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Review

Effect of mobile telephones on sperm quality: A systematic review and meta-analysis ☆

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ABSTRACT

Mobile phones are owned by most of the adult population worldwide. Radio-frequency electromagnetic radiation (RF-EMR) from these devices could potentially affect sperm development and function. Around 14% of couples in high- and middle-income countries have difficulty conceiving, and there are unexplained declines in semen quality reported in several countries. Given the ubiquity of mobile phone use, the potential role of this environmental exposure needs to be clarified. A systematic review was therefore conducted, followed by meta-analysis using random effects models, to determine whether exposure to RF-EMR emitted from mobile phones affects human sperm quality. Participants were from fertility clinic and research centres. The sperm quality outcome measures were motility, viability and concentration, which are the parameters most frequently used in clinical settings to assess fertility.

We used ten studies in the meta-analysis, including 1492 samples. Exposure to mobile phones was associated with reduced sperm motility (mean difference −8.1% (95% CI −13.1, −3.2)) and viability (mean difference −9.1% (95% CI −18.4, 0.2)), but the effects on concentration were more equivocal. The results were consistent across experimental *in vitro* and observational *in vivo* studies. We conclude that pooled results from *in vitro* and *in vivo* studies suggest that mobile phone exposure negatively affects sperm quality. Further study is required to determine the full clinical implications for both sub-fertile men and the general population.

Contents

Abbreviations: CI, confidence interval; RF-EMR, radiofrequency electromagnetic radiation, SAR, specific absorption rate; EEG, electroencephalography; ROS, reactive oxygen species; FEM, fixed effect model; REM, random effects model.

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1. Introduction

Most men of reproductive age in high- or middle-income countries now own mobile (cell) telephones. Accompanying this increase in mobile phone ownership, there is concern over the potential effects of mobile phone exposure on human health. Mobile phones emit electromagnetic radiation (EMR), a low-level radiofrequency (RF), at a frequency of between 800 and 2200 MHz (Agarwal et al., 2011), that can be absorbed by the human body. Mobile phones are legally limited to a specific absorption rate (SAR) of 2.0 W/kg (ICNIRP, 1998), and currently, most have a SAR of ~1.4 W/kg (Agarwal et al., 2011). At this low frequency EMR is unlikely to ionise atoms or molecules (Erogul et al., 2006). However, there is some evidence of potential adverse effects including headaches (Oftedal et al., 2000), increased resting blood pressure (Braune et al., 1998), and disturbances to electroencephalographic (EEG) activity during sleep (Huber et al., 2000). It has also been suggested that mobile phones, and other electromagnetic devices that emit RF-EMR radiation, are detrimental to human fertility (La Vignera et al., 2012).

Around 14% of couples in industrialized countries experience difficulty with conception at some point in their lives (Wilkes et al., 2009). Male factor infertility is involved approximately 40% of the time (Fleming et al., 1995), and a high proportion of cases are unexplained. The oscillating current and transfer of energy generated by the RF electric field can result in rapid heating (Challis, 2005), which could influence sperm quality. There are also non-thermal interactions, including changes to protein conformations and binding properties, and an increase in the production of reactive oxygen species (ROS) that may lead to DNA damage (Challis, 2005; La Vignera et al., 2012). Animal studies have suggested that RF-EMR can affect the cell cycle of sperm (Kesari and Behari, 2010), increase sperm cell death (Yan et al., 2007) and produce histological changes in the testes (Dasdag et al., 1999).

Mobile phone exposure has been linked in some animal studies to a reduction in sperm count (Kesari et al., 2010) and motility (Mailankot et al., 2009), suggesting an impairment of male fertility, although these effects are not consistently reported (Dasdag et al., 2003). In humans, the prolonged use of mobile phones has been associated with decreased motility, sperm concentration, morphology and viability (Agarwal et al., 2008), suggesting a likely impact on fertility. However, the evidence is mixed. Some studies have found an effect on sperm motility but not on sperm concentration (Erogul et al., 2006; Fejes et al., 2005), whilst no effect on sperm quality has also been found (Feijo et al., 2011). We therefore conducted a systematic review and aggregated the available published data on the effect of mobile phone exposure on sperm quality using meta-analysis. The aim was to summarise the evidence on RF-EMR exposure from mobile phones and male fertility indices.

2. Methods

2.1. Search strategy

We conducted a systematic search using Web of Knowledge and MEDLINE to identify all relevant studies published from 2000 to 2012. The MESH search terms used were '*phone*' OR 'electromagnetic' AND 'semen' or 'sperm*' OR '*fertil*'. We limited the search to studies using human subjects and those that reported information on basic semen parameters including motility, viability and concentration. Hand searches were carried out of review articles and reference lists. Authors of unpublished or incomplete datasets were contacted to request that they provide information for this meta-analysis. Insufficient information meant that some studies were excluded (Gutschi et al., 2011; Van-Gheem et al., 2011; Wdowiak et al., 2007). Articles were only included if they were written in English, reported on human participants, did not use workplace RF-EMR exposure and were not review articles. We incorporated both *in vitro* and *in vivo* studies, provided they met with our inclusion criteria (max SAR 2.0 W/kg, frequency 800–2200 MHz, based on previous literature Agarwal et al., 2011). We adhered to PRISMA guidelines and provide the PRISMA checklist in the supporting information. Studies were analysed for inclusion independently by two of the authors, any discrepancies were resolved by discussion. Sixty articles were identified from the title. This was reduced to twenty-three potentially suitable articles using the abstract, largely due to the presence of animal and non-mobile phone related EMR exposure studies. From these, ten studies fulfilled all criteria and were included in the meta-analyses (Table 1).

We specified the primary outcome measures *a priori* as sperm motility (mean %); viability (mean %); and concentration ($\times 10^6$/ml). In clinical settings, these parameters are some of the most frequent measures used for investigations of male fertility. Some of the studies provided data on all three of these outcome measures, and others on just some of them. The following characteristics were assessed for each study: (a) Study design (*in vitro versus in vivo*), (b) data collection methods (*e.g.* semen analysis according to WHO guidelines), and (c) sample size.

2.2. Analysis

Statistical analysis was undertaken using *R* (i386 2.15.1) (RCoreTeam, 2012) with the package 'Meta' (Schwarzer, 2012). Both fixed effects models (FEM) and random effects models (REM) were fitted, to permit

Table 1
Study characteristics from mobile phone exposure and sperm quality meta-analyses. (– denotes information not provided).

Sperm parameters										
Reference	Sample size	Study design	Participant group	Motility	Viability	Concentration	Radio-frequency (MHz)	SAR (W/kg)	Exposure time	Comments
Agarwal et al. (2008)	361	*In vivo*	Fertility clinic	✓	✓	✓	–	–	–	Exposed to commercially available mobile phones
Agarwal et al. (2009)	64	*In vitro*	Fertility clinic	✓	✓	✓	850	1.46	60 min	Exposed to Sony Ericsson w300i
Ahmed and Baig (2011)	44	*In vitro*	Population	✓			900	1.3	60 min	Exposed to Nokia 112 in talk mode
Dkhil et al. (2011)	40	*In vitro*	Population		✓		850	1.46	60 min	Nokia 73 in talk mode
De Iuliis et al. (2009)	8	*In vitro*	Population	✓	✓		1800	1	16 h	Exposed using a waveguide, connected to a function generator and RF amplifier.
Erogul et al. (2006)	54	*In vitro*	Population	✓		✓	900	–	5 min	Exposed to commercially available mobile phones
Falzone et al. (2008)	24	*In vitro*	Population	✓			900	2	60 min	RF-EMR chamber
Feijo et al. (2011)	343	*In vivo*	Fertility clinic	✓	✓	✓	–	–	–	Exposed to commercially available mobile phones
Fejes et al. (2005)	254	*In vivo*	Fertility clinic	✓		✓	–	–	–	Exposed to commercially available mobile phones
Sajeda and Al-Watter (2011)	300	*In vivo*	Fertility Clinic	✓		✓	–	–	–	Exposed to commercially available mobile