



What effects do mobile phones have on people's health?

November 2006

ABSTRACT

This is a Health Evidence Network (HEN) synthesis report assessing the clinical effects of daily exposure to mobile phones in general populations. It addresses the impact on developing head and brain tumours, other morbidity-related outcomes and summarizes the biological effects of RF and microwave radiation.

The report shows that the evidence available does not provide a clear pattern to support an association between exposure to RF and microwave radiation from mobile phones and direct effects on health. It however cautions that lack of available evidence of detrimental effects on health should not be interpreted as evidence of absence of such effects and recommends a precautionary approach to the use of this communication technology until more scientific evidence becomes available.

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Summary

The issue

During recent years, the use of mobile phones has increased substantially and has been paralleled by a growing concern about the effects on health attributed to exposure to the electromagnetic fields produced by them and their base stations. Demonstrating that radiation causes adverse effects on health would signal a widespread public health problem.

Findings

Mobile phones have been in extensive use for a relatively short period of time, and their technology has progressively changed, from analogue to digital systems. Mobile phones and base stations emit radio frequency or microwave radiation. Exposure to such a radiation could affect health directly. The use of mobile phones also results in indirect effects, such as car accidents and interference with health equipment.

Experimental research on the effects of radio-frequency radiation is very broad and heterogeneous. It includes both studies of cell cultures and tissues (*in vitro*) and of laboratory animals (*in vivo*), as well as of people (volunteers). On one hand, these studies focus on functional changes in the brain and the resulting effects on cognition, and (to some extent) well-being – that is, the influence of exposure to radiation on the head. On the other hand, these studies focus on the possibility of a relationship between mobile phone use and carcinogenic processes, reproduction and development, the cardiovascular system and longevity – that is, exposure of the whole body. These studies found very small and reversible biological and physiological effects that do not necessarily lead to diseases or injuries. Also, the research findings on the changes at the molecular level associated with the development of cancer are inconsistent and contradictory.

Epidemiological studies in general populations, such as communities, concentrate on a possible causal relationship between mobile phone use and the occurrence of brain tumours, acoustic neuromas, tumours of the salivary glands, and leukaemia and lymphomas. Although weak and inconclusive, most of the evidence available does not suggest that there are adverse effects on health attributable to long-term exposure to radio-frequency and microwave radiation from mobile phones. However, recent studies have reported an increased risk of acoustic neuroma and some brain tumours in people who use an analogue mobile phone for more than 10 years. Also, no data is available on the reproduction of these effects when digital mobile phones are used. Finally, there is good evidence that the use of mobile phones while driving translates into a substantially increased risk of an accidental collision.

Policy considerations

For the majority of tumours studied so far, a long latency period might exist, and the finding of any link to the use of mobile phones is complex. Consequently, most of the published research cannot elucidate the risk of long-term effects. If there is a risk, the current evidence suggests it is small.

Since there are still gaps in knowledge, continued research and better health risk analyses are needed. Moreover, without scientifically recognized adverse effects on health, it is not possible to produce evidence-based recommendations.

Therefore, a precautionary approach to the use of this communication technology should be adopted until more scientific evidence on its effects on health becomes available. Such an approach includes restricting exposure (according to existing guidelines and the European Union (EU) Directive) and providing the public with information and options.

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Introduction

In recent years, mobile telecommunication systems have grown significantly, to the point where more than a sixth of the world's population use mobile phones. By the end of 2004, more than a billion subscribers across more than 200 countries were estimated to be using mobile phones (1, 2).

The development of mobile communications has moved rapidly. In the 1980s, first generation mobile phones, using analogue technology, allowed the transmission of sound only. Digital transmission, and the global system for mobile communication, started in 1991 and includes such new developments as data and image transmission. Third generation mobile phones currently in the market offer additional services to the users (such as fax, e-mail and Internet access). For both analogue and digital mobile phones, the signals transmitted and received are in the form of waves in the radio frequency (RF) (analogue) and microwave parts of the electromagnetic spectrum. RFs are non-ionizing radiation with wavelengths that range from 3 kHz to 300 MHz, and microwaves range from 300 MHz to 300 GHz¹. The frequencies that mobile phones and telecommunication networks use range from 900 MHz to 1.8 GHz and up to 2.1 GHz, although it should be noted that the wavelength of the different types of mobile phones varies. This applies to both mobile phones and their base stations, which send and receive calls.

People have welcomed the technology, as indicated by the widespread use of mobile phones, which suggests that they do not perceive it as a potential health hazard. However, concerns about the possible adverse effects on health, as a result of the exposure to RF and microwave electromagnetic fields, have been expressed since the introduction of mobile phones.

Since the year 2000, several reports have reviewed relevant studies and summarized current knowledge about mobile phones and health, particularly that related to the commonly accepted carcinogenic effects of RF and microwave energy. The aim of this synthesis is to combine the available epidemiological evidence, to learn whether exposure to RF and microwave radiation from mobile phones and their base stations might affect health. This synthesis does not aim to analyse the effect of other man-made sources of electromagnetic fields, nor does it aim to develop safety standards. The WHO International EMF Project is currently producing this information (3).

Sources for this review

This synthesis assesses the clinical effects of day-to-day exposure to mobile phones in general populations, such as communities – specifically, the impact on developing head and brain tumours (benign and malignant). It also addresses other morbidity related outcomes and summarizes the biological effects of RF and microwave radiation.

Two main sources of information were considered and reviewed. A search of scientific and biomedical databases was performed until March 2006. Observational studies that assessed the effects of mobile phones on general populations were included in the synthesis. Experimental studies that assessed clinical effects were excluded, as were those of occupational settings. The quality of the studies was assessed by using the grading system developed by the Scottish Intercollegiate Guidelines Network (Table 1) (4). Also, a review of documents and web sites of governments, health councils, radiological protection boards, advisory and expert groups, and the like, was undertaken. Annex 1 gives details about the literature search strategy.

¹ U.S. Department of Labour, Occupational Safety & Health Administration (OSHA).
<http://www.osha.gov/SLTC/radiofrequencyradiation/>

Findings

Scientific literature

Biological and physiological effects

Experimental research on the biological effects of RF and microwave fields is very broad and includes studies of volunteers, animals and *in vitro*, cell-based techniques (5, 6). The studies cover the effects of RF and microwave radiation between 100 MHz and 60 GHz and focus both on the functional changes in the brain (influence of exposure to RF and microwave fields on the head) and on carcinogenic processes, reproduction and development, the cardiovascular system and longevity (as a result of whole body exposure to RF and microwave fields).

The biological effects observed on the cardiovascular, endocrine and immune systems and on the behaviour of animals studied seem to be thermal effects of acute exposure to RF and microwave radiation, with increases of at least 1 °C or 2 °C in temperature needed to produce these effects. As to the increased risk of developing cancer after exposure to RF or microwave fields, the evidence for such an association is extremely weak. Since the radiation from mobile phones and signal stations does not have enough energy to break chemical or molecular bonds directly, there is no basis in theory to suggest that they can damage DNA. Moreover, a biological mechanism that explains any possible carcinogenic effect from RF or microwave fields has yet to be identified. Because of the difficulties in interpreting findings from laboratory studies, the hypothesis that RF or microwave radiation is harmful and could have effects on health that have not yet been recognized cannot be rejected.

Indirect experimental results are difficult to extrapolate. *In vitro* experiments that show abnormal cell proliferation, changes in cell membranes, and movement of ions and substances across membranes are difficult to extrapolate to people. It is also difficult to extrapolate to people the observed effects on cerebral functions that relate to the behaviour of rodents since, among other reasons, the whole brain of these small animals is exposed to radiation whereas the brains of people who use mobile phones, although being exposed, receive the highest exposure in the part closest to the handset. Moreover, the thermal effects of radiation are unlikely to be seen in people, as the increase in the local temperature of the brain induced by the microwaves generated by mobile phones is negligible (it has been estimated to be up to 0.1 °C) (7). Finally, there is no evidence of non-thermal effects on human health.

It is important to distinguish between biological (or physiological) effects and psychological and health effects. The demonstration of an RF or microwave radiation effect in experimental research does not necessarily mean that such exposure will lead to harmful effects on human health. Human bodies, with the aid of their immune, nervous or endocrine systems, can effectively resist some external pressures, adapt to them and maintain the stability (homeostasis) disrupted by those changes.

Clinical effects

Within human population studies, epidemiological studies provide the most direct information on the long-term effects on health of any potential harmful agent. To assess the adverse effects on health that may result from the use of mobile phones, research with a specific focus on cancer has been carried out. By the end of the 1990s, the number of studies was small and the works presented major methodological limitations, the most outstanding one being the lack of enough people with an exposure time long enough to accurately assess the potential adverse late effects on health of mobile phone use.

The majority of those studies suggested the need for additional, high-quality research. As a result of these recommendations, a series of multinational case-control studies, coordinated by the International Agency for Research on Cancer (IARC), were set up after a detailed feasibility study was carried out in 1998 and 1999.

Overall, these studies are named the INTERPHONE Study (8), and their primary objective is to assess whether exposure to RF or microwave radiation from mobile phones is associated with a risk of cancer. Priority is given to epidemiological studies of the relationship between the use of mobile phones and the incidence of:

- brain tumours;
- salivary gland tumours, acoustic neuromas and other head and neck tumours; and
- leukaemia and lymphomas.

If the risk of developing a brain tumour exists at all, the wider use of mobile phones and the expected number of people who will develop a brain tumour will be sufficient to detect a potential 1.5-fold increase in risk 5–10 years from the start of use.

Participant countries, with the longest and highest use of mobile phones, are Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden and the United Kingdom. Initially, the study expected to find about 6000 cases of glioma and meningoma (both benign and malignant), 1000 cases of acoustic neuroma, 600 cases of parotid gland tumour and their respective controls. The first results of the INTERPHONE Study were available in 2004 (9, 10) and, since then, four additional papers have been published (11–14). It should also be noted that these studies evaluated the impact on health of exposure to RF and microwave radiation emitted by mobile phones, and not by antennas and base stations.

With regard to brain tumours, most of the studies yielded negative results, although a few of them suggested an increased risk for mobile phone users. Because of these results, it is not possible to establish an association between the use of mobile phones and an increased risk of brain tumours. With regard to acoustic neuroma – a rare, benign tumour on the auditory nerve – the studies available reported inconsistent results, except for the most recent ones, which found an association between an increase in the risk of this type of tumour and 10 years or more of mobile phone use; moreover, the increased risk is confined to the side of the head where the phone was usually held. No indications of an increased risk for less than 10 years of mobile phone use were found. Before definite conclusions can be drawn, the results of these studies have to be confirmed by additional research.

This type of research, however, faces several problems. One is that long-time users first used analogue phones, and then digital phones. No risk has been found for digital phone use only, but then the follow-up time is shorter. Other methodological problems, such as recall bias, have been identified: people, especially patients, might have a selective memory on the side of the head where the telephone was used (15).

A number of clinical complaints related to the use of mobile phones are reported in the scientific literature. They include headache, fatigue, sleep disorders, loss of memory, dizziness, feelings of heat or tingling in the auricular (or auditory) area or in the head, vertigo, deafness and blurred vision. Very few studies are available, and their results provide no evidence of an association between these symptoms and the use of mobile phones. It should be noted, however, that these are general, nonspecific symptoms that may be induced by a wide range of causes. Since they represent a problem for those suffering, the cause should be elucidated.

In summary, the evidence available does not support the hypothesis that mobile phone use is associated with an increased risk of malignant brain tumours, but an increase in the risk of acoustic neuroma after 10 years or more of mobile phone use has been found. Therefore, it seems that neither acoustic neuroma nor brain tumours are related to mobile phone use of less than 10 years. Nevertheless, those studies were conducted with data from the time when only analogue mobile phones had been in use for more than 10 years, and they cannot determine if the results would be

similar after long-term use of digital mobile phones. Likewise, a carcinogenic effect after a very long period of exposure would remain undetected.

The most important and clearly defined effect of mobile phones on health, and the only clearly established risk from an epidemiological perspective, is motor vehicle accidents, which obviously are not related to exposure to RF or microwave radiation. The results of some studies show that the use of a mobile phone up to 10 minutes before a crash is associated with a fourfold increase in the risk of having a collision that results in injury. The risk increases irrespective of whether or not a hands-free phone is used (16, 17).

Table 2 describes the characteristics of the design of epidemiological studies and the outcomes of these studies.

Reports (grey literature)

Since the year 2000, a significant number of reports and reviews on the connection between mobile phone use and health have been issued by committees, institutions, expert groups and agencies of worldwide prestige, to appraise relevant literature, draw up guidelines and make recommendations to limit exposure to RF and microwave radiation.

The National Radiological Protection Board summarized (18) the information from several sources, from the publication of the Stewart Report, in May 2000, to the end of 2004. The Board, an independent body that is now part of the Health Protection Agency, has responsibility for advising government departments and others in the United Kingdom on standards of protection for exposure to ionizing and non-ionizing radiation, which includes electric and magnetic fields.

The Stewart Report (5) is a widely quoted review on mobile phones and health. The Government of the United Kingdom commissioned the Independent Expert Group on Mobile Phones, which was chaired by Sir William Stewart, to prepare the Report. The Report concluded that the balance of evidence did not suggest that exposure below international guidelines could cause adverse effects on health. However, it recommended that a precautionary approach – that is, limiting exposure to RF and microwave radiation, planning the location and setting of base stations and encouraging a selective use of mobile phones – be adopted until more detailed and scientifically robust information on any adverse effects on health becomes available. Besides health issues, the Report offered advice on exposure standards and planning to government, industry and others and on public information and consumer choices. It also proposed setting up a research programme.

According to the National Radiological Protection Board summary report (18), most of the 26 reports examined reached similar conclusions and made comparable recommendations. Overall, the reports acknowledge that exposure to low-level RF and microwave fields may cause a variety of slight biological effects on cells, animals or people, particularly on brain activity during sleep, but the possibility of exposure causing adverse effects on health remains unproven. The reports also present guidance on public policy to decision-makers and legislators, and some of them favour any form of precautionary or prudent approach to reducing personal exposure to the fields produced by mobile phones.

Specifically, most reports recommend limiting the use of mobile phones by children. This has been recommended in the absence of explicit scientific data. However, ethical and practical concerns limit or prevent experimental studies on children. Because of a much higher cumulative exposure than today's adults when they were at the same age, children might be more vulnerable to any effects of RF and microwave radiation. As long as adverse effects on health cannot be ruled out with some degree of certainty, it appears to be appropriate to instruct children and their parents about a prudent use of mobile phones. Moreover, in the absence of new scientific evidence, WHO is focusing attention on the potential effects of exposure to electromagnetic fields on children (19). Finally, many reports agree that the distraction caused by mobile phone use while driving represents a serious threat to health.

Table 3 contains a selection of national and international reports on mobile phone use and its effects on health, along with the links to the corresponding web pages.

Discussion

Results among investigations were inconsistent, and these investigations indicated little or no association between exposure to RF and microwave radiation and cancer. It should be noted that the weak evidence on carcinogenicity obtained from several epidemiological studies applies only to the type of cancer studied and to the time intervals observed between exposure and occurrence of disease. Also, experience with cancer in people indicates that, in some cases, the period from first exposure to the development of clinical cancer is seldom less than 20 years; moreover, latency periods substantially shorter than 30 years cannot provide evidence for lack of carcinogenicity (20).

Progress and changes in mobile phone technology (such as analogue to digital signals) make it difficult to assess exposure in the people studied. Furthermore, because the use of mobile phones is relatively recent, it may be premature to conduct an exhaustive epidemiological assessment of its impact on health. In the case of cancer, for example, the information available does not rule out the possibility of an association between the use of mobile phones and the occurrence of this disease. Thus, it is advisable to monitor the incidence of tumours supposedly associated with exposure to RF and microwave radiation, to assess possible changes in trends.

Conclusions

The evidence available does not provide a clear pattern to support an association between exposure to RF and microwave radiation from mobile phones and direct effects on health (such as increasing the risk of cancer). However, the quality of this research and the relatively short-term data do not allow ruling out adverse effects on health completely. In other words, the absence of evidence of detrimental effects on health associated with mobile phone use is not evidence of absence of such effects. At the moment, it is impossible to state that exposure to RF or microwave radiation (even below the permitted levels) does not have adverse effects on the health of the general population. The current evidence, however, does suggest that if there is a risk, it is small. Therefore, a precautionary approach (as recommended by the EU (21)) to the use of this communication technology should be adopted until more scientific evidence on effects on health becomes available.

Finally, evidence shows that the use of a mobile phone while driving translates into a significantly increased risk of a traffic accident.

Annex 1. Sources of information and methods

Scientific and biomedical literature

The review was done after a bibliographic search (up to March 2006) of databases, using relevant key words, selection (inclusion/exclusion) criteria and a grading scale.

Databases

The following databases were searched:

- MEDLINE
- EMBASE
- The Cochrane Library
- ENVIROLINE
- INSPEC
- PASCAL
- SCISEARCH.

Key words

The following keywords were used in the search: telephone, phone, cell phone, cellular phone, mobile phone, cell telephone, cellular telephone, mobile telephone, antenna, station, hazards, risks, health electromagnetic fields, radio waves, microwaves.

Selection criteria

The following inclusion and exclusion criteria were used in this synthesis:

- **inclusion criteria:** papers about the effects of RF from mobile phones and their base stations on the general population published in English, French and Spanish.
- **exclusion criteria:** papers about the effects of RF from mobile phones and their base stations in experimental studies and occupational settings; however, a summary of experimental research findings is provided.

In an experiment, the exposition to the agent or putative cause is due because the investigator has assigned the exposure to the subject in order to comply with a study protocol. Because the goals of the study rather than the subject's needs determine the exposure assignment, ethical constraints limit the circumstances in which these types of studies are feasible. Experiments are ethically permissible only when adherence to the scientific protocol does not conflict with the subject's best interests.

Grading scale

The grading system used for the evidence is that developed by the Scottish Intercollegiate Guidelines Network (SIGN) (4). Table 1 shows the SIGN levels of evidence for this system.

Grey literature

A review was undertaken of major documents and web sites of governments, health councils, radiological protection boards, advisory and expert groups, and the like, since the year 2000.

Most of the epidemiological studies from which the reviewed evidence comes are case-control studies. In case-control studies, subjects are selected according to their disease status (in the case of this

synthesis, it was presence or absence of a brain tumour) and further classified according to their exposure status (in the case of this synthesis, it was exposure to mobile phones). This type of design provides mid- to low-level evidence, according to the grading system used (4), since the methodology is less strong. Nevertheless, for the ethical reasons mentioned above, which relate to experimental studies, cohorts – that is, studies in which subjects are classified according to their exposure status and followed over time to ascertain disease incidence – and case-control studies are considered the best designs to study potential risk factors for human health due to the inability to use intervention studies.

Table 1. SIGN grading system

Levels of evidence	
1++	High-quality meta-analyses, systematic reviews of RCTs or RCTs with a very low risk of bias
1+	Well-conducted meta-analyses, systematic reviews of RCTs or RCTs with a low risk of bias
1-	Meta-analyses, systematic reviews of RCTs or RCTs with a high risk of bias
2++	High-quality systematic reviews of case-control or cohort studies High-quality case-control or cohort studies with a very low risk of confounding, bias or chance and with a high probability that the relationship is causal
2+	Well-conducted case-control or cohort studies with a low risk of confounding, bias or chance and with a moderate probability that the relationship is causal
2-	Case-control or cohort studies with a high risk of confounding, bias or chance and with a significant risk that the relationship is not causal
3	Non-analytic studies, such as case reports and case series
4	Expert opinion

RCT: randomized controlled trial.

Source: Scottish Intercollegiate Guidelines Network (4).

Table 2. Characteristics and overall results of the studies on mobile phones and cancer

Study (author, year (reference no.), country)	Design	Population	Conclusions/observations
<p>Rothman et al., 1996 (22), United States</p> <p>Dreyer, Loughlin & Rothman, 1999 (23), United States</p>	<p>Cohort studies</p> <p>Extension of the previous cohort</p>	<p>255 868 users of mobile phones (mobile phones vs hands-free in car)</p> <p>285 561 users of mobile phones</p>	<p>The study did not specifically address the relationship between the use of mobile phones and brain tumours (which account for a small proportion of mortality).</p> <p>The period of time between exposure and mortality was very short.</p> <p>No increase in cancer mortality rates adjusted for age, sex and exposure was observed.</p>
<p>Hardell et al., 1999 (24), Sweden</p> <p>Hardell et al., 2000 (25), Sweden</p>	<p>Case-control study</p> <p>Previous study with analysis of different variables ^a</p>	<p>217 hospital cases and 439 controls from general population</p> <p>The same population</p>	<p>No increase in the risk for the set of brain tumours associated with exposure to mobile phones was observed. The results are similar in both types of telephones (analogue and digital).</p> <p>No dose–response effect or any effect related to induction time was observed.</p> <p>The increase of non-significant risk related to laterality included a small number of cases.</p> <p>The results are based on a small number of individuals exposed (13 cases), so they must be interpreted with caution.</p>

Study (author, year (reference no.), country)	Design	Population	Conclusions/observations
Muscat et al., 2000 (26), United States	Case-control study	469 hospital cases and 422 hospital controls	<p>No short-term effect of exposure to analogue mobile phones was observed. Further studies are needed, including longer induction periods, particularly with regard to slower-growing tumours.</p> <p>No information could be obtained on the use of mobile phones in the non-responders and in 57 cases.</p> <p>In general, the severity of the disease was greater in the cases than in the controls, which might overestimate the use of mobile phones.</p> <p>The positive association between the use of mobile phones and neuroepithelioma must be interpreted with caution, because of recent changes in morphological criteria for the classification of brain tumours.</p>
Inskip et al., 2001 (27), United States	Case-control study	782 hospital cases and 799 hospital controls	<p>The results did not support the hypothesis that exposure to radiation emitted by the use of mobile phones (analogue system) causes brain tumours (benign, malignant) or damage of the nervous system: OR = 0.9; 95% CI: 0.7–1.1</p> <p>These results must be assessed as an estimate of risk in the initial stages of this technology.</p> <p>The assessment of the risk in long induction periods, in population groups with high daily exposure or accumulated use involves limited precision.</p>

Study (author, year (reference no.), country)	Design	Population	Conclusions/observations
<p>Johansen et al., 2001 (28), Denmark</p>	<p>Cohort study</p>	<p>420 095 users of mobile phones (registry)</p>	<p>The period of use of mobile phones (mean of 3.1 years) was too brief to detect an effect on slow-growing brain tumours.</p> <p>The number of people with a high-level of use of mobile phones was too small to be able to exclude, with any certainty, the carcinogenic effect on brain tissue due to a high and prolonged use of mobile phones.</p> <p>The results did not support an association between the use of mobile phones and the risk of brain tumours, leukaemia, and cancers of the salivary glands and other locations: standardized incidence ratio.</p>
<p>Hardell et al., 2002 (29), Sweden</p>	<p>Case-control study</p>	<p>1617 cases (cancer registry) and 1617 population controls</p>	<p>Only 61% of the cases met the inclusion criteria (selection bias).</p> <p>The memory bias could not be excluded in the assessment of exposure and use of mobile phones.</p> <p>The results suggested an increased risk of malignant brain tumours when considering a reasonable latency period, but were not statistically significant: OR = 1.3; 95% CI: 1.02–1.6. The estimates were based on a small number of cases and must be interpreted cautiously.</p>
<p>Auvinen et al., 2002 (30), Finland</p>	<p>Case-control study</p>	<p>432 cases (cancer registry) and 2160 population controls</p>	<p>Mobile phone use was not associated with brain tumours or salivary gland cancers overall (OR = 1.3; 95% CI: 0.9–1.8). There was a weak association between glioma and the use of analogue cellular phones (OR = 2.1; 95% CI: 1.3–3.4).</p> <p>Registry data did not provide information on actual users of mobile phones, and frequency and duration of calls. Sensitivity and specificity of exposure tended to attenuate the effect of exposure.</p>

Study (author, year (reference no.), country)	Design	Population	Conclusions/observations
Hardell et al., 2003 (31), Sweden	Case-control study ^b	1617 cases (cancer registry) and 1617 population controls	<p>The main result was an increased risk of brain tumours associated with the use of analogue cellular phones (OR = 1.3; 95% CI: 1.04–1.6).</p> <p>Ipsilateral use significantly increased the risk (OR = 1.7; 95% CI: 1.2–2.3), whereas the use of a mobile phone on the opposite site of the brain was not associated with a risk increment. These results suggest a biological dose–response effect.</p> <p>Recall and observational bias were elucidated.</p>
Hardell et al., 2003 (32), Sweden	Case-control study ^b	1617 cases (cancer registry) and 1617 population controls	<p>A significantly increased risk was found for acoustic neuroma associated with the use of analogue mobile phones (OR = 3.45; 95% CI: 1.77–6.76). Digital- and cordless-phone use also revealed an increased risk, although it was based on low numbers and was not significant.</p>
Christensen et al., 2004 (9), Denmark INTERPHONE Project	Case-control study	106 incident cases (referrals to hospital departments) and 212 population controls (matched for age and sex)	<p>The results did not support an association between hand-held mobile phone use and the risk of developing acoustic neuroma (OR = 0.90; 95% CI: 0.51–1.57).</p> <p>Tumours did not occur more frequently on the side of the head on which the telephone was typically used, and tumour size did not correlate with the pattern of cell phone use.</p> <p>Use of a cell phone for 10 years or more did not increase the risk of acoustic neuroma over that of short-term use (however, the numbers for long-term users were small).</p>

Study (author, year (reference no.), country)	Design	Population	Conclusions/observations
Lönn et al., 2004 (10), Sweden INTERPHONE Project	Case-control study	148 cases (cancer registry) and 604 population controls	<p>The results did not indicate an increased risk of acoustic neuroma related to short-term use after a short latency period, which applies to the use of newer digital technology (OR = 1.0; 95% CI: 0.6–1.5).</p> <p>The findings suggested an increased risk of acoustic neuroma associated with mobile phones 10 years after the start of use, and thus was related to analogue technology (OR = 1.9; 95% CI: 0.9–4.1).</p> <p>The increased risk was confined to the side of the head where the mobile phone was usually held (OR = 3.9; 95% CI: 1.6–9.5).</p>
Lönn et al., 2005 (11), Sweden INTERPHONE Project	Case-control study	644 cases (hospitals and cancer registries) and 674 population controls	<p>No increased risk of glioma (OR = 0.8; 95% CI: 0.6–1.0) or meningioma (OR = 0.7; 95% CI: 0.5–0.9) related to regular mobile phone use was observed. Similar results were found for more than 10 years of use.</p> <p>No increased risk was found for ipsilateral phone use for tumours located in the temporal and parietal lobes. Furthermore, the OR did not increase, regardless of tumour histology, type of phone and amount of use.</p> <p>Recall bias may have affected some results.</p>
Hardell et al., 2005 (33), Sweden	Case-control study	413 cases (cancer registry) and 692 population controls	<p>Analogue mobile phones represent a significant risk factor for acoustic neuroma (OR = 4.2; 95% CI: 1.8–10.0).</p> <p>The results were based on small numbers and a large number of statistical comparisons, thus some findings could be expected by chance alone. There was a possibility of misclassification of exposure due to recall bias.</p>

Study (author, year (reference no.), country)	Design	Population	Conclusions/observations
<p>Schoemaker et al., 2005 (12), Denmark, Finland, Norway, Sweden and the United Kingdom</p> <p>INTERPHONE Project</p>	<p>Case-control study (six population-based studies)</p>	<p>678 cases (clinical centres and cancer registries) and 3553 population controls</p>	<p>The main finding was the risk for acoustic neuroma was not raised in relation to regular mobile phone use (OR = 0.9; 95% CI: 0.7–1.1).</p> <p>There was no association of risk with duration of use, lifetime cumulative hours of use or number of calls, for phone use overall or for analogue or digital phones separately.</p> <p>Risk of a tumour on the same side of the head, as reported phone use was raised, for use for 10 years or longer (OR = 1.8; 95% CI: 1.1–3.1).</p>
<p>Hardell et al., 2006 (34), Sweden</p>	<p>Case-control study</p>	<p>317 cases (cancer registries) and 692 population controls</p>	<p>The main finding was an increased risk for malignant brain tumours associated with the use of cellular and cordless telephones:</p> <ul style="list-style-type: none"> • analogue: OR = 2.6; 95% CI: 1.5–4.3, and OR = 3.5; 95% CI: 2.0–6.4 with a more than 10-year period; • digital: OR = 1.9; 95% CI: 1.3–2.7, and OR = 3.6; 95% CI: 1.7–7.5 with a more than 10-year period; and • cordless: OR = 2.1; 95% CI: 1.4–3.0, and OR = 2.9; 95% CI: 1.6–5.2 with a more than 10-year period. <p>A somewhat increased risk was also found for low-grade astrocytoma and other types of malignant brain tumours, although not significantly so.</p>
<p>Schüz et al., 2006 (13), Germany</p> <p>INTERPHONE Project</p>	<p>Case-control study</p>	<p>366 glioma and 381 meningioma cases (clinic files) and 1494 population controls</p>	<p>Overall use of a cellular phone was not associated with the risk of brain tumour:</p> <ul style="list-style-type: none"> • glioma: OR = 0.98; 95% CI: 0.74–1.29, and OR = 2.20; 95% CI: 0.94–5.11 for 10 or more years of phone use; and • meningioma: OR = 0.84; 95% CI: 0.62–1.13, and OR = 1.09; 95% CI: 0.35–3.37 for 10 or more years of phone use. <p>Cordless phone use was not related to either the risk of glioma or meningioma.</p>

Study (author, year (reference no.), country)	Design	Population	Conclusions/observations
<p>Hepworth et al., 2006 (14), United Kingdom</p> <p>INTERPHONE Project</p>	<p>Case-control study</p>	<p>966 cases (hospital and cancer registries) and 1716 controls (general practitioner lists)</p>	<p>Use of a mobile phone was not associated with an increased risk of glioma (OR = 0.94; 95% CI: 0.78–1.13)</p> <p>There were no relationships between risk of glioma and time since first use, lifetime years of use, and cumulative number of calls and hours of use.</p> <p>A significant excess risk for reported phone use ipsilateral to the tumour (OR = 1.24; 95% CI: 1.02–1.52) was paralleled by a significant reduction in risk (OR = 0.75; 95% CI: 0.61–0.93) for contralateral use.</p>

^a This study is the same as the previous one, but the tumour anatomical location variable was categorized differently.

^b This study uses the same database as the one in reference 29 for some further analysis.

OR = odds ratio.

Table 3. Selected reports on mobile phones and health

Institution, year	Report
The Royal Society of Canada, 1999 (updated 2001, 2004)	<i>A review of potential health risks of radiofrequency fields from wireless telecommunication devices</i> (http://www.rsc.ca/index.php?page=expert_panels_rf&lang_id=1&page_id=120 , accessed 25 September 2006)
United Kingdom Independent Expert Group on Mobile Phones, 2000	<i>Mobile phones and health (The Stewart Report)</i> (http://www.iegmp.org.uk/report/text.htm , accessed 25 September 2006)
United States General Accounting Office, 2001	<i>Research and regulatory efforts on mobile phone health issues</i> (http://www.gao.gov/new.items/d01545.pdf , accessed 25 September 2006)
British Medical Association, 2001 (updated 2005)	<i>Mobile phones and health: an update</i> (http://www.bma.org.uk/ap.nsf/Content/mobphonupd , accessed 25 September 2006)
Health Council of the Netherlands, 2002	<i>Mobile phones: an evaluation of health effects</i> (http://www.gr.nl/pdf.php?ID=377 , accessed 25 September 2006)
Advisory Group on Non-ionising Radiation, 2003	<i>Health effects from radiofrequency electromagnetic fields</i> . Report of the National Radiological Protection Board (http://www.hpa.org.uk/radiation/publications/documents_of_nrp/pdfs/doc_14_2.pdf , accessed 6 October 2006)
Swedish Radiation Protection Authority's Independent Expert Group on Electromagnetic Fields, 2003 (updated 2004)	<i>Recent research on mobile telephony and health risks</i> (http://www.ssi.se/english/EMF_exp_Eng_2004.pdf#search=%22%C2%A7%09Recent%20research%20on%20mobile%20telephony%20and%20health%20risks%22 , accessed 6 October 2006)
United Kingdom Health Protection Agency, 2003	<i>Health effects from radiofrequency electromagnetic fields: report of an independent Advisory Group on Non-ionising Radiation</i> (http://www.hpa.org.uk/radiation/publications/documents_of_nrp/abstracts/absd14-2.htm , accessed 25 September 2006)

What effects do mobile phones have on people's health?
 WHO Regional Office for Europe's Health Evidence Network (HEN)
 November 2006

Institution, year	Report
The United States National Council on Radiation Protection and Measurements, 2003	<p><i>Biological effects of modulated radio-frequency fields</i> (http://www.ncrppublications.org/index.cfm?fm=Product.Search&cid=2 , accessed 6 October 2006)</p> <p>(http://www.ncrppublications.org/index.cfm?fm=Product.AddToCart&pid=4191384437 , (executive summary) accessed 6 October 2006)</p>
United Kingdom Health Protection Agency, 2004	<p><i>Mobile phones and health 2004: report by the Board of the National Radiological Protection Board</i> (http://www.hpa.org.uk/radiation/publications/documents_of_nrp/abstracts/absd15-5.htm, accessed 25 September 2006)</p>
International Commission for Non-Ionizing Radiation Protection Standing Committee on Epidemiology, 2004	<p><i>Epidemiology of health effects of radiofrequency exposure</i> (http://www.icnirp.de/documents/epiRFreviewPublishedinEHPDec04.pdf, accessed 25 September 2006)</p>
National Radiological Protection Board, 2004	<p><i>Review of the scientific evidence for limiting exposure to electromagnetic fields (0–300 GHz)</i> (http://www.hpa.org.uk/radiation/publications/documents_of_nrp/pdfs/doc_15_3.pdf, accessed 6 October 2006)</p>
World Health Organization, 2004	<p><i>Sensitivity of children to electromagnetic fields exposure</i> (http://www.who.int/peh-emf/meetings/children_turkey_june2004/en/, accessed 25 September 2006)</p>

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