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Magnetic field exposure and neurodegenerative diseases – recent epidemiological studies

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Summary

Objectives: To analyse the results of recent studies not yet included in a 2003 report of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) on occupational exposure to low-frequency electromagnetic fields as potential risk factor for neurodegenerative diseases.

Methods: A literature search was conducted in the online databases of PubMed, ISI Web of Knowledge, DIMDI and COCHRANE, as well as in specialised databases and journals. Eight studies published between January 2000 and July 2005 were included in the review.

Results: The findings of these studies contribute to the evidence of an association between occupational magnetic field exposure and the risk of dementia. Regarding amyotrophic lateral sclerosis, the recent results confirm earlier observations of an association with electric and electronic work and welding. Its relationship with magnetic field exposure remains unsolved. There are only few findings pointing towards an association between magnetic field exposure and Parkinson's disease.

Conclusions: The epidemiological evidence for an association between occupational exposure to low-frequency electromagnetic fields and the risk of dementia has increased during the last five years. The impact of potential confounders should be evaluated in further studies.

Keywords: Occupational exposure – Electromagnetic fields – Neurodegenerative diseases – Amyotrophic lateral sclerosis – Alzheimer disease – Parkinson disease

Low-frequency electromagnetic fields mainly occur in connection with the generation, application and distribution of electric current. Significant sources of exposure for the population are high-voltage cables and other power supply lines, as well as electrical devices in households, or at the workplace. The usual domestic current in Europe has a frequency of 50 cycles per second (50 Hertz). As opposed to X-radiation, the energy content of these electromagnetic, alternating fields is not strong enough to rupture molecular bonds. Like the higher frequency fields used for mobile communication, they are thus termed non-ionising radiation.

Due to their physical properties, both components of electromagnetic fields, i.e. the electric and the magnetic field, are to be regarded as two separate fields in the low-frequency range. Since shielding against the electric field is easy, it is mainly the strength of the magnetic field that is decisive where exposure is concerned. Magnetic induction is measured in Tesla, or Mikrotesla (μT), respectively. Low-frequency magnetic fields penetrate the human body and in the case of very high intensities not prevalent in the environment, lead to malfunctions of nerve and muscle cells. These stimulative effects are scientifically founded and constitute the basis for the international standard limits valid for protecting the general population. Despite many decades of research, conflicting study results create uncertainty, however, as to whether low-frequency magnetic fields also present a health risk at intensities below these standard limits.

Among all the outcomes investigated in epidemiological studies of electromagnetic fields, childhood leukemia in relation to magnetic field exposure is the one for which there is most evidence of an association. A meta-analysis of the epidemiological studies carried out during the last twenty years showed that the risk of developing leukemia was approximately double for children who lived in homes with an average magnetic-field exposure exceeding 0.3 to 0.4 μT (Ahlbom 2000). Due to these results, the International Agency for Research on Cancer in 2001 classified low-frequency electromagnetic fields as possibly carcinogenic to humans (IARC 2002).

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With respect to other diseases, the data is less consistent. In some cases, the number of studies available is not sufficient to determine whether an association exists, while in other cases the findings are contradictory. In a 2003 review, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) summarized the findings of epidemiological studies of static and low-frequency electromagnetic fields published so far. The authors concluded that an etiological relation to low-frequency magnetic field exposure had not yet been established for any chronic disease (ICNIRP 2003). However, according to ICNIRP, epidemiological studies quite consistently indicated an association between occupational magnetic field exposure and the risk of amyotrophic lateral sclerosis (ALS). ALS is characterised by a progressive degeneration of the cortical and spinal motor nerve cells. With a prevalence of 4 to 7 in 100 000, it is a rare disease but it is the most frequent condition in the group of motor neuron diseases. Motor neuron diseases belong to the group of neurodegenerative diseases along with dementia and Parkinson's disease (Jellinger 2005). Besides genetic parameters and life-style factors, various environmental exposures are discussed as causes for neurodegenerative diseases (Brown 2005). Since some studies also indicated an increased risk of developing dementia among persons with occupational magnetic field exposure, the ICNIRP recommended further investigations into the relationship between magnetic field exposure and neurodegenerative diseases.

For the following review we searched the literature for epidemiological studies on neurodegenerative diseases and magnetic field exposure up to 2005 and not yet included in the ICNIRP review. We discuss their findings and compare the results to the pooled risk estimates given in the ICNIRP report.

Methods

Search strategy

The literature search was conducted in the online databases of PubMed, (http://www.ncbi.nlm.nih.gov), ISI Web of Knowledge (http://wos.consortium.ch), DIMDI (http://www.dimdi.de/static/de/db/index.htm), COCHRANE (http://www.informedhealthonline.org) and in the databases specialising in electromagnetic fields of Basel University (http://www.elmar.unibas.ch) and Aachen University (http://www.emf-portal.org) respectively. The following terms were searched individually or in combination: "neurodegenerative disease", "Alzheimer", "amyotrophic lateral sclerosis", "ALS", "Parkinson's disease", "parkinsonism", "exposure", "magnetic", "electromagnetic". In addition, the search was conducted in medical journals that are not recorded, or are only partially recorded in the above-mentioned databases. The comprehensiveness of the literature search was verified using reviews and the reference lists of other publications.

Inclusion criteria

We included epidemiological studies on humans investigating the relationship between exposure to low-frequency electromagnetic fields (3 to 300 Hz) and the risk of developing neurodegenerative diseases, published between January 2000 and July 2005 in peer-reviewed scientific journals in English or German. This time-frame was chosen in order to start with the pooled risk estimates presented in the 2003 ICNIRP review and to evaluate the findings of the epidemiological studies not yet included in this review.

Presentation of results

To facilitate comparison, we present the risk estimates for case-control studies and for cohort studies in graphs for each outcome (see fig. 1 to 3). For cohort studies we selected the risk estimate for the comparison between the cohort and the general population. For cohort studies without an external comparison and for case-control studies we selected the risk estimate given for the difference between the highest and the lowest exposure category. We did not consider it adequate to combine the results in a pooled analysis because of the important differences between the studies regarding design, sampling and exposure assessment.

Results

A total of eight studies with original data analyses were published between January 2000 and July 2005, fulfilling the above-mentioned inclusion criteria. As shown in the Tables (see Annex) and in Figures 1 to 3, five of these studies investigated several neurodegenerative diseases (Johansen 2000, Noonan 2002, Hakansson 2003, Feychting 2003, Park 2005) while three studies exclusively evaluated the risk of developing dementia (Li 2002; Harmanci 2003; Qiu 2004).

Findings of the recent studies

Johansen (2000) conducted a cohort study of the incidence of neurological diseases in 30 631 employees in Danish utility companies until 1993. Using a job-exposure matrix, participants in this study were classified in five categories according to their exposure to 50 Hz magnetic fields. The number of neurological diseases occurring in the cohort between 1978 and 1993 was compared with the anticipated figure for the total population by linking to the Danish National Register of Patients, and standardised incidence rate ratios (SIR) were

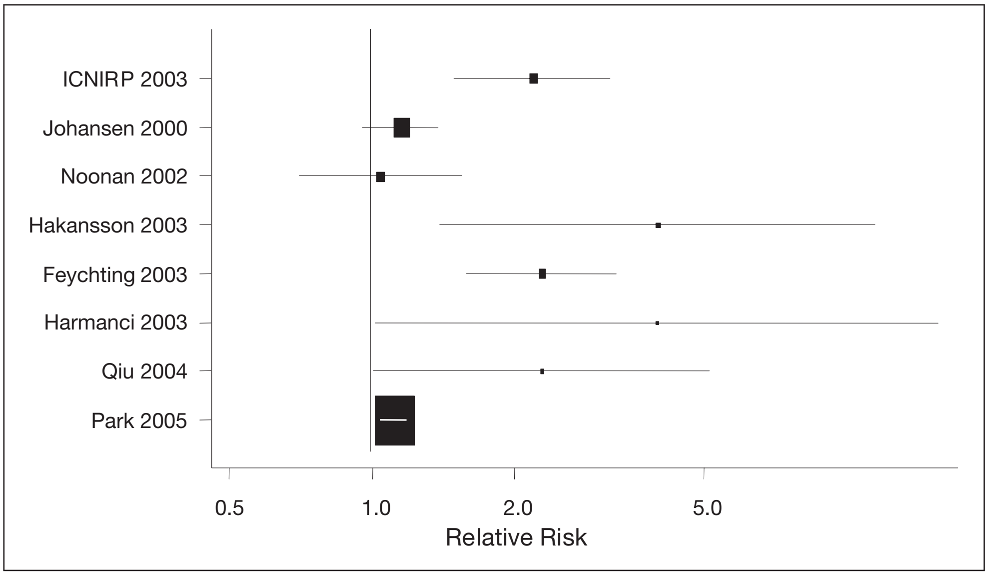

Figure 1 Occupational exposure to magnetic fields and the risk of Dementia/Alzheimer's disease

'Relative Risk' refers to the respective risk estimate provided by each study for the whole population or for men. Further details are given in Table 1 (see Annex).

calculated. When evaluating all cases of motor neuron diseases (ICD-8 348, 20 cases) an increased risk of statistical significance resulted for male employees in comparison with the Danish population. The SIR was 1.89 (95 % confidence interval: 1.16–2.93). For amyotrophic lateral sclerosis alone (ICD-8 348.09, 15 cases) a SIR of 1.72 resulted (95 % CI: 0.96–2.83). The risk of developing senile dementia (ICD-8 290.09, 122 cases) was not statistically significantly elevated in the group of employees compared to the general population (SIR: 1.16, 95 % CI: 0.96–1.39). For both outcomes, senile dementia and amyotrophic lateral sclerosis, the internal comparison showed a tendency towards a dose-response relationship (risk estimates with wide confidence intervals). For other neurological diseases, including Parkinson's disease, no statistically significantly increased risks were observed (for Parkinson's disease: SIR: 0.90, 95 % CI: 0.69–1.14). There were not enough female participants in the cohort to obtain reliable results for women.

Noonan et al. (2002) investigated cases of neurodegenerative diseases as a cause of death in all male deaths in the US State of Colorado between 1987 and 1996. They identified 1 556 deaths caused by Alzheimer's disease (ICD 331.0), 312 caused by ALS (ICD 335.2) and 1 477 caused by Parkinson's disease (ICD 332.0). Control persons without these diagnoses were selected from the death register and compared to the cases with respect to their occupation given on the death certificate. The exposure to magnetic fields was estimated using three different methods: a comparison of exposed versus not exposed; a comparison of highly exposed versus low exposed versus not exposed based on a combination of occupation and industry codes; and an approach with four exposure categories based on a job-exposure matrix. Persons were classified as exposed if they worked in "electrical occupations" such as electrical engineers, electricians and electric utility workers installing telephones or aerials. The risk of Alzheimer's disease for people with electrical occupations was estimated by an odds ratio of 1.05 (95 % CI: 0.71–1.56). Applying the other exposure assessment methods also did not reveal any increase in risk of Alzheimer's disease (see Tab. 1). For ALS, statistically significantly increased risks were observed with an odds ratio of 2.3 (95 % CI: 1.29–4.09) for the comparison between exposed and unexposed and of 1.75 (95 % CI: 1.00–3.06) for participants with definite or probable exposure. In contrast, there was no significantly increased risk of death due to ALS related to any exposure category of the job-exposure matrix (see Tab. 2). The risk of dying from Parkinson's disease was significantly higher in the upper exposure category (odds ratio: 1.50, 95 % CI: 1.02–2.19).

In a cohort study including more than 500 000 persons, Hakansson et al. (2003) investigated the mortality caused by neurodegenerative diseases in employees working in industrial branches with frequent exposure to magnetic fields, such as the automobile and metal-processing industries. The exposure assessment was based on a job-exposure matrix. During the period from 1985 to 1996, approximately 20 000 deaths occurred. Considering only the primary cause of death, there were no increased risks for Alzheimer's disease (ICD-9 331.0), ALS (ICD-9 335.2) or Parkinson's disease (ICD-9 332.0). Combining primary and contributing causes of death, the mortality risk due to Alzheimer's disease increased with rising magnetic field exposure category. The difference reached statistical significance in the highest exposure category with a relative risk of 4.04 (95 % CI: 1.40–11.66); however, only eight deaths occurred in this exposure category. The ALS death risk was also statistically significantly higher in this category (RR: 2.16, 95% CI: 1.01–4.66), with indications of an increase in risk at higher exposure levels. The Parkinson risk was not elevated (see Tab. 3).

The cohort study by Feychting et al. (2003) was based on all individuals included in the Swedish census in 1980 who were economically active in 1970 or 1980. The average magnetic field exposure in 1970 and 1980 was estimated using a job-exposure matrix. All deaths with neurodegenerative disease as an underlying or contributing cause were identified in the Cause of Death Registry. For persons who had worked at one of these two time points in an occupation with a magnetic field exposure exceeding 0.5 μT, a significant increase in the risk of dying from Alzheimer's disease (ICD-9 331.0) was shown with risk estimates between 1.3 and 2.3. For men who were exposed to an average magnetic field exceeding 0.3 μT in 1970 and 1980, the death risk was 1.5 (95% CI: 1.1–2.1). In the group with the highest exposure level (>0.5 μT) it was 2.3 (95% CI: 1.6–3.3). The risk of dying from amyotrophic lateral sclerosis (ICD-9 335.2) or Parkinson's disease (ICD-9 332.0) was not generally associated with the magnetic field exposure. There were only a few women in the two highest exposure categories, therefore the effect estimates for women have wide confidence intervals.

In a population-based case-control study in Taipei, Li et al. (2002) examined 290 persons over the age of 65 years with a cognitive impairment and 580 control persons regarding magnetic field exposure. Persons were judged as having a cognitive impairment if they made more than five errors in a neuropsychological test with ten questions. A diagnosis for dementia was not made. The participants were asked about their earlier occupations and divided into exposure categories according to the type and duration of their activity. In addition, the distance was measured between their homes and the next high-voltage transmission line. The analysis did not show an increased risk of cognitive impairment, neither related to their occupational or residential magnetic field exposure, nor to the combination of these two exposures.

Harmanci et al. (2003) conducted a case-control study in Istanbul based on the Turkish Alzheimer Prevalence Study. Fifty-seven patients with clinically diagnosed Alzheimer's disease (DSM-III-R) were compared with 127 cognitively non-impaired control persons. Their magnetic field exposure was derived from information supplied by relatives on their occupational activity and on the presence of electric heating. A total of 10 persons (5.4%) was classified as having occupational exposure. Thirty-one participants (17%) were living in a house with electric heating. After adjustment for school education as an indicator for social status and after controlling for other relevant factors, an odds ratio of 4.02 (95% CI: 1.02–15.78) resulted for occupational exposure and an odds ratio of 2.77 (95% CI: 1.12–6.85) for persons with electrical heating.

In another cohort study from Sweden, Qiu et al. (2004) followed about 1000 persons over the age of 75 who lived in Stockholm and were initially not suffering from dementia from 1987 to 1996. The life-time occupational exposure to low-frequency magnetic fields was assessed on the basis of interviews, a job-exposure matrix and measurements on historical equipment. During the period under observation, dementia was diagnosed in 265 persons, including 202 with Alzheimer's disease (DSM-III-R). A large number of factors were controlled for in the analysis, for instance, level of education, alcohol and tobacco consumption, vascular diseases, apolipoprotein E-genotype as well as mental and social activity. For men, a magnetic field exposure of over 0.20 μT in their main occupation was linked with a significantly increased risk of dementia (RR: 2.0, 95% CI: 1.1–3.7). For women, no increase in risk was observed.

In July 2005, Park et al. published the findings of a register study on mortality due to neurodegenerative diseases in persons with occupational exposures to chemicals, welding fumes and magnetic fields in 22 American states. Death certificate information for all deaths occurring in the years 1992 to 1998 was obtained using the National Occupational Mortality Surveillance System. Eighty-seven priority occupations with statistically significant elevated death risks for neurodegenerative diseases were identified from an earlier study by Schulte et al. (1996). Occupations were classified regarding magnetic fields using a job-exposure matrix and divided into ten equal exposure intervals. A significantly higher risk of dying from Alzheimer's disease (ICD-9 331.0) resulted for occupations in the highest exposure stratum. Relative to the lowest exposure category the mortality odds ratio was 1.12 (95% CI: 1.05–1.20). With respect to motor neuron disease (ICD-9 335.2) and Parkinson's disease (ICD-9 332.0), significantly increased risks were only shown for persons who had died before the age of 65 years (mortality odds ratio: 1.63, 95% CI: 1.10–2.39 or 1.87, 95% CI: 1.14–2.98, respectively).

Discussion

As in the studies summarized in the ICNIRP review of 2003, the studies on neurodegenerative diseases published between January 2000 and July 2005 mainly assessed occupational magnetic field exposure. However, the studies are heterogeneous for several parameters: data sources, population samples and the analytic methods varied. The methods for assessing the magnetic field exposure also differed, and the cut-off values of the exposure categories varied. Three studies were confined to occupational groups with a high magnetic field exposure; five studies were based on the general population. Since the cohort studies by Hakansson (2003) and Feychting (2003) were carried out in Sweden at almost the same time, the study populations partly overlap.

When interpreting the results of the studies, one should bear in mind that the investigations mainly provide information on the risk to men who are occupationally exposed. Exposure during non-occupational activity has hardly been investigated yet and the number of women in occupations involving high magnetic field exposure is low. The quality of the exposure assessment obtained in the recent investigations greatly differs among the studies. When classifying exposure according to occupations there is a danger of misclassification, especially when they are assessed only at one time point as in death certificates. As a result, the differences in risk between the groups could be blurred. Also, the recording of the health outcomes is prone to uncertainty. There is no register for recording neurodegenerative diseases and, in particular, dementia diagnoses are not always recorded on death certificates (Feychting 2003). Both exposure and outcome misclassification is expected to be non-differential. Thus, the introduction of false-positive associations is unlikely. In contrast, bias could follow from inadequate dealing with potential confounding factors.

Exposure to lead, aluminium, manganese, and other chemicals is also discussed as a cause of neurodegenerative diseases. Moreover, differences in life-style or social status could play a role. These factors are recorded particularly insufficiently in register studies.

Finally, studies with many different occupational groups and outcomes often report selectively significant associations, especially when sub-groups are also analysed. Studies of this nature, e. g. Park (2005), have an explorative character and may not be understood as evidence for causal associations. One can assume that studies of this kind also have a greater likelihood of being published if they observed a statistically significant finding (publication bias).

Dementia/Alzheimer's disease

Five of the seven studies published between January 2000 and July 2005 that investigated the risk of dementia in relation to occupational magnetic field exposure indicated an association, while two studies did not. In the study conducted by Li (2002) participants were examined with a neuropsychological test to assess whether a cognitive impairment existed, they were not diagnosed with dementia. Therefore, we did not include their results in the comparison shown in Figure 1. In the studies investigating dementia the assessment of the diagnosis was not uniform: Qiu (2004) and Harmanci (2003) based the diagnosis of Alzheimer's disease on clinical examinations. The Danish cohort study by Johansen (2000) used diagnoses from a patient register, whereas the three other cohort studies and the US case-control study evaluated death certificates. The results of the present studies show some heterogeneity (see fig. 1). Some of the differences may be explained by the fact that dementia is possibly recorded to a lesser extent in death certificates. Cultural differences in diagnosing dementia or Alzheimer's disease could also play a role. For example, the Swedish cohort study in the engineering industry by Hakansson (2003) reported only two Alzheimer diagnoses in 1 000 deaths, whereas the large occupational survey from the United States reported nearly two per cent of deaths with a diagnosis of Alzheimer's disease (Park 2005). A broader definition of illness could dilute a very specific effect on, for example, Alzheimer's disease. This might explain the higher effect estimates observed in the Swedish studies compared to the US studies. Another reason for inhomogeneity could be the diverse assessment of exposure, as is clear in Noonan's (2002) case-control study, which shows differing results according to the three methods of exposure classification.

Due to the low number of cases and the low number of highly exposed individuals, heterogeneous study results can be expected. However, with overlapping confidence intervals, most of the studies observed increased risks of dementia in the (differently defined) highest categories of magnetic field exposure. Five of the six recent studies with more than two exposure categories provide some support for an exposure-response relationship; only the study of Noonan (2002) does not. This could give qualitative support to the results of the earlier studies reviewed by ICNIRP in 2003, where five publications on the risk of developing dementia were listed with a pooled risk estimate of 2.2 (95 % CI: 1.5–3.2). Due to methodical deficiencies of the studies and inconsistency in the results, the ICNIRP advised against drawing firm conclusions regarding the causality of the association.

Motor neuron diseases/amyotrophic lateral sclerosis (ALS)

Of the five recent studies investigating the association between occupational magnetic field exposure and ALS or motor neuron diseases, the three studies with smaller numbers of death due to motor neuron diseases showed significantly increased risks for persons in the highest exposure categories (see fig. 2). However, both studies with a large number of deaths from ALS or motor neuron disease observed no overall increase in risk (Feychting 2003; Park 2005). Still, Park et al. found some evidence for an exposure-response relationship in the subgroup of deaths at a younger age. In the ICNIRP report, a pooled ALS risk of 1.5 (95 % CI: 1.2–1.7) was calculated from seven studies with a pooled number of cases comparable to those of the general population cohort study in Sweden (Feychting 2003).

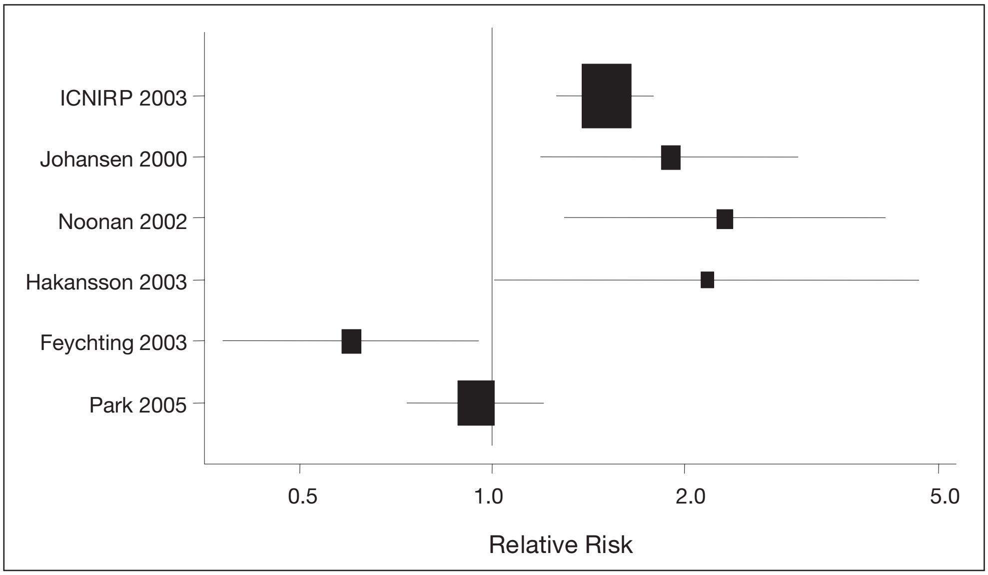

Figure 2 Occupational exposure to magnetic fields and the risk of Motor neuron disease/ Amyotrophic Lateral Sclerosis

'Relative Risk' refers to the respective risk estimate provided by each study for the whole population or for men. Further details are given in Table 2 (see Annex).

The discrepancy between the results can not be explained by a less reliable exposure assessment in the Feychting study – firstly, since the occupational exposure was based on a job-exposure matrix developed on workplace measurements in a former case-control study and secondly, since the information about occupation stemmed from census data, as is also the case in the cohort studies of Hakansson (2003) and Noonan (2002). The utility cohort study by Johansen (2000) probably had the most reliable information on cohort members' occupations because they could use the company files and employment records, which included duration and calendar periods of employment.
Noticeably, Feychting (2003) observed an association of ALS deaths with welding and also a higher risk for the combined group of telephone and telegraph installers, radio and television assemblers and electricians. The study did not show a higher risk in the jobs classified as highest exposed, such as railway engine drivers; glass, pottery and tile workers; or forest workers. These job categories were rarely included (or in low numbers only) in the other occupational studies on electromagnetic fields. For example, in contrast to the Feychting study, most workers in the highest exposed class of the cohort study by Hakansson (2003) were welders.
The case-control study of Noonan (2002) defined exposure in more than one way. Limiting the definition of exposed persons to electricians and related jobs resulted in an increase in the ALS risk. This increase did not result when exposure assessment was based on a job-exposure matrix. So, as Feychting concluded, ALS seems to be associated with some occupations, mainly work in electrical or electronic industries and in welding.
Most authors indicate that the association with magnetic fields may not be causal, because confounding by more frequent electric shocks in occupational groups with a higher magnetic field exposure cannot be excluded. There have been repeated reports on increased risks of motor neuron diseases after accidents caused by electricity, or electric shocks (for instance, Deapen et al. 1986; Gallagher et al. 1991). The possibility of confounding by electric accidents was evaluated in two of the recent studies on ALS risk: Noonan (2002) concluded that confounding was probable, yet Feychting (2003) did not come to that conclusion as their results did not support that theory. In the Feychting study the occupational group with the highest ALS risk was welders and not electricians.
Considering the above findings, estimated workday mean magnetic flux density may not be the adequate exposure parameter with respect to elevated ALS risks in some of the occupational groups. We do not know the role of mean versus peak exposure, nor of exposure to electric fields, to different frequencies (16.66 Hz of Swedish railways vs. 50 Hz of power lines), or the role of co-exposures with high-frequency electromagnetic fields, or whatever characteristics could be of biologic relevance.

Parkinson's disease
The risk of developing Parkinson's disease was investigated in five recent studies (see Fig. 3). Evidence for an association with magnetic field exposure was observed in the study conducted by Noonan (2002) and in the subgroup of death at age younger than 65 years in the study of Park (2005). The ICNIRP report of 2003 did not assess the risk of developing Parkinson's disease associated with magnetic fields. In three earlier studies no associations had been observed (Johansen 1991; Savitz 1998a; 1998b).
Along with the mainly negative results of the latest studies, there is little indication at present of an increased risk for Par-

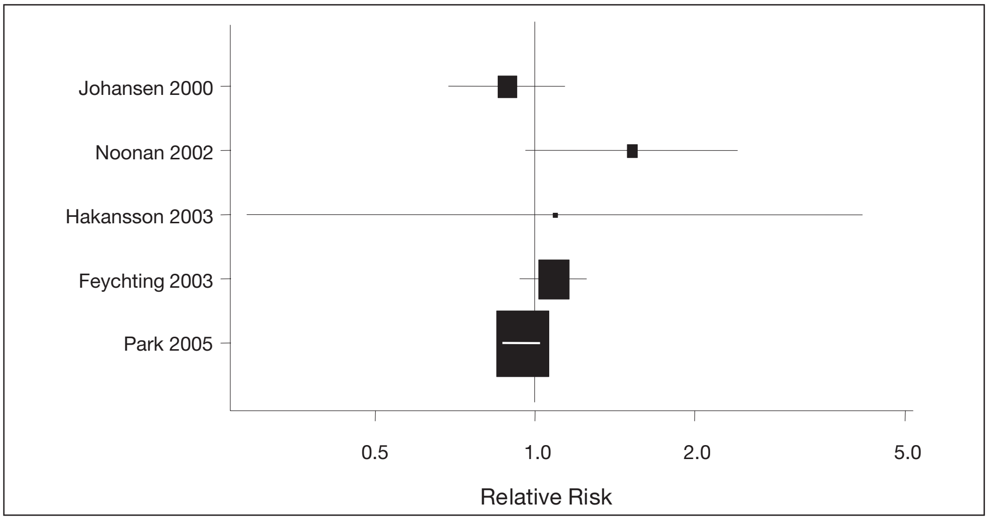

Figure 3 Occupational exposure to magnetic fields and the risk of Parkinson's disease

'Relative Risk' refers to the respective risk estimate provided by each study for the whole population or for men. Further details are given in Table 3 (see Annex).

kinson's disease in occupations with magnetic field exposure. In some studies, an increased risk was observed amongst welders who, besides being exposed to electromagnetic fields at their workplace, are also subjected to other potentially neurotoxic exposures (e. g. metallic fumes, chemicals).

Conclusions

The evidence of an association between occupational magnetic field exposure and dementia has increased since the ICNIRP report was published in 2003, as the majority of the latest studies provide indications of an association. Regarding ALS risk, the association with electric and electronic work and welding that had been observed quite consistently in earlier studies was confirmed. Including other occupational groups estimated to have a high exposure to low-frequency electromagnetic fields has shown that the relationship between ALS risk and magnetic field exposure is still an unresolved issue. For future occupational studies we should know more about the exposure characteristics and possibly relevant concomitants. Few studies have shown an association between magnetic field exposure and Parkinson's disease until now.

Even if the associations that have been observed were to be confirmed, no statements can be made on the risks for the general population, as non-occupational forms of exposure have only received limited investigation.

Zusammenfassung

Magnetfeldexposition und neurodegenerative Erkrankungen – aktuelle epidemiologische Studien

Fragestellung: Mehrere epidemiologische Studien haben Hinweise auf ein erhöhtes Risiko neurodegenerativer Erkrankungen bei Personen mit beruflicher Exposition gegenüber niederfrequenten elektromagnetischen Feldern geliefert. Eine Übersicht über diese Studien wurde im Jahr 2003 von der ICNIRP publiziert. In der vorliegenden Übersichtsarbeit werden die seither publizierten Studienresultate zu dieser Fragestellung dargestellt und diskutiert.

Methoden: Die Literaturrecherche erfolgte in den Online-Datenbanken PubMed, ISI Web of Knowledge, DIMDI und COCHRANE sowie in spezialisierten Datenbanken und Fachzeitschriften. In der Übersicht berücksichtigt wurden epidemiologische Studien, die von Januar 2000 bis Juli 2005 publiziert worden sind.

Ergebnisse: Im untersuchten Zeitraum fanden sich acht epidemiologische Studien zum Thema Magnetfeldexposition und neurodegenerative Erkrankungen. Ihre Ergebnisse bestätigen frühere Beobachtungen eines Zusammenhangs zwischen beruflicher Magnetfeldbelastung und Demenzrisiko. Hinsichtlich amyotropher Lateralsklerose bestätigen sie das bereits mehrfach beobachtete erhöhte Risiko bei Elektrikern und Elektronikern sowie bei Schweissern, zeigen aber keinen eindeutigen Zusammenhang mit der Höhe der Magnetfeldexposition. In Bezug auf die Parkinson-Krankheit wurden nur vereinzelt erhöhte Risiken bei beruflicher Magnetfeldexposition beobachtet.

Schlussfolgerungen: Die epidemiologische Evidenz für einen Zusammenhang zwischen beruflicher Magnetfeldbelastung und dem Risiko von Demenzerkrankungen hat in den letzten fünf Jahren zugenommen. Der Einfluss potenzieller Störfaktoren sollte in gezielt angelegten Studien überprüft werden.

Résumé

Maladies neurodégénératives et champs magnétiques – nouvelles études épidémiologiques

Objectifs: Plusieurs études ont indiqué un risque élevé de maladies neurodégénératives chez des personnes étant exposées, sur leur lieu de travail, à des champs électromagnétiques de basse fréquence. Cet article analyse des études récentes n'ayant pas été inclues dans le rapport de la Commission Internationale de Protection contre les rayonnements non ionisants (ICNIRP, 2003).

Méthodes: Recherche de littérature dans PubMed, ISI Web of Knowledge, DIMDI et COCHRANE ainsi que dans des bases de données et revues spécialisées. Huit études parues entre janvier 2000 et juillet 2005 sont analysées.

Résultats: Les résultats de ces études confirment un lien entre l'exposition aux champs magnétiques au travail et le risque de démence. Ils confirment un risque de sclérose latérale amyotrophique élevé pour les professions d'électricien, d'électronicien et de soudeur, sans rapport clair avec la puissance du champ magnétique. Elles n'apportent que peu d'indications en faveur d'un lien entre une exposition aux champs magnétiques et une augmentation des risques de maladie de Parkinson.

Conclusions: L'augmentation du risque de démence lié à l'exposition aux champs magnétiques au travail s'est confirmé au cours des cinq dernières années. L'influence potentielle de facteurs de confusion devrait être vérifiée dans des études ultérieures.

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Annex

Table 1 Main Characteristics and Findings of Studies on Occupational Magnetic Field Exposure and Dementia

Reference	Study design, region/country	Study population, database, total number	Study period	Outcome, total number of cases	Strength of association* (95 % Confidence Interval)	Definition and estimation of exposure
Johansen 2000	Cohort study Denmark	Male and female employees in Danish utility companies, hospital discharge records of the Danish National Register of Patients, n = 30631	1978–1993	Senile dementia Men: n = 122 Women: n = 6	Men: SIR: 1.16 (0.96–1.39) Exposure 0.1–0.29 µT: RR: 1.00 (0.51–1.95) Exposure 0.3–0.99 µT: RR: 1.15 (0.60–2.19) Exposure >1 µT: RR: 1.43 (0.74–2.77) Women: no risk increase	Job-exposure matrix
Noonan et al. 2002	Case-control study State of Colorado, USA	Male population of Colorado, death certificates	1987–1996	Deaths from Alzheimer's disease n = 1556 Controls n = 1556	Electrical occupation: OR: 1.05 (0.71–1.56) Possible exposure: OR: 1.15 (0.95–1.39) Definite or probable exposure: OR: 1.21 (0.83–1.76) Exposure 0.10–0.19 µT: OR: 0.95 (0.76–1.19) Exposure 0.20–0.29 µT: OR: 0.83 (0.63–1.10) Exposure >0.30 µT: OR: 1.01 (0.68–1.49)	Dichotomous (electrical vs. nonelectrical occupation) Combination of occupation and industry codes Job-exposure matrix
Hakansson et al. 2003	Cohort study Sweden	Swedish engineering industry workers, Causes of Death Registry, n = 718221	1985–1996	Deaths from Alzheimer's disease n = 40	Men and Women: Exposure 0.16–0.25 µT: RR: 1.34 (0.55–3.25) Exposure 0.25–0.53 µT: RR: 2.25 (0.80–6.30) Exposure >0.53 µT: RR: 4.04 (1.40–11.66)	Job-exposure matrix
Feychting et al. 2003	Cohort study Sweden	General population, Causes of Death Registry n = 4812646	1981–1995	Deaths from Alzheimer's disease n = 1321 (men) n = 679 (women)	Men: Exposure >0.3 µT: RR: 1.5 (1.1–2.1) Exposure >0.5 µT: RR: 2.3 (1.6–3.3) Women: Exposure >0.3 µT: RR: 1.1 (0.7–1.6) Exposure >0.5 µT: RR: 2.3 (1.0–5.2)	Job-exposure matrix Men: occupation in 1970 and 1980 Women: occupation in 1970
Li et al. 2002	Case-control study Taipei	Individuals >65 years of age, Population Registry	1993–1997	Persons with cognitive impairment n = 290 Controls n = 580	Men and women: Longest-held occupation: Electrical >20 J.: OR: 1.1 (0.6–1.9) Last occupation: Electrical >20 J.: OR: 1.3 (0.7–2.3)	Classification according to occupation (lifetime occupations)
Harmanci et al. 2003	Case-control study Istanbul	Individuals >70 years of age, Population Registry	Not specified	Alzheimer's disease n = 57 Controls n = 127	Men and women: Longest-held occupation: „high exposure": OR: 4.02 (1.02–15.78)	Classification according to occupation
Qiu et al. 2004	Cohort study Stockholm	Individuals >75 years of age, Population Registry n = 931	1987/89 to 1994/96	Dementia n = 265 Alzheimer's disease n = 202	Longest-held occupation: Men: All types of dementia: Exposure >0.2 µT: RR: 2.0 (1.1–3.7) Alzheimer's disease: Exposure >0.2 µT: RR: 2.3 (1.0–5.1) Women: All types of dementia: Exposure >0.2 µT: RR: 0.8 (0.6–1.1) Alzheimer's disease: Exposure >0.2 µT: RR: 0.8 (0.5–1.1)	Job-exposure matrix & spot measurements
Park et al. 2005	Registry study 22 states, USA	87 occupations, National Occupational Mortality Surveillance System, deaths with estimate of magnetic field exposure: n = 2392040 Age <65 years n = 626683	1992–1998	Deaths from Alzheimer's disease n = 45379 Age <65 years n = 641 Deaths from presenile dementia n = 25999 Age <65 years n = 296	Exposure >0.9 µT: MOR: 1.12 (1.05–1.20) Exposure >0.9 µT: MOR: 0.85 (0.46–1.49) Exposure>0.9 µT: MOR: 1.08 (0.99–1.18) Exposure >0.9 µT: MOR: 1.30 (0.57–2.69)	Job-exposure matrix & measurements

* = Risk estimate as provided by each study. For all mortality studies we refer to the risk estimates given for underlying or contributing causes of death combined. SIR: standardised incidence rate ratio, RR: relative risk, OR: odds ratio, MOR: mortality odds ratio, µT: microtesla.

Table 2 Main Characteristics and Findings of Studies on Occupational Magnetic Field Exposure and Motor Neuron Disease

Reference	Study design, region/country	Study population, database, Total number	Study period	Outcome, Number of Cases (Total)	Strength of association* (95 % Confidence Interval)	Definition and estimation of exposure
Johansen 2000	Cohort study Denmark	Male and female employees in Danish utility companies, hospital discharge records of the Danish National Register of Patients n = 30631	1978–1993	All motor neuron diseases n = 20 (men) ALS n = 15 (men) n = 0 (women)	Men (all motor neuron diseases): SIR: 1.89 (1.16–2.93) Exposure 0.1–0.29 μT: RR: 0.86 (0.16–4.71) Exposure 0.3–0.99 μT: RR: 1.27 (0.26–6.32) Exposure >1 μT: RR: 1.56 (0.29–8.53) Men (ALS only): SIR: 1.72 (0.96–2.83) Women: no risk increase	Job-exposure matrix
Noonan et al. 2002	Case-control study State of Colorado, USA	Male population of Colorado, death certificates	1987–1996	Deaths from ALS n = 312 Controls n = 1248	Electrical occupation: OR: 2.3 (1.29–4.09) Possible exposure: OR: 1.18 (0.83–1.67) Definite or probable exposure: OR: 1.75 (1.00–3.06) Exposure 0.10–0.19 μT: OR: 0.79 (0.54–1.15) Exposure 0.20–0.29 μT: OR: 1.21 (0.75–1.93) Exposure >0.30 μT: OR: 0.77 (0.37–1.59)	Dichotomous (electrical vs. non-electrical occupation) Combination of occupation and industry codes Job-exposure matrix
Hakansson et al. 2003	Cohort study Sweden	Swedish engineering industry workers, Causes of Death Registry n = 718221	1985–1996	Deaths from ALS n = 97	Men and women: Exposure 0.16–0.25 μT: RR: 1.58 (0.88–2.81) Exposure 0.25–0.53 μT: RR: 1.95 (0.97–3.92) Exposure >0.53 μT: RR: 2.16 (1.01–4.66)	Job-exposure matrix
Feychting et al. 2003	Cohort study Schweden	General population, Cause of Death Registry n = 4812646	1981–1995	Deaths from ALS n = 1411 (men) n = 554 (women)	Men: Exposure >0.3 μT: RR: 0.8 (0.6–1.1) Exposure >0.5 μT: RR: 0.6 (0.4–1.0) Women: Exposure >0.3 μT: RR: 0.6 (0.4–1.1) Exposure >0.5 μT: not calculated	Job-exposure matrix Men: occupation in 1970 and 1980 Women: occupation in 1970
Park et al. 2005	Registry study 22 states, USA	87 occupations, National Occupational Mortality Surveillance System, deaths with estimate of magnetic field exposure: n = 2392040 age <65 years n = 626683	1992–1998	Deaths from motor neuron diseases n = 5965 Age <65 years n = 2120	Exposure >0.9 μT: MOR: 0.94 (0.73–1.20) Exposure >0.9 μT: MOR: 1.63 (1.10–2.39)	Job-exposure matrix & measurements

* = Risk estimate as provided by each study. For all mortality studies we refer to the risk estimates given for underlying or contributing causes of death combined. SIR: standardised incidence rate ratio, RR: relative risk, OR: odds ratio, MOR: mortality odds ratio, ALS: amyotrophic lateral sclerosis, μT: microtesla.

Table 3 Main Characteristics and Findings of Studies on Occupational Magnetic Field Exposure and Parkinson's Disease

Reference	Study design, region/country	Study population, database, total number	Study period	Outcome, Number of Cases (total)	Strength of association* (95 % Confidence Interval)	Definition and estimation of exposure
Johansen 2000	Cohort study Dänemark	Male and female employees in Danish utility companies, hospital discharge records of the Danish National Register of Patients n = 30631	1978–1993	Parkinson's disease: Men: n = 64 Women: n = 4	Men: SIR: 0.90 (0.69–1.14) Exposure 0.1–0.29 μT: RR: 0.89 (0.42–1.87) Exposure 0.3–0.99 μT: RR: 0.68 (0.31–1.49) Exposure >1 μT: RR: 0.64 (0.26–1.54) Women: no risk increase	Job-exposure matrix
Noonan et al. 2002	Case-control study US-Bundesstaat Colorado	Male population of Colorado, death certificates	1987–1996	Deaths from Parkinson's disease n = 1477 Controls n = 1477	Electrical occupation: OR: 1.55 (0.98–2.45) Possible exposure: OR: 1.17 (0.96–1.42) Definite or probable exposure: OR: 1.76 (1.17–2.65) Exposure 0.10–0.19 μT: OR: 1.16 (0.92–1.45) Exposure 0.20–0.29 μT: OR: 1.04 (0.78–1.37) Exposure >0.30 μT: OR: 1.50 (1.02–2.19)	Dichotomous (electrical vs. non-electrical occupation) Combination of occupation and industry codes Job-exposure matrix
Hakansson et al. 2003	Cohort study Sweden	Swedish engineering industry workers, Causes of Death Registry n = 718221	1985–1996	Deaths from Parkinson's disease n = 45	Men and women: Exposure 0.16–0.25 μT: RR: 1.89 (0.90–4.00) Exposure 0.25–0.53 μT: RR: 0.26 (0.03–2.08) Exposure >0.53 μT: RR: 1.11 (0.29–4.18)	Job-exposure matrix
Feychting et al. 2003	Cohort study Sweden	General population, Cause of Death Registry n = 4812646	1981–1995	Deaths from Parkinson's disease n = 5136 (men) n = 1153 (women)	Men: Exposure >0.3 μT: RR: 1.1 (0.9–1.2) Exposure >0.5 μT: not calculated Women: Exposure >0.3 μT: RR: 0.8 (0.6–1.1) Exposure >0.5 μT: not calculated	Job-exposure matrix Men: occupation in 1970 und 1980 Women: occupation in 1970
Park et al. 2005	Registry study 22 states, USA	87 occupations, National Occupational Mortality Surveillance System, deaths with estimate of magnetic field exposure: n = 2392040 Age <65 years n = 626683	1992–1998	Deaths from Parkinson's disease n = 31797 Age <65 years n = 696	Exposure >0.9 μT: MOR: 0.96 (0.88–1.04) Exposure >0.9 μT: MOR: 1.87 (1.14–2.98)	Job-exposure matrix & measurements

* = Risk estimate as provided by each study. For all mortality studies we refer to the risk estimates given for underlying or contributing causes of death combined. SIR: standardised incidence rate ratio, RR: relative risk, OR: odds ratio, MOR: mortality odds ratio, μT: microtesla.