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Exposure to extremely low and intermediate-frequency magnetic and electric fields among children from the INMA-Gipuzkoa cohort

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ABSTRACT

Detailed assessment of exposure to extremely low frequency (ELF) and intermediate frequency (IF) fields is essential in order to conduct informative epidemiological studies of the health effects from exposure to these fields. There is limited information available regarding ELF electric fields and on both magnetic and electric field exposures of children in the IF range. The aim of this study was to characterize ELF and IF exposure of children in the Spanish INMA cohort. A combination of spot and fixed measurements was carried out in 104 homes, 26 schools and their playgrounds and 105 parks. Low levels of ELF magnetic fields (ELF-MF) were observed (with the highest 24-h time-weighted average (TWA) exposure being 0.15 μT in one home). The interquartile range (IQR) of ELF electric fields (ELF-EF) ranged from 1 to 15 V/m indoors and from 0.3 to 1.1 V/m outdoors and a maximum value observed was 55.5 V/m in one school playground. IQR ranges for IF magnetic and electric fields were between 0.02 and 0.23 μT and 0.2 and 0.5 V/m respectively and maximum values were 0.03 μT and 1.51 V/m in homes. Correlations between magnetic and electric fields were weak for ELF (Spearman 0.04–0.36 in different settings) and moderate for IF (between 0.28 and 0.75). Children of INMA-Gipuzkoa cohort were exposed to very low levels of ELF-MF in all settings and to similar levels of ELF-EF compared to the range of previously reported levels, although somewhat higher exposures occurred at home. Children enrolled to our study were similarly exposed to IF in all settings.

1. Introduction

Exposure to extremely low frequency (ELF) electromagnetic fields (EMFs) is ubiquitous in the general population. Since in 1979 Wertheimer and Leeper found a doubling of the risk of leukemia in children living near high current configurations, many researchers have made efforts to investigate this association (Greenland et al., 2000; Ahlbom et al., 2000). Due to the observed elevated risk of leukemia in children exposed to levels above 0.4 μT of ELF magnetic fields (ELF-MF), these EMFs were classified as possibly carcinogenic to humans by the International Agency for Research on Cancer (IARC) in 2002. Nevertheless, the association between exposure and other health effects remain unclear (Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 2015; World Health Organization, 2007).

Great efforts have been made to characterize magnetic fields, but there is less data available regarding exposure to ELF electric fields (ELF-EF). Regarding interaction with the human body, electric fields also charge the body surface. If they are strong enough they can induce electric currents inside the body and stimulate nerve and muscle cells (Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 2015), but this occurs only in the case of very high exposures above 5000 V/m (International Commission on Non-Ionizing Radiation Protection (ICNIRP), 1998). Electric fields are

Abbreviations: ELF, extremely low frequency; ELF-MF, extremely low frequency magnetic field; ELF-EF, extremely low frequency electric field; IF, intermediate frequency; IF-MF, intermediate frequency magnetic field; IF-EF, intermediate frequency electric field; EMF, electromagnetic field; INMA, Environment and childhood (from INfancia y Medio Ambiente) cohort; THD, total harmonic distortion; IARC, International Agency for Research on Cancer; RF, radiofrequency; WHO, World Health Organization; SCENIHR, Scientific Committee on Emerging and Newly Identified Health Risks; TWA, time-weighted average

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attenuated by most common building materials and objects whereas magnetic fields are able to penetrate such materials (Kheifets and Oksuzyan, 2008; Kheifets et al., 2010). Hence, electric fields from outdoor sources are weaker in indoor settings and exposure to ELF-EF inside buildings is mainly due to indoor sources such as electrical wiring and home appliances. Notably, electric fields are more complicated to measure and characterize, mainly due to their higher spatial variability and the fact that they are perturbed easily by any conducting material, which is possibly one of the reasons behind the scarcity of studies in this field.

The World Health Organization (WHO) categorizes electromagnetic fields of non-ionizing radiation (EMF-NIR) into three major groups apart from static fields (i.e., 0 Hz): ELF fields from > 0 to 300 Hz, intermediate frequency (IF) fields from 300 Hz to 10 MHz and radio-frequency (RF) fields from 10 MHz to 300 GHz (WHO, 2017). In the scientific literature, ELF is often used to refer to the frequencies ranging from > 0 Hz to 100 kHz, that is, partially overlapping with the aforementioned IF range. IF-emitting sources are not very common, although the number of electric devices using these frequencies has been on the rise over recent years and include, for example, induction hobs, liquid-crystal displays (LCDs), fluorescent lightning and some types of microwave ovens (Aerts et al., 2017). Some studies have described exposure levels from these sources and observed that, in close proximity, IF magnetic fields (IF-MF) may exceed reference levels (Christ et al., 2012; Alanko et al., 2011). Such high exposure levels are likely not representative of the average population or children's exposure levels. To the best of our knowledge, however, no studies have assessed IF exposure levels in general population settings under conditions of daily life (Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 2015). Comprehensive exposure assessments are essential both for acquiring knowledge on current levels of exposures and for conducting future epidemiological studies. For this reason, and given the lack of data, characterization of children's exposure to ELF-EF and to IF-MF and IF electric fields (IF-EF) was identified as a priority by the WHO (2005, 2007, 2010) and by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) (2015).

This study was conducted within the INMA-Gipuzkoa (*Infancia y Medio Ambiente*– Environment and childhood) birth cohort (www.proyectoinma.com) (Guxens et al., 2012). The aim of the study presented here was to characterize the exposure to ELF-MF, ELF-EF, IF-MF and IF-EF in the settings where the children tend to spend most of their time, i.e., in homes, schools and public open spaces, namely, parks and urban squares (hereon “parks”).

2. Methods

2.1. Study population

INMA-Gipuzkoa is part of the Spanish INMA birth cohort and is located in the Basque Country. The INMA cohorts have been described in detail elsewhere (Guxens et al., 2012).

In brief, the recruitment of mother-child pairs took place during the first antenatal visit (10–13 weeks of gestation) to the physician in the public referral hospital (Zumarraga hospital) between April 2006 and January 2008.

In total, 638 out of 993 mother-child pairs invited to participate met the inclusion criteria and were enrolled in the study. Over the period 2014–2016, when the children reached 8 years of age, cohort members were contacted; at that time, 397 children (62.2 %) participated in the study.

2.2. Study procedure

We performed ELF-MF, ELF-EF, IF-MF and IF-EF measurements in places where children tend to spend most of their time, specifically, in homes, schools and parks. Due to time constraints, home measurements were performed in the living room and child's bedroom of a subsample of 104 households. Participants for these measurements were selected primarily based on their availability, as nearly all cohort members contacted agreed to have measurements performed in their homes (386 of 397 contacted, 97.2%). Families who gave consent were randomly contacted when the children were 8 years ± 3 months to determine the date and time for the measurements. If the families were available (and not e.g. on holidays) and it was possible to arrange an appointment with the study assistant to make the measurements in their homes, they were carried out. All primary schools in the study area (n = 26) were included in our measurement survey, given that our children are distributed within those schools. In each school, in order to have an overall idea of the levels on the areas of the schools where our participants use to be, measurements were taken in two classrooms of INMA children as well as the main school playground. Classrooms with greater number of INMA students were selected in each grade (second and third year of primary school). All cohort members filled in a questionnaire that inquired, among other items, about the parks and other public spaces where the children spent most time. For that purpose, we provided them with a list of parks that they had mentioned during previous follow-ups and they were allowed to add other relevant parks to the list. From this full list of parks (125), 105 (84%), including those most frequently named by families, were selected for the measurements, since we assumed that these parks represented those where children were most likely to spend most of their time.

2.2.1. Measurement devices

We used two EHP-50D electric field and magnetic flux density isotropic probe analyzers for frequencies between 5 Hz and 100 kHz together with a NBM-550 Broadband Field Meter Basic Unit, all from Narda Safety Test Solutions (Germany). The three axes are measured simultaneously, resulting in true root-mean-square measurements, but magnetic flux density (further referred to as magnetic fields) and electric fields are measured in sequence. The device also offers the possibility of narrowband spectrum analysis, to allow the user to estimate the contribution from a selected frequency band to the total broadband measurement. The EHP-50D allows relatively long-term measurements, up to 24 h, in stand-alone mode and it also allows spot measurements when connected to the Basic Unit. The highest resolution of the probes was selected, i.e., 1 nT and 1 mV/m when measuring in stand-alone mode and 0.1 nT and 1 mV/m with the Basic Unit for the magnetic and electric fields respectively. The measurement range was from 0.3 nT to 100 μT and from 5 mV/m to 1 kV/m, for magnetic and electric fields for all measurements. Total expanded uncertainty of the probes has been described to be up to 8% for magnetic field and up to 15% for electric field (Aerts et al., 2017). The devices were calibrated by the manufacturer prior to the measurement survey. Post-survey calibration showed very little deviation in accuracy; up to 3% for the magnetic field and up to 7% for the electric field.

2.2.2. Measurement procedure

Measurements were made following the methodology detailed in a previous publication (Gallastegi et al., 2016). In brief, short-term spot magnetic and electric field measurements (32 consecutive readings) were carried out in homes, schools and parks. Spot measurements were made at the center and in the four corners of rooms (homes and school classrooms), at 1.10 m above the floor (considering the age and heights of the participants) and at 1.40 m (diagonally) from the corners, in order to capture variability of exposure across the room. Similar procedures have been previously suggested for ELF-MF fields (Hareuveny et al., 2011), as well as for RF-EMF fields (European Committee for Electrotechnical Standardization (CENELEC) European Standard EN 50492, 2008). Outdoor measurements were only taken in the center of the corresponding space (geographical center or center of the children's play area in the case of parks with playground equip-