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Mobile phone base stations and well-being — A meta-analysis

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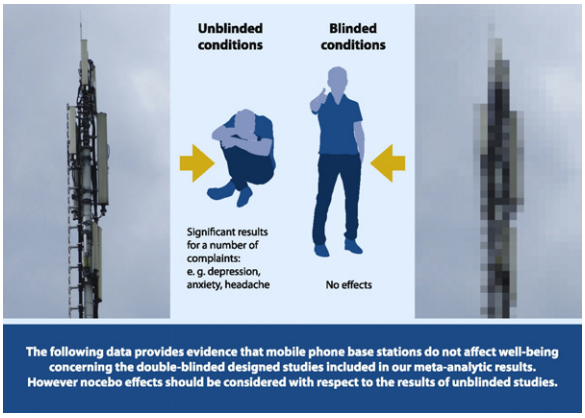
HIGHLIGHTS

- Our meta-analytic results provide evidence that mobile phone base stations do not affect human well-being.
- When concerning unblinded studies nocebo effects should be considered.

GRAPHICAL ABSTRACT



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ABSTRACT

It is unclear whether electromagnetic fields emitted by mobile phone base stations affect well-being in adults. The existing studies on this topic are highly inconsistent. In the current paper we attempt to clarify this question by carrying out a meta-analysis which is based on the results of 17 studies. Double-blind studies found no effects on human well-being. By contrast, field or unblinded studies clearly showed that there were indeed effects. This provides evidence that at least some effects are based on a nocebo effect. Whether there is an influence of electromagnetic fields emitted by mobile phone base stations thus depends on a person's knowledge about the presence of the presumed cause. Taken together, the results of the meta-analysis show that the effects of mobile phone base stations seem to be rather unlikely. However, nocebo effects occur.

1. Introduction

In view of the increasing use of mobile phones, potential impacts of electromagnetic fields emitted by base stations are of great public interest (Augner et al., 2012). The single base stations support a cellular

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system, keep track of the mobile phones within a cell, provide the connection and handle the carry-over to the next one, if a user moves from one cell to another (Kundi and Hutter, 2009). Due to the increasing numbers of providers, the number of base stations keeps growing (Khurana et al., 2010; Kundi and Hutter, 2009).

Effects on a wide range of health parameters such as cognitive functions, well-being, sleep and even cancer have been discussed over the last decade (Kundi and Hutter, 2009; Röösli et al., 2010). However, the findings have been ambiguous and inconsistent. There are different endpoints, study designs and target populations that can be studied which have different intrinsic difficulties and problems. Concerning endpoints, (chronic) diseases, physiological indicators, well-being, and performance indicators can be differentiated. Acute effects of base station signals can be studied experimentally in the lab or in the field, and also observational studies can be carried out applying different methodologies such as exposure estimation, spot measurements, or personal dosimetry. The study of chronic effects affords an epidemiological design with cross-sectional, case–control, or cohort studies as the most frequent types. There are a number of crucial problems for investigating the effects of base station signals (Hutter et al., 2006; Neubauer et al., 2007). The first problem concerns the proper definition of the independent variable: exposure to base station signals is defined by three aspects — (average) intensity, duration, and pattern (time course) of exposure. There is an infinite number of possibilities to map these three aspects into a (feasibly small) set of exposure indicators. While field studies contain the risk of missing crucially important exposure characteristics, experimental studies face the problem of deciding about the appropriate manipulation of these characteristics, since experimental conditions must be restricted to but a few. Another problem concerns appropriate outcome assessment. In experimental trials including people suffering from "idiopathic environmental intolerance with attribution to electromagnetic fields (IEI-EMF)", the lab conditions might cause too much arousal to observe any additional effect of base station signals on subjective well-being, physiological or performance indicators. The limitations of sensitivity of the outcome assessment are not restricted to experimental investigations, but also extend to field studies. In general, test procedures designed for discriminating in the pathological range are not suitable for the study of the general population living near base stations. A further problem is the selection of the appropriate study population. It has to be borne in mind that although base stations are ubiquitous, actual exposure intensity is very low and rarely exceeds a few tenths of a microwatt per meter squared. Therefore, a random selection from the general population carries the risk of finding too few persons or virtually no-one who can be considered exposed. Another issue, especially if subjective symptoms are targeted, is concerns about adverse effects by study participants, as these could distort and bias outcome assessment. Appropriate control for such concerns is therefore an important design aspect. While these and other difficulties must not be neglected, there is no reason to consider studies of base stations unfeasible.

At first sight, the results of the various studies about the effects of EMF may seem inconsistent, providing strikingly significant results as well completely inconspicuous ones. However, a more detailed inspection tells that this variation closely follows the variation in approach and design of the different studies, and in the different criteria on which the evaluation was based.

Field studies tend to report significant effects regarding the distance to EMF in real life regarding some aspects of well-being, but not for all of them. On the other hand, actual exposure measurements are less successful in predicting symptoms: In a cross-sectional study, Hutter et al. (2006) found increased risks for headache, vegetative symptoms, and concentrations difficulties, but no significant effects on sleep quality were detected, at least if concerns about negative health effects of the base station were controlled for. In contrast, Blettner et al. (2009) found a significant relationship between distance to the nearest base station (less than or more than 500 m) and subjective symptoms *even after* correcting for concerns about effects of base stations. However, in a subgroup of this sample with actual measurements, Berg-Beckhoff et al. (2009) found no difference in symptoms when comparing extreme groups regarding exposure, but actual exposure was very low even for the high-exposure group. Abdel-Rassoul et al. (2007) diagnosed inhabitants living near mobile phone base stations to be at risk of developing neuropsychiatric problems and changes in performance during neurobehavioral tests. Studies from Germany applying personal dosimetry revealed various results as well: while Heinrich et al. (2007) found some symptoms significantly related to exposure and Thomas et al. (2010) observed a significant increase in conduct problems in children and adolescents, no significant effects were reported by Thomas et al. (2008) concerning acute and Heinrich et al. (2007) concerning chronic symptoms in adults. Bortkiewicz et al. (2012) found an increased prevalence of headaches at a distance of 101–150 m from the base station where the highest levels of exposure can be expected (Viel et al., 2010), but no association with actual measurements which were, again, flawed by participant's low exposure. In a series of investigations by the Qualifex team, Basel, Switzerland, combining a cross-sectional and follow-up design, Mohler et al. (2010, 2012), Röösli et al. (2010); Röösli and Hug (2011) and Frei et al. (2012) found no indications of strong relationships between exposure to stationary sources of EMF and various health-relevant endpoints. However, exposure levels in the highest exposure groups were still extremely low because of the random sampling of participants (only 10% were exposed above a level of 0.05 mW/m^2).

In stark contrast, in blinded experiments – where people could not know about the exposure condition they are in – well-being measures seem rather unaffected by EMF exposure: Regel et al. (2006) could not confirm a short-term effect of base station-like exposure on well-being that was observed in an earlier study by Zwamborn et al. (2003) (whereby the findings of the Zwamborn study are no longer significant when corrected for multiple testing). The study carried out by Riddervold et al. (2008) observed an increase in the 'headache rating' when data from adolescents and adults were combined. In a laboratory experiment in women with and without self-reported symptoms when using a mobile phone, Furubayashi et al. (2009) found no evidence of any difference in symptoms during exposure to EMF from base station signals between these groups. In a field-intervention study, Danker-Hopfe et al. (2010) did not detect any short-term effects of EMF on objective and subjective sleep quality. Wallace et al. (2010, 2012) investigated a TETRA (terrestrial trunked radio) base station in a semianechoic chamber and subjects with and without self-reported hypersensitivity to EMF, but no significant difference in physiological responses was reported between both groups and between sham and actual exposure. Eltiti et al. (2007, 2009) found that short-term exposure to an experimental base station signal did not affect physiological functions in sensitive or control individuals. However, in particular sensitive individuals had reduced well-being under an open-provocation condition in Eltiti et al. (2007) and Wallace et al. (2010), which means under a condition where they explicitly knew whether they were exposed or not.

Because of the inconsistency regarding the study designs, actually leading to inconsistency of the results, the following systematic meta-analysis will have to split between different types of studies: blinded experimental studies, unblinded (open provocation) experiments, and field studies.

2. Materials and methods

We used PubMed for our literature search by focusing on articles published in English until July 2014. The search procedure consists of the following steps:

First we used the following phrases: "mobile phone base station", "cellular phone base station", "cell tower". In the second step we excluded all studies on animals and children. Third, we focused on papers dealing with measures or symptoms (e.g. headaches, dizziness, fatigue)