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Personal radiofrequency electromagnetic field exposure measurements in Swiss adolescents

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ABSTRACT

Background: Adolescents belong to the heaviest users of wireless communication devices, but little is known about their personal exposure to radiofrequency electromagnetic fields (RF-EMF).
Objectives: The aim of this paper is to describe personal RF-EMF exposure of Swiss adolescents and evaluate exposure relevant factors. Furthermore, personal measurements were used to estimate average contributions of various sources to the total absorbed RF-EMF dose of the brain and the whole body.
Methods: Personal exposure was measured using a portable RF-EMF measurement device (ExpoM-RF) measuring 13 frequency bands ranging from 470 to 3600 MHz. The participants carried the device for three consecutive days and kept a time-activity diary. In total, 90 adolescents aged 13 to 17 years participated in the study conducted between May 2013 and April 2014. In addition, personal measurement values were combined with dose calculations for the use of wireless communication devices to quantify the contribution of various RF-EMF sources to the daily RF-EMF dose of adolescents.
Results: Main contributors to the total personal RF-EMF measurements of 63.2 $\mu W/m^2$ (0.15 V/m) were exposures from mobile phones (67.2%) and from mobile phone base stations (19.8%). WLAN at school and at home had little impact on the personal measurements (WLAN accounted for 3.5% of total personal measurements). According to the dose calculations, exposure from environmental sources (broadcast transmitters, mobile phone base stations, cordless phone base stations, WLAN access points, and mobile phones in the surroundings) contributed on average 6.0% to the brain dose and 9.0% to the whole-body dose.
Conclusions: RF-EMF exposure of adolescents is dominated by their own mobile phone use. Environmental sources such as mobile phone base stations play a minor role.

1. Introduction

Mobile phones and other wireless communication devices emitting radiofrequency electromagnetic fields (RF-EMF) are nowadays omnipresent and undergo a rapid development. In 2014, there were almost 7 billion mobile phone subscriptions worldwide, corresponding to 96% of the population (ICT, 2015). In Switzerland, the number of mobile phone subscriptions reached 11.5 million in 2014, what corresponded to 141% of the population (ICT, 2015). The proportion of the world population covered by a 2G mobile phone network grew from 58% in 2001 to 95% in 2015 and mobile internet access increased 12 times since 2007 reaching 47% of the population in 2015 (ICT, 2015). Along that line, the ownership and use of wireless communication devices is growing. A recent representative survey in 1086 adolescents aged between 12 and 19 years in Switzerland revealed that 98% of the adolescents owned a mobile phone, 76% a computer or laptop, and 29% a tablet (Willemse et al., 2014). This development leads to ubiquitous exposure to RF-EMF in our everyday environment, but little is known about the extent of personal exposure to RF-EMF, in particular in adolescents. As a result, the current World Health Organization (WHO) research agenda for radiofrequency fields rates the quantification of personal exposures high priority (WHO, 2010).

Adolescents spend most of their time at home and in school. Spot measurements of environmental RF-EMF in different European countries showed that exposure at home was mainly caused by mobile phone base stations and cordless phone (Digital Enhanced Cordless Telecommunications (DECT)) base stations (Breckenkamp et al., 2012; Tomitsch and Dechant, 2015; Tomitsch et al., 2010; Verloock et al.,

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2014a; Verloock et al., 2014b; Vermeeren et al., 2013) or WLAN (Wireless Local Area Network) access points (Breckenkamp et al., 2012). Main contributors to the environmental exposure in schools in Belgium and Greece were mobile phone base stations, radio broadcast transmitters and WLAN access points (Verloock et al., 2014a; Verloock et al., 2014b; Vermeeren et al., 2013).

Data from spot measurements are useful to estimate exposure to RF-EMF in our everyday environments, but personal exposure to RF-EMF depends not only on exposure levels in different environments, but also on individual behaviours such as the use of wireless communication devices and time spent in various environments (Röösli et al., 2010). Personal measurements are measurement campaigns where volunteers carry a portable measurement device during their everyday life activities. Such measurements enable to measure at times and places representative of real-life situations.

Personal measurements in Europe were mainly conducted in adults (Bolte and Eikelboom, 2012; Frei et al., 2009; Thomas et al., 2008a; Thuróczy et al., 2008; Valic et al., 2009; Viel et al., 2009); measurements in children and adolescents are scarce. Researchers in Hungary conducted in 2009 personal measurements in 31 school teachers as a proxy for children's exposure (Juhasz et al., 2011). In Slovenia, measurements in 18 children and adolescents (5–17 years) were performed in 2010/2011 (Valic et al., 2015), and in Germany, measurements in 1524 adolescents (13–17 years) were conducted in 2006/2007 (Thomas et al., 2008b). However, since then smartphones have been introduced and the use of wireless communication devices in this age group has changed tremendously. Measurements in Austria and Switzerland indicate that RF-EMF exposure in residential areas may have increased over the last few years (Tomitsch and Dechant, 2015; Urbinello et al., 2014).

Exposure to RF-EMF can be divided into two different types, the exposure from environmental sources such as broadcast transmitters, mobile phone base stations, cordless phone base stations, WLAN access points, and mobile phones in the surroundings (far-field), and the exposure from the use of wireless communication devices such as mobile phones, cordless phones and computers, laptops and tablets connected to WLAN (near-field). It is known that personal measurements may not adequately record the latter part of exposure, because measured values depend highly on the distance between the emitting source and the measurement device, which is not necessarily the same as the distance between the emitting source and the body (Bolte, 2016; Inyang et al., 2008; Röösli et al., 2010). Thus, to obtain a comprehensive overview on the personal RF-EMF exposure, personal measurements need to be combined with dosimetric approaches that quantify absorbed RF-EMF by the body.

The aim of this paper is to describe the personal RF-EMF exposure of Swiss adolescents in daily life and evaluate factors affecting personal exposure. Further, it is aimed to use personal measurements to estimate average contributions from far-field and near-field sources to the total absorbed RF-EMF dose by using a recently developed RF-EMF dose modelling approach (Roser et al., 2015a).

2. Methods

2.1. HERMES study

The HERMES (Health Effects Related to Mobile phonE use in adolescentS) study, a cohort study conducted in Central Switzerland, aims to prospectively investigate whether the exposure to RF-EMF emitted by mobile phones and other wireless communication devices causes behavioural problems and non-specific health disturbances or affects cognitive function in adolescents (Roser et al., 2015b; Roser et al., 2016; Schoeni et al., 2016; Schoeni et al., 2015a; Schoeni et al., 2015b). The baseline investigation took place between June 2012 and March 2013; the follow-up investigation was conducted approximately one year later. The study participants filled in a paper and pencil questionnaire at school during school time supervised by two study managers. Participants could indicate whether they were willing to participate in the measurement study. Furthermore, paper and pencil questionnaires for the parents were distributed and they were asked to send these back directly to the study managers.

2.2. Personal measurements

Personal measurements were conducted in a subgroup of the HERMES study participants. The participants of the personal measurements were selected so that they represented a broad range of the HERMES cohort according to basic criteria such as age, gender, school level, and urbanization of home and school place. Data collection took place between May 2013 and April 2014. The instructions for the personal measurements were given at school. The participants were instructed to carry the portable measurement device, a so-called exposimeter, for three consecutive days. They were asked to carry the exposimeter in a padded hip bag if they were moving and to place it in their vicinity, but not directly on the body, when not moving. During the night, they were instructed to charge the exposimeter and place it on their bedside table or close to their bed but not directly on the floor.

Two versions of the ExpoM-RF exposimeter (the current version and a not commercialized prototype) were used to measure 12 frequency bands ranging from DVB-T (Digital Video Broadcasting – Terrestrial, centre frequency of 620 MHz) to ISM 2.4 GHz (Industrial, Scientific and Medical 2.4 GHz, 2450 MHz) (Fields at Work, 2015; Lauer et al., 2011) with a measurement range of frequency specific lower reporting limits up to 5 V/m (upper reporting limit; Table 1). The sum of them is referred to as total personal RF-EMF measurements (Table 1). The devices have the size of $16 \times 8 \times 3$–5 cm and a weight of 300 g.

A sampling interval of 4 s was used. The devices were calibrated before the start of the measurements in January 2013, again in January 2014, and after the measurements in February 2015. Additionally, the participants kept a time-activity diary installed as an application on a smartphone provided by the study managers. The smartphone was operating in flight-mode to prevent influencing the measurements. The diary contained predefined locations categorized into home, school, outdoors, train, bus, car, and various locations. During the measurement period, GPS coordinates were recorded by the diary smartphone. At the end of the measurement period, they filled in a short questionnaire on exposure relevant factors such as WLAN at home, ownership of mobile phone subscription or prepaid mobile phone, and their mobile phone use during the measurement period (Table 2). Missing values in this questionnaire were imputed using answers to the same questions in the baseline or follow-up HERMES questionnaire whichever was temporally closer. The information about WLAN at school was obtained from the teacher or the head of the school during the school visit.

Ethical approval for the conduct of the study was received from the ethical committee of Lucerne, Switzerland on May 9, 2012.

2.3. Data cleaning

The personal measurement data were occasionally disrupted because of technical failures or because participants forgot to charge the device during night. We considered only those measurements which lasted at least 23 h and which had corresponding diary entries available for analysis. Diaries were manually cleaned for implausible chronologies of diary entries (e.g. being at school followed by being at home without a period of outdoor, public transport or car in-between) using the smartphone-recorded GPS coordinates and visualisation of the paths and the measurements corresponding to the diary entries.

2.4. Data analysis

2.4.1. Calculation of mean values

The calculations were performed in power flux density unit (μW/m^2). According to the sensitivity range specified by the manufacturer,