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Outdoor and indoor sources of residential radiofrequency electromagnetic fields, personal cell phone and cordless phone use, and cognitive function in 5–6 years old children

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ABSTRACT

Background: Little is known about the exposure of young children to radiofrequency electromagnetic fields (RF-EMF) and potentially associated health effects. We assessed the relationship between residential RF-EMF exposure from mobile phone base stations, residential presence of indoor sources, personal cell phone and cordless phone use, and children's cognitive function at 5–6 years of age.
Methods: Cross-sectional study on children aged 5–6 years from the Amsterdam Born Children and their Development (ABCD) study, the Netherlands (n=2354). Residential RF-EMF exposure from mobile phone base stations was estimated with a 3D geospatial radio wave propagation model. Residential presence of indoor sources (cordless phone base stations and Wi-Fi) and children's cell phone and cordless phone use was reported by the mother. Speed of information processing, inhibitory control, cognitive flexibility, and visuomotor coordination was assessed using the Amsterdam Neuropsychological Tasks.
Results: Residential presence of RF-EMF indoor sources was associated with an improved speed of information processing. Higher residential RF-EMF exposure from mobile phone base stations and presence of indoor sources was associated with an improved inhibitory control and cognitive flexibility whereas we observed a reduced inhibitory control and cognitive flexibility with higher personal cordless phone use. Higher residential RF-EMF exposure from mobile phone base stations was associated with a reduced visuomotor coordination whereas we observed an improved visuomotor coordination with residential presence of RF-EMF indoor sources and higher personal cell phone use.
Conclusions: We found inconsistent associations between different sources of RF-EMF exposure and cognitive function in children aged 5–6 years.

Abbreviations: ABCD, Amsterdam Born Children and their Development; DASS, Depression Anxiety Stress Scale; LTE, Long Term Evolution technology; NOSI, Nijmeegse Ouderlijke Stress Index; RF-EMF, radiofrequency electromagnetic fields; Wi-Fi, Wireless Fidelity

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1. Introduction

Radiofrequency electromagnetic fields (RF-EMF) have developed into a nearly ubiquitous environmental exposure. RF-EMF exposure sources include mainly cell phone and cordless phone use, outdoor sources (i.e. mobile phone base stations and broadcasting stations), and indoor sources (i.e. cordless phone base stations and Wireless Fidelity (Wi-Fi) access points). Each exposure source leads to different patterns and levels of exposure: whereas personal cell phone and cordless phone use lead to localised exposures at the head of usually short duration, outdoor and indoor sources result in more homogeneous whole-body and longer duration exposure of considerably lower RF-EMF levels (Health Protection Agency, 2012).

Observational studies using self-reported data on cell phone use (Abramson et al., 2009; Redmayne et al., 2016; Thomas et al., 2010), cordless phone use (Redmayne et al., 2016), measured residential RF-EMF levels from mobile phone base stations (Hutter et al., 2006), or measured total spectrum RF-EMF levels in the immediate surrounds of the participant's house (Calvente et al., 2016) showed associations with certain cognitive function tests in adults and adolescents or children of 8–15 years old although results were inconsistent between studies. No previous observational studies have evaluated the association between several RF-EMF exposure sources and cognitive function in younger children. It has been suggested that children may be more vulnerable to different environmental exposures because of their developing nervous system (Rice and Barone, 2000). Due to the ubiquity of the RF-EMF exposure, even if low risks associate with RF-EMF they may translate into large public health implications.

Therefore, the aim of the present study was to assess the association between residential RF-EMF exposure from mobile phone base stations, residential presence or absence of indoor sources of RF-EMF, cell phone use, and cordless phone use, and children's cognitive function at 5–6 years of age in a large population-based cohort study.

2. Material and methods

This study was embedded in the Amsterdam Born Children and their Development (ABCD) Study (www.abcd-study.nl), a community-based prospective cohort study that examines the relationship of maternal lifestyle and psychosocial determinants during pregnancy, to multiple aspects of development and health of the child (van Eijsden et al., 2011). Between January 2003 and March 2004, 8266 pregnant women were enrolled during their first prenatal visit to an obstetric care provider. Their children were followed from birth. Children's cognitive function was assessed at 5–6 years old. When children were 7 years old a questionnaire (postal or via web) was administered to the mothers including retrospective information on RF-EMF exposure sources pertaining to the time point of the cognitive function tests. A total of 2354 children with available data on exposure and outcome variables were included (Supplementary Fig. A.1). Approval of the study was obtained from the Central Committee on Research involving Human Subjects in the Netherlands, the Medical Ethical Committees of the participating hospitals, and the Registration Committee of the Municipality of Amsterdam. The study was conducted in accordance with The Code Ethics of the World Medical Association (Declaration of Helsinki).

2.1. Residential RF-EMF exposure from mobile phone base stations

Residential RF-EMF exposure from mobile phone base stations was estimated using the 3D geospatial radio wave propagation model NISMap (Bürgi et al., 2010; Beekhuizen et al., 2013, 2014; Huss et al., 2015). In brief, NISMap computes the field strengths of mobile phone base stations for any location in 3D-space using detailed characteristics of the antennas (location, service and frequency, direction, output power, height of each antenna) and the 3D geometry of the urban environment. The 3D geometry consisted of a box model of all buildings in the Netherlands, retrieved by combining building data of the Netherlands' Mapping Agency (Kadaster) and the Netherlands' elevation model (Actueel Hoogtebestand Nederland, AHN2) from 2013. NISMap uses the box model to estimate shielding and diffraction by buildings. Since we were interested in mobile phone base station radiation, we assessed the downlink component of the three mobile phone communication bands (GSM900, GSM1800, and UMTS), using a country-wide mobile phone base station data set from 2011. At the time of the study, Long Term Evolution technology (LTE, also called 4G) was not yet implemented in the Netherlands. Home addresses where children were living at the time of the cognitive function tests were geo-coded using Dutch cadastral data. As the intensity of RF-EMF differs with height, we estimated height above ground of the room in which children spent most of their time, i.e. their bedroom. We collected information on the floor level of their bedroom and the total number of floors using questionnaires administered to the mothers and obtained the height of the building from our 3D-building data. We computed the height above ground with the following formula: Height=(BuildingHeight in m/TotalNrFloors)*BedroomFloor+1.5 m. Using NISMap and the retrieved x,y,z coordinates, we computed the RF-EMF exposure from mobile phone base stations at each home location. NISMap has been validated with outside, inside, and personal measurements and has been shown to make reliable rank-order predictions of downlink exposure (Beekhuizen et al., 2014, 2013; Martens et al., 2015). Continuous RF-EMF exposure levels were categorized as low ($<$50th percentile), medium (50–90th percentile), and high exposure ($>$90th percentile). For a subset of 478 children, we performed measurements of RF-EMF fields in the classroom where they were studying at the time point of the cognitive function tests. These measurements have been described elsewhere (Beekhuizen et al., 2014). Of the 201 classrooms where we did measurements, 6 had both a cordless phone base station and a Wi-Fi router inside or within 5 m of the classroom, 15 had only a cordless phone base stations, and 11 only a Wi-Fi router inside or within 5 m of the classroom. Reliable information on presence or absence of cordless phone base station and Wi-Fi routers was unavailable for 35 classrooms. For another subset of 349 children we had exact location information (x, y, z coordinates) on where their classroom was situated within the building. For these children we could additionally model the exposure at the classroom using NISMap. We used the best available measure of RF-EMF exposure from mobile phone base stations at the classroom that we had for the children, meaning measured exposure when we had measurements and modelled exposure for the remaining subgroup. We first accounted for the slight overestimation of our modelled (at home and at school) compared to the measured exposure (factor 1.29) (Beekhuizen et al., 2014). We then combined residential exposure by weighing it 6/7th and classroom exposure by 1/7th. This corresponds to roughly 24 h children of that age spend at school per week in the Netherlands. Combined residential and classroom RF-EMF exposure levels were categorized as low, medium, and high exposure, using the cut-off points ($<$50th, 50t–90th, and $>$90th percentile) of the residential RF-EMF exposure in order to be comparable.

2.2. Residential presence or absence of indoor sources of RF-EMF

Presence or absence of the main residential RF-EMF indoor sources (i.e. cordless phone base stations and Wi-Fi) at the time