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Personal exposure to radio-frequency electromagnetic fields in Europe: Is there a generation gap?

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ABSTRACT

Background: Exposure to radiofrequency electromagnetic fields (RF-EMF) from mobile communication technologies is changing rapidly. To characterize sources and associated variability, we studied the differences and correlations in exposure patterns between children aged 8 to 18 and their parents, over the course of the day, by age, by activity pattern, and for different metrics of exposure.

Methods: Using portable RF-EMF measurement devices, we collected simultaneous real-time personal measurements of RF-EMF over 24 to 72 h in 294 parent-child pairs from Denmark, the Netherlands, Slovenia, Switzerland, and Spain. The devices measured the power flux density (mW/m^2) in 16 different frequency bands every 4 s, and activity diary Apps kept by the participants were used to collect time-activity information in real-time. We analyzed their exposures by activity, for the different source constituents of exposure: downlink (radiation emitted from mobile phone base stations), uplink (transmission from phone to base station), broadcast, DECT (digital enhanced cordless telecommunications) and Wi-Fi. We looked at the correlations between parents and children overall, during day (06:00–22.00) and night (22:00–06:00) and while spending time at home.

Results: The mean of time-weighted average personal exposures was 0.16 mW/m^2 for children and 0.15 mW/m^2 for parents, on average predominantly originating from downlink sources (47% for children and 45% for parents), followed by uplink (18% and 27% respectively) and broadcast (25% and 19%). On average, exposure for downlink and uplink were highest during the day, and for Wi-Fi and DECT during the evening. Exposure during activities where most of the time is spent (home, school and work) was relatively low whereas exposure during travel and outside activities was higher. Exposure to uplink increased with age among young people, while DECT decreased slightly. Exposure to downlink, broadcast, and Wi-Fi showed no obvious trend with age. We found that

Abbreviations: RF-EMF, radio-frequency electromagnetic fields; DECT, digital enhanced cordless telecommunications; GSM, Global System for Mobile communications; ICNIRP, International Commission on Non-Ionizing Radiation Protection; UMTS, Universal Mobile Telecommunication System

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exposure to total RF-EMF is correlated among children and their parents ($R_{spearman}$ = 0.45), especially while at home (0.62) and during the night (0.60). Correlations were higher for environmental sources such as downlink (0.57) and broadcast (0.62) than for usage-related exposures such as uplink (0.29).

Conclusion: The generation gap between children and their parents is mostly evident in uplink exposure, due to more and longer uplink and cordless phone calls among parents, and their tendency to spend slightly more time in activities with higher environmental RF-EMF exposure, such as travel. Despite these differences in personal behavior, exposure to RF-EMF is moderately correlated between children and their parents, especially exposures resulting from environmental RF-EMF sources.

1. Introduction

On a global scale, the ownership of mobile phones has rapidly increased, with most adults and adolescents in Europe now owning a smartphone (International Telecommunication Union, 2017). Many people are concerned about exposure to radiofrequency electromagnetic fields (RF-EMF) from their environment and the possible implications for public health (Eurobarometer; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2013). Concern is especially targeted at children and adolescents, because of their rapid early-life adoption and increased use of mobile technologies (Kheifets et al., 2005). In addition, it has been suggested that children typically suffer higher exposures to their brain regions than adults (Christ et al., 2010). Possible effects on cognitive ability, cancer incidence, non-specific symptoms and other outcomes have been suggested and challenged (Baan et al., 2011; Group, 2010; Röösli and Hug, 2011; van Deventer et al., 2011).

The World Health Organization puts high priority on the characterization of real-life exposure to electromagnetic fields (EMF) and its determinants (van Deventer et al., 2011). Personal measurements using exposimeters are considered to be a feasible and accurate method to gain a comprehensive picture of the complex mixture of real-life RF-EMF exposure (Röösli et al., 2010). Neither questionnaires nor propagation modelling are able to quantify objectively the band-specific level of exposures resulting from both environmental sources (mobile phone base stations, Wi-Fi access points, broadcast towers) as well as personal use (e.g. use of mobile and cordless phones). Several personal exposure surveys have been carried out in recent years, mostly in Europe (Bolte and Eikelboom, 2012; Frei et al., 2009; Joseph et al., 2010; Röösli et al., 2016; Roser et al., 2017; Thomas et al., 2008a; Thomas et al., 2008b; Viel et al., 2009) but also in other parts of the world (Choi et al., 2018), showing that exposure levels generally comply with recommended standards, but that they differ greatly between different microenvironments and activity patterns. This stresses the importance of taking into account time-activity to derive representative exposure estimates for the population.

Conclusions from previous personal surveys about exposure patterns are quickly outdated because of rapidly evolving mobile technologies (GSM; Global System for Mobile communications, UMTS; Universal Mobile Telecommunications System, LTE; Long-Term Evolution) and functionalities (video streaming, gaming, WhatsApp). Contemporary children grew up surrounded by these new technologies, readily adopting new functionalities. Meanwhile, their parents have typically attempted to enhance traditional functionality such as phone calls and text messages, with typically slower adoption of new functionalities (Prensky, 2001). The combination of differences in time-activity patterns, age and early-age exposure to mobile technologies results in different user patterns of mobile technologies, and -hence- a different RF-EMF exposure pattern (Foerster and Röösli, 2017; Sudan et al., 2016). Besides personal use of mobile technologies, other personal measurement campaigns have found that environmental RF-EFM exposure varies with the level of urbanicity (Bolte and Eikelboom, 2012; Röösli et al., 2016; Thomas et al., 2008a; Thomas et al., 2008b; Viel et al., 2009), activity pattern or microenvironment (Bolte and Eikelboom, 2012; Frei et al., 2009; Joseph et al., 2010; Röösli et al., 2016; Roser et al., 2017; Sagar et al., 2017; Viel et al., 2009), time of day (Bolte and Eikelboom, 2012; Frei et al., 2009; Roser et al., 2017; Thomas et al., 2008b; Viel et al., 2009), between males/females (Röösli et al., 2016) and with age (group) of the study participants (Bolte and Eikelboom, 2012; Röösli et al., 2016; Thomas et al., 2008b; Viel et al., 2009). This has not previously been studied simultaneously in members of the same family.

As part of the GERoNiMO project (Generalized EMF Research using Novel Methods), we carried out a personal exposure survey among child-parent couples in five European countries (Switzerland, Slovenia, Spain, Denmark, and the Netherlands). We present some results by country, but emphasize that our main focus is on those exposure patterns which can be generalized to the whole sample. Exposure variability among children measured for the study in relation to personal characteristics and usage, was published separately (Birks et al., 2018). To better understand the determinants of the differences and similarities in exposure between children and their parents, this paper describes and compares the RF-EMF exposure levels and variability in children and their parents, in relation to their behavioral patterns and environments.

2. Methods

2.1. Study design

Exposure to RF-EMF was measured in five European countries: Switzerland, Slovenia, Spain, Denmark and the Netherlands. Dutch, Spanish and Danish children were recruited from the Amsterdam Born Children and Development study (ABCD) (Van Eijsden et al., 2010), the Sabadell branch of the Spanish Environment and Childhood project (INMA) (Guxens et al., 2011) and the Danish National Birth Cohort in Copenhagen (Olsen et al., 2001). Slovenian children were recruited from the general population in Ljubljana through public announcements and direct invitation. Half of the Swiss children were recruited from the Health Effects Related to Mobile phonE use in adolescentS (HERMES) cohort in central, rural Switzerland (Roser et al., 2017; Schoeni et al., 2016; Schoeni et al., 2015) and the other half from cohort from 10 communities within the canton of Zurich (Röösli et al., 2016). Each country targeted recruitment of 50 child-parent pairs (Appendix 1), who were asked to carry an exposimeter for at least 24 h, keep track of their activities over the same period and fill out a questionnaire on their use of mobile technologies. Sampling campaigns were conducted over six month periods in each region between September 2014 and February 2016. Participating regions used the same sampling protocols, equipment and procedures for calculating the exposure metrics. After each measuring campaign, the exposimeters were sent for calibration to ETH Zurich (Switzerland).

2.1.1. Exposure measurements

We used the ExpoM-RF personal radiofrequency exposimeter (Fields At Work, Zurich, Switzerland, http://www.fieldsatwork.ch/). The ExpoM-RF samples 16 different frequency bands in the range of FM radio (87.5–108 MHz) to ISM 5.8 GHz/U-NII 1-2e (5150–5875 MHz), allowing a detailed specification of the exposure from all major wireless communication and broadcasting services, see Appendix 2. In addition,