Mobile phone use during pregnancy: Which association with fetal growth?

Nathalie Boileau, François Margueritte, Tristan Gauthier, Nedjma Boukeffa, Pierre-Marie Preux, Anaïs Labrunie, Yves Aubard

TITLE PAGE

Mobile phone use during pregnancy: which association with fetal growth?

Nathalie Boileau[1], François Margueritte[2], Tristan Gauthier[2], Nedjma Boukeffa[2], Pierre-Marie Preux[3], Anaïs Labrunie[4], Yves Aubard[2]

[1] Department of Gynecology and Obstetrics, University Hospital Center of Limoges, 8 Avenue Dominique Larrey 87042 Limoges cedex, France. nboileau87@gmail.com.

[2] Department of Gynecology and Obstetrics, University Hospital Center of Limoges, 8 Avenue Dominique Larrey 87042 Limoges cedex, France.

[3] University Limoges, UMR_S 1094, Tropical Neuroepidemiology, Institute of Neuroepidemiology and Tropical Neurology, 2 rue du Docteur Marcland, 87025 Limoges Cedex, France.

[4] University Hospital Center of Limoges, CEBIMER, 2 avenue Martin Luther-King, 87042 Limoges cedex, France.

Corresponding author : Nathalie Boileau, nboileau87@gmail.com.

ABSTRACT:

Introduction: Few studies have investigated the effect of electromagnetic waves on the human fetus whereas nowadays mobile phone use is ubiquitous. The aim of this study was to evaluate the association between mobile phone use by pregnant women and fetal development during pregnancy in the general population.

Material and methods: Data came from the NéHaVi cohort ("prospective follow-up, from intrauterine development to the age of 18 years, for children born in Haute-Vienne"), a prospective, longitudinal, multicenter (three maternity units in Haute-Vienne) observational cohort focusing on children born between April 2014 and April 2017. Main objective was to investigate the association of mobile phone use on fetal growth. Univariate and multivariate models were generated adjusted for the socioprofessional category variables of the mother, and other variables likely to influence fetal growth.

Results : For the analysis 1,378 medical charts were considered from which 1,368 mothers (99.3%) used their mobile phones during pregnancy. Mean phone time was 29.8 minutes (range: 0.0 - 240.0 minutes) per day. After adjustment, newborns whose mothers used their mobile phones for more than 30 minutes/day were significantly more likely to have an AUDIPOG score ≤ 10th percentile than those whose mothers used their mobile phones for less than 5 minutes/day during pregnancy (aOR = 1.54 [1.03; 2.31], p = 0.0374). For women using their cell phones 5 to 15 min and 15 to 30 min, there wasn't a significant association with an AUDIPOG score ≤ 10th, respectively aOR = 0.98 [0.58; 1.65] and aOR = 1.68 [0.99; 2.82].

Conclusion: Using a mobile phone for calls for more than 30 minutes per day during pregnancy may have a negative impact on fetal growth. A prospective study should be performed to further evaluate this potential link.

Keywords : mobile phone, maternal exposure, fetal growth, pregnancy, birth weight

INTRODUCTION

Electromagnetic waves, especially domestic radiofrequencies (radio waves, Wi-Fi, 4G, Bluetooth), are ubiquitous in the environment and it is difficult to characterize their individual effects on health. Several simulations and in vivo studies have searched for potentially deleterious effects on the human body, such as involvement in carcinogenesis or effects on fertility or children.

In their review, Feychting and al. reported an increased risk of childhood leukemia associated with extremely low frequency magnetic fields [1], INTERPHONE [2] and CERENAT [3] studies reported a higher risk of brain tumors in intensive mobile phone users.

In response to concerns about radiofrequency use, the ANSES (*Agence Nationale de Sécurité Sanitaire de l'alimentation, de l'environnement et du travail*), the French National Agency for the Sanitary Safety of Food, the Environment and Labor has conducted several expert reviews of potential health effects, publishing advice and collective expert reports in 2003 and 2005 for mobile phones and in 2009 [4], 2013 [5], and 2016 [6] for all applications using radio frequencies.

Studies of children exposed to mobile phones in utero during pregnancy have yielded conflicting results (Table 1): Divan and al. [7,8] and Sudan and al. [9] reported behavioral disorders in exposed children, whereas Guxen and al. [10] and Choi and al. [11] found no effect, and Papedopoulou and al. [12] even found a beneficial effect on child's neurodevelopment whose mothers used their mobile phone during pregnancy.

Few studies have investigated the effect of radiofrequencies on the human fetus and its development. Studies modeling radiofrequency exposure have shown that a mobile phone held close to the body of a pregnant woman would result in a very low rate of Specific Absorption Rate (SAR) of radiofrequencies in the fetus [13]. Several studies on animal fetuses have reported that electromagnetic waves have little or no effect on development in utero [14,15]. Shirai and al. didn't find any consequences on rats exposed in utero to electromagnetic waves (GSM, 3G, Wi-Fi). In the National Toxicology Program (2G and 3G exposure) a risk of heart schwannoma was described on little rats but probably because of a thermic effect [14,15]. These data are reassuring but fears about mobile phone use during pregnancy remain. Moreover there isn't any data available about mobile phone use in French pregnant women population as the use of a mobile phone has become ubiquitous every day.

The aim of this study was to evaluate the association between mobile phone use by pregnant women and fetal development during pregnancy in the general population.

MATERIAL AND METHODS

The data for this study came from the NéHaVi cohort ("prospective follow-up, from intrauterine development to the age of 18 years, for children born in Haute-Vienne"). This prospective, longitudinal, multicenter (three maternity units in Haute-Vienne) observational cohort was designed to collect epidemiological data relating to the mother-fetus, the infant, and the environment and sociofamilial data [16]. Local Institutional review board approved the design of the cohort as informed consent was obtained from all individual participants included in the cohort study.

We focused on children born between April 2014 and April 2017.

Population

For inclusion, the neonates from the cohort had to have dossiers considered complete after processing by the data manager.

The exclusion criteria for the mother were multiple pregnancy and known or suspected toxoplasmosis or CMV infection during pregnancy. The exclusion criteria for the child were the presence of a genetic or chromosomal abnormality. Mothers for whom the time spent on the phone (phone time) was not reported or was aberrant (> 240 min/day) were not included in the study. We use the personalized AUDIPOG score to assess neonatal growth. It involves the plotting of a neonatal morphometric curve derived from a model based on the height, birth order, and sex of the child, and the age, height, and weight of the mother [17]. The threshold for growth restriction is generally set at the 10th percentile [18,19]. It is currently recommended to use individual adjusted fetal weight curves to standardize practices [19,20].

The main objective was to investigate the impact of mobile phone use on fetal growth (growth restriction at birth, defined by an AUDIPOG score ≤ 10th percentile at birth).

The secondary objectives were to determine whether there was an association between phone time and APGAR score at birth, the presence of any fetal malformations, birth weight, or head circumference.

Data collection

The data used here came from questionnaires completed during face-to-face interviews in the post-partum period during stay at the maternity unit with the parents immediately for the NéHaVi cohort, and the child's and parents' medical records.

The questionnaire completed during the face-to-face interview with the parents consisted of a series of questions concerning demographic and professional characteristics, data concerning psychological aspects of the pregnancy and various types of exposure of the mother during her pregnancy (tobacco, alcohol, mobile telephone use, etc.). Dedicated staff were responsible for administering the questions and collecting the responses from the parents.

Analysis

Phone time was recorded in minutes or hours per day or month. For the purposes of the analyses, we converted all phone times into minutes per day.

We first performed a global descriptive analysis, and then an analysis by group, of phone time. We tested the hypothesis of an association between phone time and the occurrence of growth restriction at birth.

Quantitative variables are expressed as the mean ± standard deviation, minimum and maximum, and were compared by phone time category, defined according to quartiles, in non-parametric Kruskal-Wallis tests, as the data were not normally distributed.

Qualitative variables are expressed as absolute numbers and percentages and were compared by phone time category in Chi² tests.

These tests were used to identify potential confounding factors ($p < 0.2$), which were then integrated in the models as potential adjustment variables.

Univariate analysis was first performed to identify potential confounding factors linked to the presence of growth restriction at birth (defined as an AUDIPOG score ≤ 10th percentile).

A multivariate model was then generated with phone time adjusted for the socioprofessional category variables of the mother likely to influence phone time as the variable of interest. Variables known to influence fetal growth were also considered and forced into the model: smoking, alcohol consumption, history of diabetes or high blood pressure, gestational diabetes, gestational hypertension, and potential confounding factors.

Linear regression analysis was performed to determine the effect of phone time on head circumference or birth weight.

Statistical analyses were performed by the CEBIMER (Center for Epidemiology, Biostatistics and Methodology Research) and were conducted and presented according to STROBES recommendations, with SAS V9.3 software (SAS Institute Cary, NC). The significance threshold retained for all analyses (p) was an alpha risk of 0.05.

RESULTS

Population characteristics

There were about 12,000 births in Haute-Vienne between April 2014 and April 2017. Over this period, 7,287 mothers in the three maternity units (one tertiary center, a university hospital, and two primary center) of the NéHaVi cohort were contacted and data were collected for 2,722 children born to 2,677 mothers. In total, 1,415 of the newborns had complete dossers that could be exploited as they were processed by the data manager at the time of the study. Thirty-seven dossiers were excluded. We therefore included 1,378 dossiers in this study (Fig 1).

Descriptive analysis

In our population, 1,368 mothers (99.3%) used their mobile phones during pregnancy. Mean phone time was 29.8 minutes (range: 0.0 - 240.0 minutes) per day.

Table 2 presents the characteristics of the mothers included in the study.

The groups were comparable for both sociodemographic variables, such as BMI, parity, gestational age, alcohol and tobacco use, and obstetric variables, such as history of diabetes, gestational diabetes mellitus, AHT (Arterial Hyper Tension), and the risk of preterm birth.

Only maternal age and the use of medically assisted procreation techniques differed between the groups (p = 0.0243 and p = 0.0342, respectively) so as the repartition among the three different centers (p = 0.0028).

The mothers who called the most (communication time ≥ 15 minutes/day) were those who also sent or received the most SMS, made the greatest use of Internet with their mobile phone, and kept the phone within reach at night ($p < 0.001$).

Statistical analysis

Primary endpoint

The records of six of the 1,378 children included lacked AUDIPOG information and others had missing information concerning confounding factors. The final population for analysis thus consisted of 1,353 women and their offspring. Mean AUDIPOG score at birth was the 43.5 ± 26.5 percentile [0.01; 99.7], and the median value was the 41.3 percentile (21.2, 64.7). There were 175 infants with an AUDIPOG score ≤ 10th percentile (12.9%).

Table 3 presents the results of univariate and multivariate analyses for the presence or absence of an AUDIPOG score ≤ 10th percentile.

After adjustment for confounding factors, newborns whose mothers used their mobile phones for more than 30 minutes/day were significantly more likely to have an AUDIPOG score ≤ 10th percentile than those whose mothers used their mobile phones for less than 5 minutes/day during pregnancy (aOR = 1.54 [1.03; 2.31], $p = 0.0374$).

In the multivariate model, women who smoked during pregnancy were found to be more likely to have a child with an AUDIPOG score ≤ 10th percentile than women who had "no tobacco use throughout pregnancy" (Table 3; aOR = 2.40 [1.62; 3.56], $p < 0.0001$). Similarly, for maternal age, being over the age of 30 was associated with growth restriction in the infant at birth ($p = 0.02$ after 30 years). A significant association was also found for gestational hypertension (Table 3; aOR = 1.93 [1.11; 3.37], p-value = 0.0201).

Secondary endpoints

Birthweight and head circumference

Results of univariate and multivariate analysis of birthweight and head circumference as a function of phone time revealed an interaction between phone time and birthweight ($p = 0.0435$). A few significative associations were found between phone time and every category of smoking status (no smoking, stopped smoking, smoking). Same was found for head circumference with also an interaction ($p = 0.0441$). Nonetheless, no significant association was described between head circumference and every category of smoking status (Table 4 and 5).

APGAR score and malformations

There was no association between APGAR score at 5 minutes and phone time (p between 0.41 and 0.90).

In total, 16 malformations were detected during the study. This number of events was too small (1.2%) and too close to the rate of malformations in the general population for any significant difference to be detected. No association was detected between the presence of a malformation at birth and phone time during pregnancy.

DISCUSSION

This study was original in that it evaluated the impact of electromagnetic waves on the human fetus in terms of growth, birthweight, head circumference, APGAR score, and fetal malformation in the general population. Also it depicted mobile use during pregnancy as there wasn't any data available so far in France.

The results suggested that greater mobile phone use by pregnant women (≥ 30 minutes per day) was associated with a higher frequency of growth restriction at birth. This association was of borderline significance for phone times between 15 and 30 minutes per day ($p = 0.0508$), becoming significant for phone times of at least 30 minutes per day ($p = 0.0374$).

Nevertheless, we found no such association between head circumference and phone time. And the few significant association between birthweight and smoking status (among non-smoking women, those who phone more than 30 minutes, have significantly a birthweight of baby lower than those who phone 0 to 5 minutes per day $p = 0.0079$) don't seem to be relevant (among women who stopped smoking during pregnancy, association between phone time and birthweight was described significant only for those who phone 5 to 15 min ($p = 0.0185$) and not found when phone time was longer). This can be explained by the determination of growth restriction from adjusted morphometric curves (height, birth order, and sex of the child, and age, height and weight of the mother) for predicting the growth potential of each child: focusing not on birthweight but on the AUDIPOG curves allow us a better comparison between children.

Growth restriction at birth was also more frequent among the children of the oldest mothers ($p = 0.0788$ for a maternal age of 27 to < 30 years vs. < 27 years, $p = 0.0206$ for 30 to < 33 years vs. < 27 years, and $p = 0.0203$ for ≥ 33 years vs. < 27 years) and among those whose mother smoked ($p < 0.0001$) or had gestational hypertension ($p = 0.0201$). These findings were consistent with published results, as being older, smoking and gestational hypertension were known risk factors for growth restriction at birth [21]. By contrast, no association was found between phone time and APGAR score or fetal malformations.

The effects of electromagnetic waves on fetuses have been investigated in animals, but few studies have focused on the human fetus. Shirai and al. [14] found that electromagnetic waves had no impact on pregnancy or pup development in rats. Similar findings were reported in the February 2018 report of the National Toxicology Program [15], which included several rat studies. The results of these studies showed no direct effect of electromagnetic waves. Only an increase in the risk of malignant schwannoma in the heart was noted, which might have been due to a thermal effect of the waves, as it occurred in male rats exposed to the highest SAR. The animal studies performed to date are, therefore, reassuring, as they suggest that antenatal exposure to the electromagnetic waves emitted by mobile phones has no impact. All these data supported the notion that studies of fetuses are essential.

In Japan, Lu and al. [22] also investigated the impact of mobile phone use during pregnancy. They found that neonates of mothers considered being intensive mobile phone users had a low birthweight and were more likely to require resuscitation than other neonates. However, the study by Lu and al. was based on a sample of only 500 women. As in our study, mobile phone use was assessed with a questionnaire completed by the mother during hospitalization for the birth. The results obtained by Lu and al. was not comparable to ours, because intensive use was based on a composite score, whereas we defined intensive use based on phone time.

There was a classification bias in our study, because we used a declarative questionnaire, as in the study performed by Lu and al. mobile phone use, including the time spent talking on the telephone, may have been under- or overestimated. The use of mobile phone data from telephone operators, as in the COSMOS study [23], or collected via an application, would improve data collection and the relevance of the data. Thus, our results should be interpreted cautiously.

Evaluation of SMS or internet use were not analyzed in our study. Data of internet use wasn't available. The SMS use wasn't the purpose of our study. Therefore, mobile phone use should be evaluated not only with time spend in communication but also with internet and SMS use through an objective composite variable. Also position of mobile phone during pregnancy should be evaluated (close to the uterus), and utilization in each trimester of pregnancy to explore their respective impact.

We cannot rule out a selection bias in our study because some of the medical charts were non-exploitable records. Differences in socioprofessional categories were noted between the exploitable and non-exploitable data. However, our study population was larger than that of Lu and al. and included data for 1,378 women from a general population cohort.

We cannot also rule out other confounding factors which weren't taken into account in this study (housing type for example).

We showed here that there was an association between time spent using a mobile phone during pregnancy and growth restriction of the infant at birth, but it was difficult to evaluate the strength of this association because the confidence intervals obtained were broad ($p = 1.54$ [1.03; 2.31] for ≥ 30 min/day vs. 0 to < 5 min / day). This may be because there were too few newborns with growth restriction for a high-powered statistical analysis (AUDIPOG $\leq 10\%$: 175 for 1,353 newborns).

The results must therefore be interpreted with caution, particularly given that no clinical relevant association was found between phone time and birthweight or head circumference. Further studies are therefore required to confirm the association observed here.

Using a mobile phone for calls for more than 30 minutes per day during pregnancy may have a negative impact on fetal growth, resulting in a higher incidence of growth restriction at birth. A prospective study should now be performed, with data from a mobile application or telephone operators, to obtain reliable data on phone use for confirmation of these results. Recommendations on the use of mobile phones during pregnancy could then be formulated, according to the results obtained.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ACKNOWLEDGMENTS

We thank numerous colleagues who help in the design management and data collection of the cohort NEHAVI.

REFERENCES

[1] M F, A A, L K. EMF and Health. Annual Review of Public Health 2005. https://doi.org/10.1146/annurev.publhealth.26.021304.144445.

[2] INTERPHONE Study Group. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Int J Epidemiol 2010;39:675–94. https://doi.org/10.1093/ije/dyq079.

[3] Coureau G, Bouvier G, Lebailly P, Fabbro-Peray P, Gruber A, Leffondre K, et al. Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med 2014:oemed-2013-101754. https://doi.org/10.1136/oemed-2013-101754.

[4] Mise à jour de l'expertise relative aux radiofréquences - Les radiofréquences - Avis de l'Afsset - Rapport d'expertise collective - Édition scientifique - Agents physiques - Octobre 2009 n.d.

[5] Radiofréquences et santé - Mise à jour de l'expertise - Avis de l'Anses - Rapport d'expertise collective - Édition scientifique - Octobre 2013 n.d.

[6] Exposition aux radiofréquences et santé des enfants - Avis de l'Anses - Rapport d'expertise collective - Édition scientifique Juin 2016 n.d.

[7] Divan HA, Kheifets L, Olsen J. Prenatal cell phone use and developmental milestone delays among infants. Scand J Work Environ Health 2011;37:341–8.

[8] Divan HA, Kheifets L, Obel C, Olsen J. Prenatal and postnatal exposure to cell phone use and behavioral problems in children. Epidemiology 2008;19:523–9. https://doi.org/10.1097/EDE.0b013e318175dd47.

[9] Sudan M, Birks LE, Aurrekoetxea JJ, Ferrero A, Gallastegi M, Guxens M, et al. Maternal cell phone use during pregnancy and child cognition at age 5 years in 3 birth cohorts. Environ Int 2018;120:155–62. https://doi.org/10.1016/j.envint.2018.07.043.

[10] Guxens M, van Eijsden M, Vermeulen R, Loomans E, Vrijkotte TGM, Komhout H, et al. Maternal cell phone and cordless phone use during pregnancy and behaviour problems in 5-year-old children. J Epidemiol Community Health 2013;67:432–8. https://doi.org/10.1136/jech-2012-201792.

[11] Choi K-H, Ha M, Ha E-H, Park H, Kim Y, Hong Y-C, et al. Neurodevelopment for the first three years following prenatal mobile phone use, radio frequency radiation and lead exposure. Environmental Research 2017;156:810–7. https://doi.org/10.1016/j.envres.2017.04.029.

[12] Papadopoulou E, Haugen M, Schjølberg S, Magnus P, Brunborg G, Vrijheid M, et al. Maternal cell phone use in early pregnancy and child's language, communication and motor skills at 3 and 5 years: the Norwegian mother and child cohort study (MoBa). BMC Public Health 2017;17. https://doi.org/10.1186/s12889-017-4672-2.

[13] Cabot E, Christ A, Bühlmann B, Zefferer M, Chavannes N, Bakker JF, et al. Quantification of RF-exposure of the fetus using anatomical CAD-models in three different gestational stages. Health Phys 2014;107:369–81. https://doi.org/10.1097/HP.0000000000000129.

[14] Shirai T, Wang J, Kawabe M, Wake K, Watanabe S, Takahashi S, et al. No adverse effects detected for simultaneous whole-body exposure to multiple-frequency radiofrequency electromagnetic fields for rats in the intrauterine and pre- and post-weaning periods. J Radiat Res 2017;58:48–58. https://doi.org/10.1093/jrr/rrw085.

[15] National Toxicology Program n.d. https://ntp.niehs.nih.gov/ (accessed March 21, 2018).

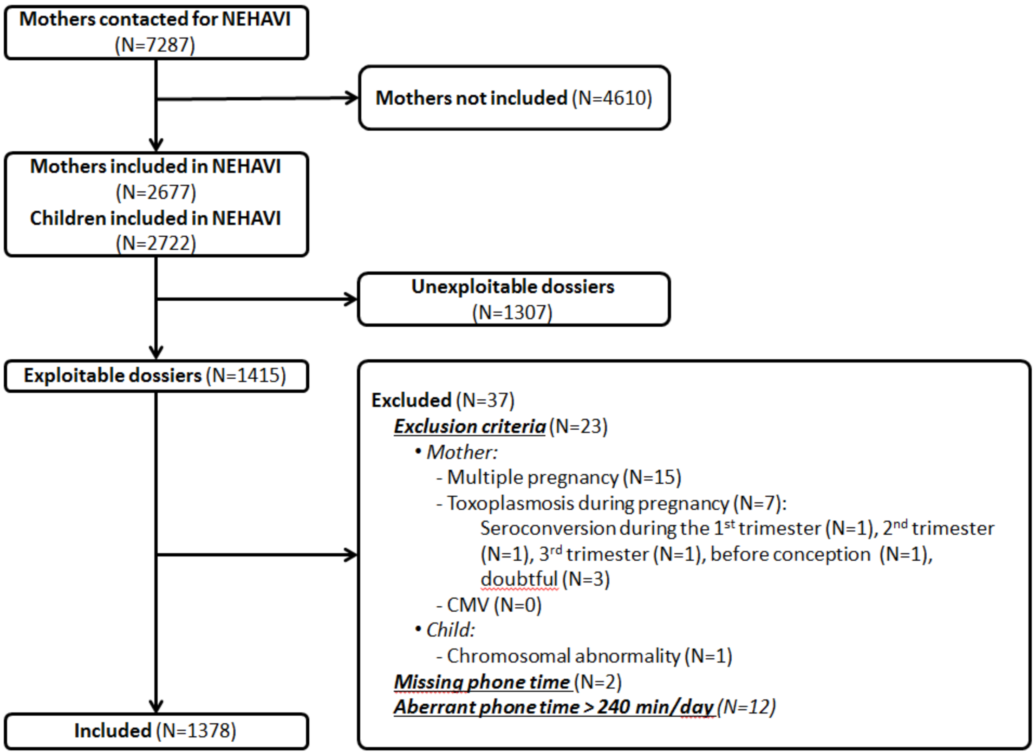
[16] Yves Aubard - Responsable de la chaire "Cohorte prospective de suivi des enfants nés en Limousin : étude NéHaVi." Université de Limoges Recherche 2017. https://www.unilim.fr/recherche/2017/03/13/yves-aubard/ (accessed June 7, 2020).

[17] AUDIPOG (Association des Utilisateurs de Dossiers Informatisés en Pédiatrie, Obstétrique et Gynécologie) n.d. http://www.audipog.net/index.php (accessed March 18, 2018).

[18] Small-for-Gestational-Age Fetus, Investigation and Management (Green-top Guideline No. 31). Royal College of Obstetricians & Gynaecologists n.d. https://www.rcog.org.uk/en/guidelines-research-services/guidelines/gtg31/ (accessed January 13, 2019).

[19] Vayssière C, Sentilhes L, Ego A, Bernard C, Cambourieu D, Flamant C, et al. Fetal growth restriction and intra-uterine growth restriction: guidelines for clinical practice from the French

College of Gynaecologists and Obstetricians. European Journal of Obstetrics & Gynecology and Reproductive Biology 2015;193:10–8. https://doi.org/10.1016/j.ejogrb.2015.06.021.
[20] Ego A. Définitions : petit poids pour l'âge gestationnel et retard de croissance intra-utérin. Journal de Gynécologie Obstétrique et Biologie de La Reproduction 2013;42:872–94. https://doi.org/10.1016/j.jgyn.2013.09.012.
[21] Gaudineau A. Prévalence, facteurs de risque et morbi-mortalité materno-fœtale des troubles de la croissance fœtale. Journal de Gynécologie Obstétrique et Biologie de La Reproduction 2013;42:895–910. https://doi.org/10.1016/j.jgyn.2013.09.013.
[22] Lu X, Oda M, Ohba T, Mitsubuchi H, Masuda S, Katoh T. Association of excessive mobile phone use during pregnancy with birth weight: an adjunct study in Kumamoto of Japan Environment and Children's Study. Environ Health Prev Med 2017;22:52. https://doi.org/10.1186/s12199-017-0656-1.
[23] Schüz J, Elliott P, Auvinen A, Kromhout H, Poulsen AH, Johansen C, et al. An international prospective cohort study of mobile phone users and health (Cosmos): Design considerations and enrolment. Cancer Epidemiology 2011;35:37–43. https://doi.org/10.1016/j.canep.2010.08.001.



Mothers contacted for NEHAVI (N=7287)
Mothers not included (N=4610)
Mothers included in NEHAVI (N=2677)
Children included in NEHAVI (N=2722)
Unexploitable dossiers (N=1307)
Exploitable dossiers (N=1415)
Excluded (N=37)
Exclusion criteria (N=23)
• Mother:
- Multiple pregnancy (N=15)
- Toxoplasmosis during pregnancy (N=7):
Seroconversion during the 1st trimester (N=1), 2nd trimester (N=1), 3rd trimester (N=1), before conception (N=1), doubtful (N=3)
- CMV (N=0)
• Child:
- Chromosomal abnormality (N=1)
Missing phone time (N=2)
Aberrant phone time > 240 min/day (N=12)
Included (N=1378)

Authors	Country	Year	Number of subjects	Association	p-value or OR
Lu	Japan	2017	461	Mean birth weight lower in excess mobile phone use group	$p < 0.05$
Papadopoulou	Norway	2017	45 389	Children of cell phone user's mother have lower adjusted risk of having low sentence complexity at 3 years	OR 0.83 [95% CI ; 0.77-0.89]
Birks	International (Denmark, Korea, Netherlands, Norway, Spain)	2017	83 884	Increasing risk of child behavioral problem in maternal cell phone use categories	OR 1.11 [95% CI ; 1.01-1.22]
Guxens	Netherlands	2013	2 618 children	Exposition to prenatal cell phone use show non-significant association of teacher-reported behaviour problems	OR 2.12 [95% IC ; 0.95-4.74]
Sudan	International (Denmark, Korea, Spain)	2018	3 089	No association between prenatal cell phone use and children's cognition scores at 5 years	NA
Choi	Korea	2017	1 198	Psychomotor development index and mental development index at 6, 12, 24 and 36 months of age not significantly associated with maternal mobile phone use during pregnancy	NA

Table 1 : Summary of studies about children exposed to mobile phone in utero during pregnancy

Characteristic	0 to < 5 min/d (N = 428) N (%) or mean ± SD (N) [Min ; Max]	5 to < 15 min/d (N = 264) N (%) or mean ± SD (N) [Min ; Max]	15 to < 30 min/d (N = 179) N (%) or mean ± SD (N) [Min ; Max]	≥30 min/d (N = 507) N (%) or mean ± SD (N) [Min ; Max]	Total (N = 1378) N (%) or mean ± SD (N) [Min ; Max]	P-value
Age of the mother (yrs) (N = 1378)	30.9±4.6 [15 ; 45]	30.1±5.0 [18 ; 44]	30.1±4.6 [19 ; 42]	30.0±5.0 [18 ; 44]	30.3±4.8 [15 ; 45]	0.0243 (KW)
BMI of the mother before pregnancy (N = 1375)	24.2±5.4 [16.1;54.8]	23.6±5.0 [17.2;49.6]	23.8±4.7 [16.7;39.1]	24.2±5.4 [15.2;56.1]	24.0±5.2 [15.2;56.1]	0.4110 (KW)
Parity (N = 1377)	0.8±1.1 [0;8]	0.7±0.78 [0;8]	0.7±0.9 [0;4]	0.7±0.9 [0;7]	0.8 ± 1.0 [0;8]	0.4971 (KW)
Gestational age (weeks) (N = 1376)	39.7±1.3 [29.5;41.6]	39.5±1.6 [28;42]	39.7±1.2 [35;42]	39.6±1.5 [28.4;42]	39.6±1.4 [28;42]	0.7554 (KW)
Birthweight of the child (kg) (N = 1378)	3.3±4.5 [1.2;4.6]	3.2±4.2 [1.8;4.4]	3.3±4.3 [2.3;4.5]	3.2±4.3 [1.9;5.2]	3.3±4.3 [1.2;5.2]	0.0981 (KW)
Head circumference at birth (cm) (N = 1339)	34.5±1.5 [24.5;46.5]	34.4±1.2 [30.5;37]	34.5±1.3 [30;38.5]	34.4±1.3 [30;39]	34.4±1.3 [24.5;46.5]	0.2201 (KW)
Risk of preterm birth (N = 1378)	39 (9.1%)	24 (9.1%)	23 (12.8%)	67 (13.2%)	153 (11.1%)	0.1302 (X²)
Medically assisted procreation (N = 1377)	26 (6.1%)	7 (2.7%)	4 (2.2%)	16 (3.2%)	53 (3.8%)	0.0342 (X²)
History of diabetes (N = 1377)	28 (6.6%)	13 (4.9%)	9 (5.0%)	19 (3.7%)	69 (5.0%)	0.2781 (X²)
Gestational diabetes (N = 1377)	45 (10.5%)	21 (8%)	9 (5%)	56 (11%)	131 (9.5%)	0.0774 (X²)
History of AHT (N = 1375)	23 (5.4%)	11 (4.2%)	6 (3.4%)	37 (7.3%)	77 (5.6%)	0.1354 (X²)
Gestational AHT (N = 1377)	33 (7.7%)	11 (4.2%)	7 (3.9%)	39 (7.7%)	90 (6.5%)	0.0878 (X²)
Tobacco consumption during pregnancy (N = 1377)	63 (14.7%)	43 (16.3%)	32 (17.9%)	82 (16.2%)	220 (16%)	0.9357 (X²)
Alcohol consumption during pregnancy (N = 1377)	20 (4.7%)	12 (4.5%)	5 (2.8%)	22 (4.3%)	59 (4.3%)	0.7586 (X²)
Employment (N = 1375)	333 (78%)	204 (77.3%)	142 (79.3%)	392 (77.6%)	1071 (77.9%)	0.9606 (X²)
Medical center (N=1378):						0.0028 (X²)
- Tertiary center (universitary hospital)	213 (49.8%)	130 (49.2%)	101 (56.4%)	287 (56.6%)	731 (53%)	
- Primary center 1	177 (41.4%)	126 (47.7%)	72 (40.2%)	194 (38.3%)	569 (41.3%)	
- Primary center 2	38 (8.9%)	8 (3.0%)	6 (3.4%)	26 (5.1%)	78 (5.7%)	

Table 2 : Characteristics of the population (n = 1,378), X² = Chi2 test, KW = Kruskal-Wallis non-parametric test

Presence of an AUDIPOG score ≤ 10th percentile	Univariate analysis		Multivariate* analysis	
	OR brut [IC95%]	**P-value**	**OR adj [IC95%]**	**P-value**
Phone time				
- 5 to < 15 min/d vs 0 to < 5min/d	0.93 [0.56 ; 1.54]		0.98 [0.58 ; 1.65]	0.9423
- 15 to < 30 min/d vs 0 to < 5 min/d	1.62 [0.98 ; 2.68]	0.0585	1.68 [0.99 ; 2.82]	0.0508
- ≥ 30 min/d vs 0 to < 5 min/d	1.48 [1.00 ; 2.19]		1.54 [1.03 ; 2.31]	0.0374
Tobacco consumption during pregnancy:				
- Giving up smoking vs. no consumption during pregnancy	0.77 [0.42 ; 1.4]	<.0001	0.82 [0.45 ; 1.52]	0.5387
- Continuing to smoke vs. no consumption during pregnancy	2.38 [1.64 ; 3.46]		2.40 [1.62 ; 3.56]	<.0001
Age of the mother:				
- 27 to < 30 yrs vs. < 27 yrs	1.60 [0.94 ; 2.71]		1.63 [0.94 ; 2.80]	0.0788
- 30 to < 33 yrs vs. < 27 yrs	1.88 [1.12 ; 3.15]	0.0945	1.90 [1.10 ; 3.28]	0.0206
- ≥ 33 yrs vs. < 27 yrs	1.77 [1.07 ; 2.91]		1.88 [1.10 ; 3.20]	0.0203
Gestational AHT:				
- Yes vs. no	2.11 [1.24 ; 3.56]	0.0055	1.93 [1.11 ; 3.37]	0.0201

*OR adj : Odds Ratios adjusted on the study level of the mother, kind of contract of the mother, tobacco use, alcohol use, age of the mother, gestational AHT, history of AHT, gestational diabetes, history of diabetes.

Table 3 : Univariate and multivariate analyses of the primary endpoint

Birthweight (g) : Mean ± SD (N) [Min ; Max]	**Univariate**	**P-value**	**Multivariate : No smoking women during pregnancy**	**P-value**	**Multivariate : women who stopped smoking during pregnancy**	**P-value**	**Multivariate : women who smoked during pregnancy**	**P-value**
<u>Phone time:</u>								
- 0 to < 5 min/d (Ref)	3305.2 ± 452.4 (N = 423) [1190 ; 4560]	0.0959	3329.0 ± 424.8 (N = 318) [2220.0 ; 4560.0]	-	3392.2 ± 507.2 (N = 44) [2440.0 ; 4450.0]	-	3118.5 ± 508.1 (N = 61) [1190.0 ; 4230.0]	-
- 5 to < 15 min/d	3259.8 ± 422.9 (N = 261) [1795 ; 4390]		3276.1 ± 407.1 (N = 190) [1795.0 ; 4390.0]	0.1271	3168.8 ± 480.7 (N = 28) [2360.0 ; 4100.0]	0.0185	3246.9 ± 453.7 (N = 43) [2180.0 ; 4140.0]	0.1456
- 15 to < 30 min/d	3257.3 ± 434.5 (N = 178) [2270 ; 4470]		3301.7 ± 463.8 (N = 125) [2270.0 ; 4470.0]	0.4348	3255.7 ± 323.2 (N = 22) [2495.0 ; 3840.0]	0.1715	3079.7 ± 333.1 (N = 31) [2450.0 ; 3950.0]	0.8820
- ≥ 30 min/d	3233.1 ± 427.3 (N = 496) [1860 ; 5230]		3258.3 ± 395.9 (N = 362) [2150.0 ; 5230.0]	0.0079	3384.4 ± 473.5 (N = 52) [1940.0 ; 4195.0]	0.7346	3025.6 ± 463.5 (N = 82) [1860.0 ; 4450.0]	0.2077

Table 4 : Univariate analysis of weight at birth for the various phone-time categories

Head circumference at birth (cm) Mean ± SD (N) [Min ; Max]	**Univariate**	**P-value**	**Multivariate : No smoking women during pregnancy**	**P-value**	**Multivariate : women who stopped smoking during pregnancy**	**P-value**	**Multivariate : women who smoked during pregnancy**	**P-value**
Phone time:								
- 0 to < 5 min/d (Ref)	34.5 ± 1.5 (N = 411) [24.5 ; 46.5]	0.3354	34.7 ± 1.4 (N = 310) [31.0 ; 46.5]	-	34.7 ± 1.4 (N = 42) [30.0 ; 37.5]	-	33.9 ± 1.9 (N = 59) [24.5 ; 38.0]	-
- 5 to < 15 min/d	34.4 ± 1.2 (N = 244) [30.5 ; 37.0]		34.5 ± 1.1 (N = 177) [30.5 ; 37.0]	0.0974	34.2 ± 1.1 (N = 27) [32.0 ; 36.0]	0.1677	34.4 ± 1.4 (N = 40) [31.0 ; 37.0]	0.0942
- 15 to < 30 min/d	34.4 ± 1.3 (N = 175) [30.0 ; 38.5]		34.4 ± 1.4 (N = 123) [30.0 ; 38.5]	0.0902	34.7 ± 1.1 (N = 22) [32.0 ; 37.0]	0.8835	34.4 ± 1.1 (N = 30) [32.0 ; 36.5]	0.0963
- ≥ 30 min/d	34.4 ± 1.2 (N = 485) [30.0 ; 39.0]		34.5 ± 1.1 (N = 353) [31.5 ; 39.0]	0.0849	34.8 ± 1.4 (N = 52) [30.0 ; 37.0]	0.6515	33.8 ± 1.3 (N = 80) [30.0 ; 37.0]	0.7257

Table 5 : Univariate analysis of head circumference at birth for the various phone-time categories