

Wireless Technology and Health Outcomes: Evidence and Review

Are there human health effects related to the use of wireless internet technology (Wi-Fi)?

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Background

Wireless internet technology (also known by its trademark name Wi-Fi) initially was conceived in the mid 1980s but only came into widespread use in the mid-2000s, most notably as part of municipal free-internet projects¹ (e.g. Toronto Hydro OneZone².) Today, wireless internet is ubiquitous in homes, hotels, airports, and public institutions such as schools, libraries and long-term care homes.

Although Wi-Fi is a relatively new communication technology, use of the radiofrequency (RF) band for communications and other applications is not new and widespread public exposure to these frequencies has occurred for decades. In addition to Wi-Fi, numerous other technologies also employ the RF band, including cellular phones and their base tower infrastructure, conventional television and radio signals, home cordless phones, and microwave ovens.³

The RF band is a band of non-ionizing radiation that ranges from 3 kHz – 300,000 MHz^{1,4,5}. The RF band is part of the electromagnetic spectrum, with frequencies below those associated with visible light and X-rays and higher than those frequencies associated with power lines. Unlike the much higher frequencies associated with X-rays and ultraviolet radiation, including sunlight, RF lacks sufficient energy to break chemical bonds.

Of these technologies, the bulk of research in RF has been on cellular phones. Cellular phones have been in use longer than Wi-Fi and are associated with higher field strengths. Thus, when considering total RF exposure in terms of power density, duration, distance (from source) and frequency of exposure⁶, it is important to remember that Wi-Fi may represent only a small proportion of an individual's overall RF exposure³.

In most countries exposure limits for RF are set at the national level. Industry Canada regulates RF in Canada⁷. For protection of human health from adverse effects of RF exposure, they have adopted Health

Canada's Safety Code 6 (revised 2009), which sets exposure limits⁸ for controlled and uncontrolled environments.

Limits for RF are typically specified in two ways. The first is as a specific absorption rates (SARs), which are measured in power absorbed (Watts) per unit mass (kilograms), given as a whole-body average, or a localized measurement⁸. Secondly, limits are also set for power densities measured from the source in Watts per square meter⁹.

SARs are based on non-human primate studies; the predominant health effect addressed is tissue heating, which occurs at 4 W/kg of exposure over whole body. Applying a safety factor of 10, Safety Code 6 sets exposure limits for controlled environments to whole body, head and trunk of 0.4 Watts per kilogram, 8 Watts per kilogram, and 20 Watts per kilogram respectively⁸.

For uncontrolled environments to protect the general public, a safety margin of 50 is used to derive exposure limits to whole-body, head, and trunk of 0.08 Watts per kilogram, 1.6 Watts per kilogram and 4 Watts per kilogram respectively. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) also sets limits on power-density emissions from sources of 10 Watts per square metre⁹.

The recent proliferation of Wi-Fi devices has increased concerns about potential effects of RF exposure on human health and raised questions as to whether exposure limits set on the basis of tissue heating are sufficiently protective. This document considers Wi-Fi exposures in context with other current sources of RF exposure and recent reviews of health outcomes research on RF exposures.

Methods

This report represents a review of the scientific literature on radio frequency energy and effects on health. It is based on a review of the most up to date published reviews, supplemented by a review of primary literature published after the last review available.

Various reports, regulations and reviews from the World Health Organization, government, commissions, and health agencies, as well as other interest groups (example Council on Man and Radiation (COMAR) or the BioInitiatives Working Group) were sought out and reviewed, and references from these publications also considered for inclusion.

A primary literature review for new publications was then carried out using PubMed. Searches were conducted using MeSH terms "Radio Waves", "Microwaves" and "Electromagnetic Fields" combined with "adverse effects" and "public health". Free text searches were also carried out using search terms "radiofrequency and health", "wi-fi and health", and "cellular phones health".

Title review identified reviews and key large studies, whose abstracts were then reviewed for relevance. Articles were then selected for review if they had been published in reputable peer-reviewed journals, published within the last two years, or had significant public interest or impact. Reference lists of selected articles were then further hand searched for relevant articles and reports.

Exposure research

Exposure research addresses source intensity and power density, frequency and duration of exposure, and distance from the source, in measuring potential exposures and health effects⁶.

Modeling of RF exposure has been undertaken by researchers at the United Kingdom National Radiological Protection Board. In studies on mobile phone exposures, they found that head and neck exposures to RF with maximum handset use (resembling a controlled exposure of 100% RF absorbed by tissue) was 3.09-4.61 W/kg¹⁰.

By comparison, for Wi-Fi, the same researchers found that for a child typically using a laptop within good signal range of a wireless router, RF exposure to the head was 0.0057 W/kg. This represents less than 1% of the SAR calculated for a typical mobile phone exposure and well below the 1.6 W/kg limit to head for uncontrolled exposures³.

With regards to source power densities, Foster and others demonstrated that maximum and median Wi-Fi exposures were significantly below the exposure limit set by the ICNIRP (see Table 1⁶). Another study found cellular base antenna power densities to be 0.05 W/m²¹¹.

Table 1 – Comparison of measured RF fields with Wi-Fi (adapted from Foster)

RF activity being measured or calculated	Maximum time-averaged power density (W/m ²)	Median time-averaged power density (W/m ²)
Laptop not communicating with Wi-Fi, measured directly next to Wi-Fi access point	0.007	0.000012
Laptop uploading/downloading file, measured 1 metre away from laptop Wi-Fi card	0.001	0.000016
Laptop uploading/downloading file, average of measurements taken at different distances from laptop	0.04	0.00006

Outcomes research

As Wi-Fi is a more recent application of RF and generally results in much lower levels of exposure to RF, much of the available scientific literature on potential health effects of RF is based on studies of cell phones.

Multiple biologic outcomes have been explored, including cancer, infertility in animals, behavioural changes, and “electromagnetic hypersensitivity” (EHS), defined as a set of non-specific symptoms such as nausea, headache, and dizziness¹².

Reviews by regulatory and standard setting organizations

The Health Protection Agency in the United Kingdom has done extensive work researching the potential effects of Wi-Fi. Their review¹³ concluded there is no consistent evidence that Wi-Fi has adverse human health effects; it also concludes by stating there is no reason why schools and other public facilities should not use Wi-Fi equipment.

Health Canada has issued statements reaffirming Safety Code 6:

“Safety Code 6 offers the best protection for Canadian workers and the general public, for several reasons: it is based on [...] evidence [...] from hundreds of peer-reviewed RF studies; has been reviewed and recommended by independent third parties such as the Royal Society of Canada; and [has limits] among the most stringent in the world.”¹⁴

A recent Health Canada statement released on Aug. 18, 2010, has highlighted that all Wi-Fi devices must meet Safety Code 6 and that “radiofrequency energy emitted from Wi-Fi equipment are typically well below these safety limits.”¹⁵

The World Health Organization has published extensively about the risks of low-level RF exposure. In a background document about electromagnetic fields, the WHO states:

“No obvious adverse effect of exposure to low level radiofrequency fields has been discovered [...] further research aims to determine whether any less obvious effects might occur at very low exposure levels.”¹⁶

Published reviews

The Bio-Initiatives Working Group is an ad-hoc group of scientists and public policy analysts who produced “The BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields.”

This report reached different conclusions and recommendations as compared to the international health and standard setting organizations¹⁷. The authors review a number of selected papers and draw the conclusion that the evidence clearly supports health effects related to RF exposure and dramatically stated that “it is not unreasonable to question the safety of RF at any level”.

The report goes on to suggest a precautionary level for human exposure to electromagnetic fields that is approximately 10,000 times lower than existing regulatory limits.

This conclusion was reviewed and challenged in a publication by the Committee on Man and Radiation (COMAR)¹⁸. This 46 member expert group raised a number of criticisms of the BioInitiatives Report, such as selectiveness in papers reviewed, inconsistencies in the review process, and questions as to the impartiality of the reviewers on the panel.

Moreover, the COMAR report also points out that BioInitiatives suggested RF limits of human exposure would affect the use of public safety RF devices, including airport radar installations, and police and emergency communication systems.

The Royal Society of Canada commissioned a panel in 1999 to review the adequacy of Safety Code 6 and possible revisions in view of potential non-thermal biologic effects; the panel report¹⁹ “found no evidence of documented health effects in animals or humans exposed to non-thermal levels of radiofrequency fields” although calling for additional research.

An update by the same panel in 2003²⁰ repeated the same conclusion, and again noted the need for additional research.

Finally, a third update by many of the original authors was published in 2009²¹. As this is the most recent comprehensive review of the literature on the effects of RF exposure, its conclusions are summarized below.

This most recent review summarizes outcomes from cellular and animal studies as follows:

"Effects of RF fields on various biological systems were investigated in some depth. Although the majority of studies provided no evidence of genotoxic effects, there are a few positive findings that warrant follow up. Some cellular studies provided evidence that gene expression is affected at RF field exposure levels close to current safety limits. If these studies are replicated and confirmed, they will be of importance in understanding how RF fields may interact with biological tissues. It is possible that small temperature elevations may have accounted for some of the observations in cell culture studies. Accordingly, the importance of non-RF heat studies is stressed. Overall, there is little evidence of cellular effects of RF fields of health significance below current safety limits. In the future, it would be of interest to investigate the complex modulation patterns and intensity variations corresponding to the RF fields produced by actual mobile phones."

The review of human clinical studies including those on electromagnetic hypersensitivity is summarized as:

"Various subjective symptoms, including dermatological symptoms (redness, tingling and burning sensations) as well as neurasthenic and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitation, and digestive disturbances and other unpleasing feelings such as a burning sentiment or a faint pain), were suggested as being triggered by exposure to RF fields. However, the limited number of studies conducted to date found no evidence for an association between these reported symptoms of EHS and exposure to electromagnetic fields. Small changes in electrical activity and neurotransmitter biochemistry were observed in some studies, although no evidence of impaired cognitive functioning was attributed to these observations. Scientific evidence to date has found no consistent evidence of altered cardiovascular system or auditory parameters following RF field exposures. A recent study suggested that exposure to RF fields from mobile phones may be associated with sperm quality; this finding warrants follow-up."

The final group of studies reviewed, epidemiological studies, is summarized as:

"At present, the results from epidemiologic studies do not provide sufficient evidence to support a clear association between mobile phone use and an increased risk of head and neck benign tumours. However, there have been reports of a higher risk of brain tumour and acoustic neuroma in some studies.

Exposure assessment in these studies was based largely on self-reports of past mobile phone use. Additional investigations of the possible association between mobile phone use and cancer risk, particularly among chronic heavy users of mobile phones, are needed to clarify this issue."

Recent studies

Since the publication of the review by Habash et al, additional research has been published. While none of the recent research invalidates or overturns the previously accumulated weight of evidence, some of the recently published studies do provide additional insights.

As indicated by the Habash et al review, numerous case-control studies^{22,23,24,25} using cancer as an outcome conducted in different countries around the world have not supported a clear association between cancer and cellular phone use. The most recent study is the INTERPHONE study, whose results were published in June 2010.

In a meta-analysis of several studies of cellphone use and its association with tumours carried out by Hardell et al. there was no demonstrable increase in risk for most tumours considered. However, there was an indication of an increased risk for glioma, acoustic neuroma, and meningioma with ipsilateral cellphone use of greater than 10 years²⁶.

A review by Kundi and Hutter described studies conducted in France, Spain and Austria, where participants estimated their distance from a cellular base station. They then rated a list of 18 symptoms (e.g. fatigue, headaches, and sleeping problems) and how frequently they experienced them. None of the studies showed any statistically significant relationship between symptoms and proximity to a base station²⁷.

A review on base stations by Khurana and others reviewed 10 studies, eight of which were positive for neuro-behavioural changes or cancer; however, the reviewers did state that the studies reviewed involved low numbers of participants and were of poor methodological quality which limits the reliability of any conclusions²⁸. The authors indicated that further research into these outcomes is urgently required.

A review of 46 blind or double-blind studies with exposure to active or sham electromagnetic fields concluded that despite the conviction of sufferers from electromagnetic hypersensitivity that their symptoms are triggered by exposure to electromagnetic fields, repeated experiments have been unable to replicate this phenomenon under controlled conditions. For this reason, clinicians and policymakers are cautioned that a narrow focus on bio-electromagnetic mechanisms is unlikely to help these patients in the long-term.²⁹

Three recent publications have looked at the effects of RF exposures or cellphone use in young people. Abramson et al³⁰ studied 317 7th graders. Self reported cellphone use was associated with more rapid but less accurate responses on a computerized cognitive test battery.

As the findings were similar for use of text messaging the authors' opinion was that the behaviours may have been learned through frequent use and were unlikely due to RF exposure. Heinrich et al³¹ studied 3022 Bavarian children and adolescents. Half the children and nearly every adolescent owned a mobile phone.

Measured RF exposure was well below ICNIRP reference levels. No statistically significant association was found between measured exposure and chronic symptoms. While concluding that their cross-sectional study did not indicate any association between exposure to RF and chronic well-being in children and adolescents, they called for additional prospective studies to confirm their results. The same group also published a study³² looking at behavioural problems in the children and adolescents.

The adolescents, but not the children, with the high RF exposures (associated with greater cellphone use) had more overall behavioural problems as assessed by a questionnaire. There was an association between conduct problems and RF exposure for both adolescents and children.

Conclusions

Research on potential health effects from exposure to RF energy is an active field of investigation. Not surprisingly there is inconsistency and in some cases conflict between the results of individual studies.

Given this inconsistency, it is possible to select the results of individual research studies in support of a variety of opinions; which may range from no risk of health effects on the one hand, to a clear need to reduce current exposure limits on the other.

For this reason, up-to-date reviews of literature which follow a weight of evidence approach are far more useful for informing debate and sound policymaking than reliance on individual studies.

The Royal Society of Canada performed a highly credible review in 1999. Updates to this review have been published; the most recent in 2009. While the most recent review continues to call for additional research to follow up on new findings, after a decade of additional research, there is still no conclusive evidence of adverse effects on health at exposure levels below current Canadian guidelines.

While far from conclusive, there is emerging evidence that long-term frequent use of cellphones may be associated with an increased risk of tumours on the side of the head where the cellphone is used. This is an active area of research and additional studies may confirm or refute this association.

The degree of 'precaution' that should be incorporated into exposure limits for the public is always a subject for debate. There is general agreement that the exposure limits in Health Canada's Safety Code 6 are protective against effects produced through tissue heating. Consistent evidence on the level at which this occurs is available and exposure limits can be set on the basis of this well-established effect and use of safety factors selected by the standard setting organization.

Recently published research demonstrates that Wi-Fi exposure are not only well within recommended limits, but are only a small fraction (less than 1%) of what is received during typical use of cellphones³.

For this reason much of the research on possible effects of RF energy has been focused, and will likely continue to focus, on exposures from cellphones rather than the lower exposures associated with RF uses such as Wi-Fi. RF exposures to the public, including school children, from Wi-Fi are far lower than occur with cellphone use and to date there is no plausible evidence that would indicate current public exposures to Wi-Fi are causing adverse effects on health.

Given the experience with other sources of non-ionizing radiation (e.g. power lines) that have been in use much longer than cellphones or Wi-Fi, it is unlikely that all controversies related to potential RF effects will be resolved even after decades of additional research.

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