phones and neurobehavioral problems in children at the age of 7 years.

Methods: A birth cohort was established in Sabadell, Spain between 2004 and 2006. Mothers completed questions about cell phone use in week 32 of the pregnancy (n = 587). Neurodevelopment of their children was tested at age 14 months using the Bayley Scales of Infant Development (n = 530).

Results: We observed only small differences in neurodevelopment scores between the offspring of cell phone users and nonusers. Those of users had higher mental development scores and lower psychomotor development scores, which may be due to unmeasured confounding. There was no trend with amount of cell phone use within users.

Conclusion: This study gives little evidence for an adverse effect of maternal cell phone use during pregnancy on the early neurodevelopment of offspring.

Recently, an association was observed between prenatal and (to a lesser extent) postnatal exposure to cell phones and behavioral problems in children aged 7 years in the Danish National Birth Cohort.[1] Fetal exposure to radio frequency or extremely low frequency (RF or ELF) fields from cell phones used near the head is extremely low, making it unlikely that a direct biologic effect is responsible for these findings.[1–3] Reporting errors in outcome or exposure (both reported by the parents at age 7 of the child) or unmeasured confounding factors could have biased results, and the authors[1] cautioned against a causal interpretation. Adverse neurobehavioral effects of cell phone use on the fetus or baby would have important public health implications, given the ubiquity of the exposure and the common occurrence of the outcome. We use data from a prospective birth cohort study to examine the relationship between the use of cell phones during pregnancy and neurodevelopment at 14 months of age.

METHODS

A population-based birth cohort was established in the city of Sabadell (Spain) as part of the Infancia y Medio Ambiente (Childhood and Environment) project.[4] Between July 2004 and July 2006, pregnant women who visited the primary health-care center of Sabadell for a first-trimester ultrasound were invited to participate.[4] Of 1099 eligible women, 657 (60%) agreed to participate. The educational achievement of women who declined was lower than that of participants (58% had secondary education or less, compared with 28% in participants). Information on education, social class (ISCO-88 coding of maternal and paternal occupation), maternal health and obstetric history, alcohol consumption, active and passive smoking, dietary intake, and many other factors was obtained through questionnaires administered in person during the first and third trimesters of pregnancy. The third-trimester environmental exposure questionnaire contained 2 questions on cell phone use, "Do you use a cell phone?" and "How many calls do you make or receive each day?"; responses to these questions were obtained from 587 women. Informed consent was signed and the study was approved by the ethics committee of the Institut Municipal d'Asistencia Sanitaria, Barcelona.

Mental and psychomotor development was assessed at age 14 months (range 12–17 months) using the mental and psychomotor development scale of the Bayley Scales of Infant Development, first edition.[5] All testing was done at the primary health-care center in the presence of the mother by 2 specially trained psychologists unaware of any exposure information. The mental development scale consists of 163 items that assess age-appropriate cognitive development in areas such as performance ability, memory, and first verbal learning. The psychomotor scale consists of 81 items assessing fine and gross motor development. To reduce interobserver variability, the assessments followed a strict protocol and fieldwork included training and quality control exercises. Interobserver variability was lower than 5%. The Cronbach's

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Alpha Coefficient, calculated to assess the internal consistency of the test,[6] was 0.73 for the mental scale and 0.78 for the psychomotor scale—each higher than the acceptable level of 0.7. We excluded test results for 4 children because of specific pathologies (Down's syndrome, autistic traits, hypotonia). Ninety percent of mother-child pairs with completed cell phone use information also had a completed Bayley assessment (n = 530). Those without Bayley assessment (n = 57) had somewhat lower maternal educational and social class and younger maternal age. Index scores were computed based on the assumption of a normal distribution with a mean of 100 corresponding to the mean of the raw scores, and standard deviation of 15. Maternal intelligence quotient (IQ) was assessed by Cattell's intelligence test, which seeks to measure mental general capacity.[7]

Multivariate linear regression models were used to examine the impact of cell phone use on the mental and psychomotor index of the Bayley Scales. We categorized the number of phone calls per day was into 0, 1, 2–4, and 5+ calls. Models always included age of the child (in days), sex and psychologist (Model 1). A second model (Model 2) also included those covariates reported to be important a priori predictors of neurodevelopment (maternal socio-economic status, maternal education, and maternal IQ) as well as other potential risk factors related to phone use in our data (maternal age, maternal smoking at any time during pregnancy, and smoker in the house). We imputed maternal IQ for 34 subjects with missing data; predictor variables were maternal social class, education, age, parity, and country of origin. All models were repeated using 1 call per day as referent category to control for

TABLE 1. Characteristics of Children and Mothers by Number of Cell Phone Calls per Day. Sabadell Cohort, Spain, 2004–2006 (n = 530).

	Average Number of Cell Phone Calls per Day			
	0 (n = 61)	1 (n = 162)	2–4 (n = 239)	5 or More (n = 68)
Child's characteristics				
Female sex; %	44	49	52	40
Gestational age ≥37 week; %	98	97	97	97
Birth weight (g); mean (SD)	3342 (404)	3206 (422)	3247 (416)	3216 (438)
Birth height (cm); mean (SD)	49.8 (1.8)	49.2 (1.9)	49.4 (1.9)	49.5 (2.0)
Breastfeeding (week); mean (SD)	21.9 (18.3)	22.4 (18.3)	24.1 (18.4)	25.7 (20.4)
Cord-blood mercury concentration; mean (SD) (n = 389)	9.0 (9.0)	9.5 (6.8)	9.6 (11.8)	9.1 (6.0)
Nursery attendance; %	67	68	72	58
Mother's characteristics				
Social class; %				
Professionals, managers, technicians	12	24	24	24
Other nonmanual	44	48	43	54
Skilled, semi-skilled, and unskilled manual	25	17	23	13
Unclassifiable: housewife, unemployed	20	11	10	9
Education; %				
Primary or first 4 years of secondary school	30	24	26	29
High school	52	42	43	38
University	18	35	32	32
IQ; mean (SD)	97.0 (15.0)	100.6 (15.7)	100.5 (15.1)	98.1 (14.1)
Country of birth; %				
Spain	90	91	92	87
Latin America	7	6	8	9
Other	3	4	1	5
Age; %				
≤25	22	22	6	12
26–30	25	35	31	29
31–35	37	43	41	47
36	37	21	23	12
Parity ≥1 previous pregnancies; %	56	36	46	35
Smoking in pregnancy; %	25	17	37	44
Smoking in the house; %	36	27	46	57
Alcohol during pregnancy; %	27	19	21	19

differences between cell phone users and nonusers. Trend tests were conducted by introducing phone use category or number of calls into the models as continuous variables.

RESULTS

Of the 530 mother-child pairs with information on prenatal cell phone use and Bayley Scales assessments, only 11% of mothers reported not using a cell phone, 31% reported making or receiving 1 call per day, 45% between 2 and 4 calls, and 13% 5 or more calls. Cell phone use was not related to the child's sex, birth weight, prematurity, weeks of breast-feeding, nursery attendance, or cord blood mercury concentration (Table 1). Mothers from the highest social and educational classes were more likely to be phone users, but within users there were few social or educational class differences among levels of phone use. Maternal age was a strong predictor of phone use, with younger age groups reporting more calls. Cell phone use was also related to smoking status, with higher active and passive smoking levels in those who made more calls.

Among those exposed to cell phone use, scores on the Bayley mental score tended to be higher, and those on the psychomotor score lower, compared with nonusers (Table 2). The largest decrease on the psychomotor scale was seen in the heaviest users (−5.6 points [95% confidence interval = −10.7 to −0.5]). However, using 1 call as referent category, we observed no differences among the categories of phone users and no evidence for a trend with level of use (Table 2).

DISCUSSION

Our findings lend little support to the hypothesis of an early adverse neurodevelopmental effect on offspring from maternal cell phone use during pregnancy. Some differences in neurodevelopment scores were observed between users and nonusers, but there was no trend with amount of cell phone use within users. The differences observed between users and nonusers may indicate residual confounding between cell phone users and the very small group of mothers who did not use cell phones at all, possibly related to social class, maternal age, or other correlates of not using a cell phone. This study cannot exclude effects beyond 14 months of age nor, because numbers of heavy users were small, effects of very heavy cell phone use.

An important strength of this study is its prospective design, which eliminates the possibility of recall bias related to outcome. Random errors in self-reported phone use are likely, but self-reporting of numbers of phone calls has been shown to be reasonably accurate on average (with less than 10% error) and more accurate than reporting of duration of phone use.[8,9] Also, the average number of calls reported by

TABLE 2. Bayley Scores of Mental and Psychomotor Development at 14 Months of Age in Relation to Prenatal Cell Phone Use

	Bayley Scale Regression Coefficient (95% CI)							
	Model 1[a]				Model 2[b,c]			
	All Subjects		Excluding 0 Calls		All Subjects		Excluding 0 Calls	
Bayley mental score								
Number of calls per day								
0	1.0				1.0			
1	2.9	(−1.3 to 7.1)	1.0		1.6	(−2.6 to 5.8)	1.0	
2–4	2.8	(−1.2 to 6.7)	−0.1	(−2.8 to 2.6)	2.0	(−2.1 to 6.0)	0.5	(−2.3 to 3.3)
5 or more	3.4	(−1.4 to 8.3)	0.7	(−3.2 to 4.5)	2.8	(−2.2 to 7.8)	1.5	(−2.5 to 5.5)
Trend per category of phone use	0.8	(−0.6 to 2.2)	0.2	(−1.6 to 2.1)	0.8	(−0.7 to 2.3)	0.7	(−1.2 to 2.6)
Trend per phone call	0.008	(−0.3 to 0.3)	−0.1	(−0.4 to 0.3)	−0.006	(−0.3 to 0.3)	−0.03	(−0.4 to 0.3)
Bayley psychomotor score								
Number of calls per day								
0	1.0				1.0			
1	−2.9	(−7.1 to 1.3)	1.0		−3.5	(−7.8 to 0.8)	1.0	
2–4	−1.9	(−5.9 to 2.1)	1.1	(−1.2 to 3.9)	−2.8	(−6.9 to 1.3)	0.7	(−2.3 to 3.7)
5 or more	−4.2	(−9.2 to 0.7)	−1.3	(−5.3 to 2.8)	−5.6	(−10.7 to −0.5)	−2.0	(−6.3 to 2.2)
Trend per category of phone use	−0.8	(−2.2 to 0.6)	−0.3	(−2.2 to 2.7)	−1.2	(−2.7 to 0.3)	−0.6	(−2.7 to 1.5)
Trend per phone call	−0.1	(−0.4 to 0.3)	−0.01	(−0.4 to 0.3)	−0.1	(−0.5 to 0.2)	−0.1	(−0.4 to 0.3)

[a]Model 1: adjusted for age of the child in days, sex of the child, psychologist.
[b]Model 2: adjusted for variables in Model 1 and maternal socioeconomic status (categories: professional, managerial, technical and associated; other non-manual; skilled, semi and unskilled manual; unclassified), maternal education (primary or first 4 years of secondary school, high school, university), maternal IQ (continuous), smoking during the pregnancy (yes, no), and smoking in the home (yes, no).
[c]eAppendix (http://links.lww.com/EDE/A362) shows all parameters of this model and a sensitivity analysis excluding subjects for whom maternal IQ was missing and imputed.

the study subjects (2.9 per day) is within the range objectively recorded in adult volunteer populations in other European countries during a similar time period.[10] We did not, however, have information on other factors that may influence prenatal exposure, such as the place where the cell phone is carried by the mother. This study collected extensive information about potential confounding variables. Heavy cell phone users were more likely to be younger, to be smokers, and to live with other smokers. Heavy users may be involved in other behaviors that could explain the somewhat lower scores of their offspring on the psychomotor scale.

The Bayley Scales have been widely used to assess early neurodevelopmental effects of chemical exposures, including polychlorinated biphenyls,[11] organophosphate pesticides,[12] and polycyclic aromatic hydrocarbons,[13] with reported decreases of up to 6 points.[12,13] Our Bayley test results had good internal consistency and performed as expected in relation to other variables known to influence neurodevelopment (sex, age, social class, education: eAppendix, http://links.lww.com/EDE/A362). However, the importance of these early neurodevelopment test scores for cognition or behavior later in childhood, such as those assessed in the cell phone analysis of the Danish National Birth Cohort,[1] is unclear. Further follow-up of this and similar cohorts will be informative.

Prenatal exposures to the fetus from maternal cell phone use are extremely low—many magnitudes lower than to the head of the user. Thus, a direct biologic effect is unlikely. Nevertheless, indirect mechanisms (such as a recently proposed hypothesis in which maternal phone use would affect the melatonin secretion pathway between retina and pineal gland located in the most exposed part of the head and, in turn, alter neurodevelopment of the unborn fetus[14]) may warrant further exploration. Most importantly, effects of postnatal cell phone use will need to be monitored closely[15] because of the rapidly increasing use of cell phones in ever younger children, the higher exposures received by the child's brain compared with the adult brain,[16] and the vulnerability of the developing central nervous system into adolescence.[17]

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