Evaluation of the literature on high-voltage power lines and cancer in adults

No. 2022/14Ae, The Hague, 29 June 2022

Background document to:
Power lines and health: cancer in adults
No. 2022/14e, The Hague, 29 June 2022

Gezondheidsraad

Contents

1 Introduction

In this background document to the advisory report *Power lines and health: cancer in adults,* drafted by the Electromagnetic Fields Committee of the Health Council of the Netherlands, chapter 2 describes the search strategies the Committee has used and how relevant papers have been selected.
In chapter 3, the Committee describes the protocol it followed in order to analyse the data.
Chapter 4 features tables presenting the key data for all relevant papers by topic.
Finally, in chapter 5 the Committee describes the meta-analyses it has carried out and presents the results. The main conclusions can be found in the advisory report.

2 Search strategy

Searches were performed in the PubMed and EMF Portal databases for publications on epidemiological research into cancer in general and different types of cancer, and exposure to extremely low frequency magnetic fields or distance to high-voltage power lines. Additional information on the search strategy is provided below: the search terms, the date the search was performed and the number of papers found. A number of papers were also found via other sources: reviews, reference lists and own literature collections. The papers found were selected for further analysis based on title. The relevant information was retrieved and transferred to an Excel file. In a number of cases, examination of the full text revealed that some publications did not contain the information sought or the research did not meet the criteria for inclusion in the analysis (see the protocols in chapter 3). The number of papers ultimately included in the analyses is stated for each type of cancer. The relevant information from these papers can be found in the tables in chapter 3.

PubMed

Searched for: ("extremely low frequency" OR "magnetic fields" OR "electromagnetic fields" OR "power line" OR "power lines" OR ELF) NOT (epithelial lining fluid OR ELF-phosphatase) AND cancer AND epidemiol* OR case-control OR cohort OR cross-sectional).

Performed on 10-15-2017 with updates on 02-09-2020 and 25-01-2022. Result: 1119 papers. Selected based on title: 275 papers.

Searched for: (("extremely low frequency" OR "magnetic fields" OR "electromagnetic fields" OR "power line" OR "power lines" OR ELF) NOT (epithelial lining fluid OR ELF-phosphatase) AND (leukaemia OR leukemia) AND epidemiol*) not ("childhood" OR "children").

Performed on 25-01-2022. Result: 192 papers. Selected based on title: 83 papers.

EMF Portal

Searched for: Keyword: Cancer; Topic: Epidemiologic studies; Frequency range: Power frequencies (50/60 Hz); Time span: Complete time span.

Performed on 15-07-2019. Result: 1152 papers. Selected based on title: 268 papers.

Searched for: Keyword: Leukaemia; Topic: Epidemiologic studies; Frequency range: Power frequencies (50/60 Hz); Time span: Complete time span.

Performed on 25-01-2022. Result: 214 papers. Selected based on title: 32 papers.

Leukaemia general, residential:

From sources other than PubMed and EMF Portal: 1 paper. Total full text analysis: 20 papers. Criteria for inclusion in analysis not met: 12 papers. In report: 8 papers.

Leukaemia general, occupational:
From sources other than PubMed and EMF Portal: 21 papers. Total full text analysis: 62 papers. Criteria for inclusion in analysis not met: 32 papers. In report: 30 papers.

Acute myeloid leukaemia (AML), residential:
Subselection of papers on leukaemia. In report: 6 papers.

Acute myeloid leukaemia (AML), occupational:
Subselection of papers on leukaemia. In report: 17 papers.

Breast cancer in women, residential:
From sources other than PubMed and EMF Portal: 13 papers. Total full text analysis: 19 papers. Criteria for inclusion in analysis not met: 1 paper. In report: 18 papers.

Breast cancer in women, occupational:
From sources other than PubMed and EMF Portal: 15 papers. Total full text analysis: 29 papers. Criteria for inclusion in analysis not met: 10 papers. In report: 19 papers.

Breast cancer in men, occupational:
From sources other than PubMed and EMF Portal: 13 papers. Total full text analysis: 19 papers. Criteria for inclusion in analysis not met: 6 papers. In report: 13 papers.

Brain cancer, residential:
From sources other than PubMed and EMF Portal: 5 papers. Total full text analysis: 14 papers. Criteria for inclusion in analysis not met: 6 papers. In report: 8 papers.

Brain cancer, occupational:
From sources other than PubMed and EMF Portal: 39 papers. Total full text analysis: 56 papers. Criteria for inclusion in analysis not met: 24 papers. In report: 43 papers.

Testicular cancer, residential:
From sources other than PubMed and EMF Portal: 0 papers. Total full text analysis: 2 papers. Criteria for inclusion in analysis not met: 0 papers. In report: 2 papers.

Testicular cancer, occupational:
From sources other than PubMed and EMF Portal: 15 papers. Total full text analysis: 18 papers. Criteria for inclusion in analysis not met: 8 papers. In report: 10 papers.

Pancreatic cancer, residential:
From sources other than PubMed and EMF Portal: 0 papers. Total full text analysis: 2 papers. Criteria for inclusion in analysis not met: 0 papers. In report: 2 papers.

Pancreatic cancer, occupational:
From sources other than PubMed and EMF Portal: 8 papers. Total full text analysis: 15 papers. Criteria for inclusion in analysis not met: 4 papers. In report: 11 papers.

Lung cancer, residential:
From sources other than PubMed and EMF Portal: 0 papers. Total full text analysis: 2 papers. Criteria for inclusion in analysis not met: 0 papers. In report: 2 papers.

Lung cancer, occupational:
From sources other than PubMed and EMF Portal: 11 papers. Total full text analysis: 20 papers. Criteria for inclusion in analysis not met: 7 papers. In report: 13 papers.

Prostate cancer, residential:
From sources other than PubMed and EMF Portal: 0 papers. Total full text analysis: 2 papers. Criteria for inclusion in analysis not met: 0 papers. In report: 2 papers.

Prostate cancer, occupational:
From sources other than PubMed and EMF Portal: 8 papers. Total full text analysis: 14 papers. Criteria for inclusion in analysis not met: 5 papers. In report: 9 papers.

Skin melanomas, residential:
From sources other than PubMed and EMF Portal: 0 papers. Total full text analysis: 4 papers. Criteria for inclusion in analysis not met: 0 papers. In report: 4 papers.

Skin melanomas, occupational:
From sources other than PubMed and EMF Portal: 0 papers. Total full text analysis: 8 papers. Criteria for inclusion in analysis not met: 2 papers. In report: 6 papers.

3 Protocol for the systematic analysis of epidemiological data

Searches occupational and residential exposure

- Search PubMed using (without time limit) for:
    - ("extremely low frequency" OR "magnetic fields" OR "electromagnetic fields" OR "power line" OR "power lines" OR ELF) NOT (epithelial lining fluid OR ELF-phosphatase) AND cancer AND epidemiol* OR case-control OR cohort)
    - ("extremely low frequency" OR "magnetic fields" OR "electromagnetic fields" OR "power line" OR "power lines" OR ELF) NOT (epithelial lining fluid OR ELF-phosphatase) AND leukaemia AND epidemiol* OR case-control OR cohort)
- Additionally check EMF-portal (www.emf-portal.org) using ‘Cancer’ [or ‘Leukaemia’], ‘Power frequencies’, ‘Epidemiological studies’, ‘Complete time span’
- Check reference lists of other reviews

Selection of search results

- Select relevant studies based on title
- Select studies on any type of cancer in adults
- Refine selection if necessary based on abstract or full text
- Selected studies will be categorized as occupational or residential studies

Inclusion criteria

- Peer-reviewed publications in English, French, German
- Published until 25-01-2022
- If several reports were published on the same population, for each outcome only the most complete, preferentially the most recent, report will be included. Also when multiple studies were based on overlapping populations only the most relevant/complete study was included.

Exclusion criteria

- Studies on cancer in children
- Studies where the main study goals did not include assessment of the effect of ELF-MF exposure, or proxies of these such as electrical occupation and distance to power lines
- Ecological studies
- Cross-sectional studies
- Studies with self-reported exposure to ELF EMF
- Residential studies with measurements of less than 24 h

PECOS

Occupational exposure to ELF-MF

- **P**articipants: people that have been actually or likely exposed to ELF-MF above background levels during performance of their work duties, and people that have not been exposed above background levels during performance of their work duties
- **E**xposures:
    - exposure to ELF-MF above background levels as classified by a job-exposure matrix (JEM) or actual measurements or assessment by an occupational hygienist
    - working or having worked in a job that most likely involved exposure to ELF-MF above background levels ("electrical occupations"); exposure based on job title
- **C**omparisons:
    - all analyses will be stratified according to study type: industrial cohort vs other
    - exposed vs non-exposed
    - all studies
    - only studies with complete work history
    - all studies stratified for incidence vs mortality
    - all studies stratified for exposure assessment method: BBM or actual measurements or assessment by an occupational hygienist vs job title
    - highest/longest vs non-exposed (if available)
    - exposure-response relations (if feasible)
- **O**utcomes: cancer in general, leukaemia, AML, breast cancer in women, breast cancer in men, brain cancer, testicular cancer, pancreatic cancer, lung cancer, prostate cancer, skin melanoma.
- **S**tudy design: (nested) case-control, cohort

Residential exposure to ELF-MF

- **P**articipants: general population
- **E**xposures: measured or calculated exposure to ELF-MF or distance to the nearest overhead power line (used as a proxy for exposure to ELF-MF generated by the power line)
- **C**omparisons:
  - All analysis will be stratified for exposure to power lines only vs exposure to all sources of ELF-EMF
  - Exposed vs lowest
  - All studies
  - Mortality vs incidence
  - Stratified for exposure assessment method: measurements, modelled, distance to power line (categories 0-50, 50-200, 200-400/600 or >400/600 m)
  - Highest/longest vs lowest
- **O**utcomes: cancer in general, leukaemia, breast cancer in women, breast cancer in men, brain cancer, testicular cancer, pancreatic cancer, lung cancer, prostate cancer, skin melanoma.
- **S**tudy design: (nested) case-control, cohort

Data extraction

- First author, year of publication
- Study population: general population (residential studies) or workers (occupational studies)
- Study design: cohort, (nested) case-control
- Calendar years during which subjects were included in the study
- Details of the assessment of exposure (occupational: case-by-case assessment by expert, JEM; occupational and residential: measurements, calculations, distance)
- Case-control studies: selection of controls and whether cases and controls come from the same population at risk
- Residential studies: exposure assessment at one or multiple addresses (completeness of exposure history)
- Type of outcome (incidence, mortality)
- Outcome assessment
- In mortality studies: was outcome the primary cause of death or registered anywhere on the death certificate
- Total numbers of cases / controls, deaths
- Risk estimates of all reported ELF-MF exposure categories for all exposure durations; if risk estimates are available for ELF-MF exposure and for (groups of) electrical occupations, extract separately
- If available, both crude and adjusted risk estimates
- Confounding factors used for adjustment of risk estimates

In case of doubt, discuss and resolve questions in Committee

Research aims (for each type of cancer) for occupational studies:

Primary objectives

- Assess the association between (a proxy for) the exposure to ELF-MF and the incidence of, or death from, the disease
- Assess whether there is an increasingly stronger association between the incidence of, or death from, the disease with increasing level of exposure to ELF-MF

Secondary objectives

- Assess whether there is a different association with (a proxy for) exposure to ELF-MF for studies that report the incidence of the disease (morbidity) vs studies that report the disease as a cause of death (mortality)
- Assess whether there is a stronger association between (a proxy for) exposure to ELF-MF and the incidence of, or death from, the disease in studies with a more complete occupational history vs studies that have an incomplete occupational history
- Assess whether there is a different association between the incidence of, or death from, the disease and occupations for which exposure characterization has been done by JEM or actual measurements or assessment by an occupational hygienist vs exposure characterization by job title

Research aims (for each type of cancer) for residential studies:

Primary objectives

- Assess whether there is an association between the distance to power lines and the incidence of, or death from, the disease
- Assess whether there is an association between the measured or calculated ELF-MF exposure level and the incidence of, or death from, the disease

Analyses

- For each meta-analysis, there should be at least three studies from which data can be used, otherwise only the results of the studies will be reported
- Ever vs never exposed
    - If in a study risk estimates for two or more ELF-MF exposure levels compared to a reference level are given, a pooled risk estimate for all exposure categories will be calculated using a fixed-effects-within-study meta-analysis
    - Random effects meta-analysis will be used to calculate summary risk estimates stratified for the categories defined above
    - For males and females together with types of cancer that occur in both sexes (if necessary, a pooled risk estimate for males and females will be calculated, using a fixed-effects-within-study meta-analysis)
- Longest/highest exposed
    - Summary risk estimates will be calculated for all highest/longest exposure categories for studies with more than two exposure categories (including the reference category) using random effects meta-analysis
- Meta-regression will be used to assess exposure-response relations based on data from studies with quantitative ELF-MF exposure, where exposure is expressed in microtesla (µT)
- To assess heterogeneity, I^2 and the between-study standard deviation tau^2 will be calculated
- Meta-regression will be used if necessary and feasible to explain heterogeneity
- Forest plots will be made

4 Criteria for the classification of value as evidence of a causal relationship

The Committee applies the US Environmental Protection Agency (EPA)[1] methodology when assessing the strength of evidence of a causal relationship, which uses the following classifications:

Value as evidence of a causal relationship	Description of associated evidence
Causal relationship proven	Evidence is sufficient to conclude that there is a causal relationship with relevant exposures. Multiple high-quality studies conducted by multiple research groups in which chance, confounding, and other biases could be ruled out with reasonable confidence have shown health effects. Such studies include controlled human exposure studies or observational studies that are supported by other lines of evidence (e.g., animal studies or mode of action information).
Causal relationship likely	Evidence is sufficient to conclude that a causal relationship is likely to exist. Multiple high-quality studies where results are not explained by chance, confounding, and other biases have shown health effects, but uncertainties remain in the evidence overall. For example: observational studies show an association, but exposures to other agents are difficult to address and/or other lines of evidence (controlled human exposure, animal, or mode of action information) are limited or inconsistent. Or animal toxicological evidence from multiple studies from different laboratories demonstrate effects, but limited or no human data are available.
Suggestive of a causal relationship	Evidence is suggestive of a causal relationship but is limited, and chance, confounding, and other biases cannot be ruled out. For example: at least one high-quality epidemiologic study shows an association and/or at least one high-quality animal study shows effects relevant to humans. Or, when the body of evidence is relatively large, evidence from studies of varying quality is generally supportive but not entirely consistent.
Inadequate to infer a causal relationship	Evidence is inadequate to determine that a causal relationship exists. The available studies are of insufficient quantity, quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of an effect.
Not likely to be a causal relationship	Several adequate studies, covering the full range of levels of exposure that human beings are known to encounter and considering at-risk populations and lifestages, are mutually consistent in not showing an effect at any level of exposure.

5 Explanatory notes on forest plots

In this advisory report, the results of the meta-analyses are presented in ‘forest plots’. These graphs show the risk estimate and confidence interval both for each individual study and the combined result of the meta-analysis. The symbol (the small square in the figure below) shows the mean value for the individual studies. The size of the symbol represents the weighing ratio, which is related to the number of people in the study: the more people and the bigger the symbol, the greater the contribution of the study towards the combined result. The horizontal lines show the 95% confidence interval, which is a measure of the precision of the risk estimate (see box). In this background document, the 95% confidence interval (95% CI) is always shown in brackets after the risk estimate.
The diamond shows the risk estimate with confidence interval for the combined effect. I^2 and tau^2 are measures of heterogeneity. The greater the heterogeneity, the less value can be attributed to the result of the meta-analysis.

Risk estimate and confidence interval

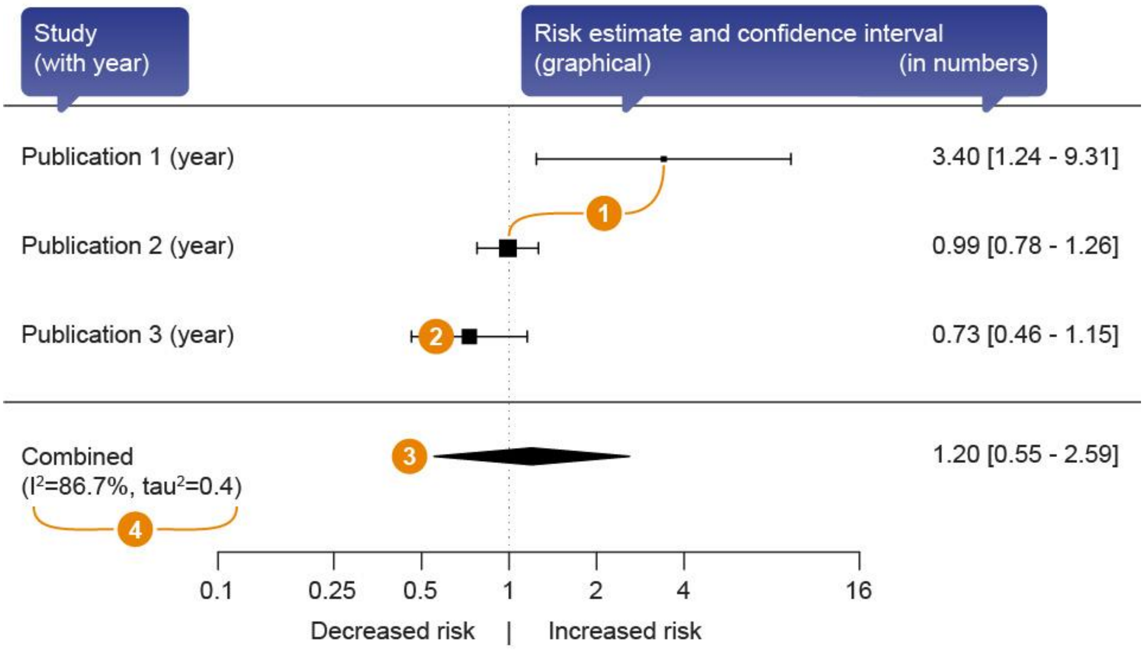
The risk estimate shows the estimated probability of a specific effect in a specific situation relative to the control situation, in other words the relative risk. For example, a risk estimate of 1.3 means that the estimated probability of a disease occurring is 1.3 times as great, or 30% higher, in people who have been exposed than in people with no or less exposure. A risk estimate of 0.9 means that the probability found is 0.9 times as great, or 10% lower. A risk estimate of 1 means that the probability of the disease is similar in both situations.

Most studies report relative risks, rate ratios (RR) or odds ratios (OR) as a risk estimate. Some studies also use other measures of risk: the SMR (standardised mortality ratio), SIR (standardised incidence ratio) and SRR (standardised rate ratio). A ratio of 1 or 100% signifies no difference between the exposed group and the population as a whole.
The 95% confidence interval shows how uncertain the risk estimate is and the limits within which we expect the actual effect to lie. It means that if we were to repeat the study 100 times in the same population with different random samples, the actual effect would lie within the confidence interval in 95 cases. If the 95% confidence interval contains the value 1, we refer to the association found as not statistically significantly increased or decreased. If the lower limit of the 95% confidence interval is greater than 1, we refer to a statistically significantly increased risk. If the upper limit of the 95% confidence interval is below 1, we refer to a statistically significantly decreased risk.

Figure 1 Example forest plot

Explanation: a forest plot

The results of the meta-analyses are presented in this advisory report in so-called forest plots. These show the risk estimate and confidence interval of both each individual study and the combined result of the meta-analysis.



1 Square
The location indicates the risk estimate, the size indicates the number of subjects in the study as well as the contribution to the combined result.

2 Horizontal line
The horizontal line indicates the confidence interval.

3 Diamond
The diamond shape indicates the risk estimate with confidence interval for the combined result.

4 I^2 en tau^2
I^2 en tau^2 are measures of the heterogeneity of the results of the individual studies.
The more the heterogeneity, the less value can be given to the results of the meta-analyses.

6 Data summary

The tables below summarise the data from the studies included in the meta-analyses of the relationship between the different types of cancer and residential or occupational exposure. A list of studies that were not included in the meta-analyses and the reason for exclusion is also provided in each case.
According to the protocol, if a publication contains more than two exposure categories, the Committee has used a fixed-effect-within-study-meta-analysis to calculate a risk estimate for 'ever exposed'. The risk estimate for highest or longest exposure is also stated where possible.

6.1 Leukaemia and residential exposure

Table 5 Studies that investigate the relationship between residential exposure to magnetic fields and risk of leukaemia in general that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Youngson 1991[2]	England	Case-control, general population	Distance, average field strength	Incidence	0-50 m: OR=1.29 (0.99-1.68) Ever exposed (calculated): OR=1.03 (0.80-1.32) Highest exposure: OR=1.87 (0.79-4.42)
Verkasalo 1996[3]	Finland	Cohort, general population	Cumulative exposure	Incidence	Ever exposed (calculated): SIR=0.96 (0.83-1.10) Highest exposure: SIR=0.71 (0.19-1.81)
Feychting 1997[4]	Sweden	Case-control, general population	Average exposure	Incidence	Ever exposed (calculated): RR=1.15 (0.79-1.67) Highest exposure: RR=1.30 (0.80-2.20)
Li 1997[5]	Taiwan	Case-control, general population	Average exposure	Incidence	0-50 m: OR=2.0 (1.4-2.9) Ever exposed (calculated): OR=1.36 (1.05-1.76) Highest exposure: OR=1.40 (1.00-1.90)
Tynes 2003[6]	Norway	Case-control, general population	Proximity of high-voltage power line	Incidence	Ever exposed (calculated): OR=1.39 (0.88-2.20) Highest exposure: OR=1.50 (0.80-3.00)
Marcilio 2011[7]	Brazil	Case-control, general population	Average exposure	Mortality	0-50 m: OR=1.47 (0.99-2.18) Ever exposed (calculated): OR=1.50 (0.96-2.35) Highest exposure: OR=1.61 (0.91-2.86)
Elliott 2013[8]	England	Case-control, general population	Distance, average field strength	Incidence	0-50 m: OR=1.11 (0.83-1.48) Ever exposed (calculated): OR=1.11 (0.89-1.38) Highest exposure: OR=1.03 (0.57-1.86)

Khan 2021[9]	Finland	Cohort, general population	Proximity of transformer in residential building	Incidence	Ever exposed: HR=0.69 (0.36-1.35)

Abbreviations: HR: hazard rate; OR: odds ratio; RR: rate ratio; SIR: standardised incidence ratio.
* In some cases the Committee has aggregated categories.

Table 6 Studies that investigate the relationship between residential exposure and risk of leukaemia in general that were not included in the analysis

Reference	Reason for exclusion
McDowall 1986[10]	Cross-sectional study
Severson 1988[11]	Acute non-lymphocytic leukaemia only
Coleman 1989[12]	Insufficient patients and controls to calculate confidence interval
Schreiber 1993[13]	No leukaemia patients
Feychting 1994[14]	Update in later publication
Lovely 1994[15]	Appliance exposure only
Verkasalo 1996[16]	The same study as Verkasalo 1996[3]
Gurvich 1996[17]	Paper in Russian
Fazzo 2005[18]	Update in later publication
Lowenthal 2007[19]	Lymphomas and leukaemia combined
Fazzo 2009[20]	Only 1 patient
Kaufman 2009[21]	Lack of proper exposure assessment

Table 7 Studies that investigate the relationship between residential exposure to magnetic fields and risk of AML that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Preston-Martin 1988[22]	USA	Case-control, general population	Electric bed warmer use	Incidence	Regular use: OR=0.9 (0.5-1.6)
Feychting 1997[4]	Sweden	Case-control, general population	Average exposure	Incidence	Ever exposed (calculated): RR=1.90 (0.95-3.80) Highest exposure: RR=2.4 (0.9-5.7)
Li 1997[5]	Taiwan	Case-control, general population	Average exposure	Incidence	Ever exposed (calculated): OR=1.26 (0.90-1.76) Highest exposure: OR=1.1 (0.7-1.7)
Oppenheimer 2002[23]	USA	Case-control, general population	Electric bed warmer use	Incidence	Ever used: OR=0.9 (0.7-1.2)
Tynes 2003[6]	Norway	Case-control, general population	Proximity of high-voltage power line	Incidence	Ever exposed (calculated): OR=1.62 (1.05-2.50) Highest exposure: OR=1.6 (0.4-1.0)
Khan 2021[9]	Finland	Cohort, general population	Proximity of transformer in residential building	Incidence	Ever exposed: HR=0.25 (0.03-1.77)

Abbreviations: HR: hazard rate; OR: odds ratio; RR: rate ratio; SIR: standardised incidence ratio.
* In some cases the Committee has aggregated categories.

6.2 Leukaemia and occupational exposure

Table 8 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of leukaemia in general that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Pearce 1989[24]	New Zealand	Case-control, general population	Occupation	Incidence	Ever exposed: OR=1.62 (1.04-2.52)
Juutilainen 1990[25]	Finland	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.47 (1.17-1.85)
Loomis 1990[26]	USA	Case-control, general population	Occupation	Mortality	Ever exposed: OR=1.00 (0.80-1.20) Longest exposure: OR=0.80 (0.60-1.10)
Pachocki 1991[27]	Poland	Case-control, general population	Occupation	Incidence	Ever exposed: OR=1.22 (0.71-2.10) (95% CI calculated)
Törnqvist 1991[28]	Sweden	Cohort, general population	Occupation	Incidence	Ever exposed (calculated): SMR=1.14 (1.01-1.28)
Tynes 1992[29]	Norway	Cohort, general population	JEM	Incidence	Ever exposed: SIR=1.41 (1.10-1.76)
Richardson 1992[30]	France	Case-control, general population	JEM	Incidence	Ever exposed: OR=3.19 (0.95-10.67)
Sahl 1993[31]	USA	Case-control, general population	JEM	Mortality	Ever exposed: RR=1.41 (0.74-2.68)
Guénel 1993[32]	Denmark	Cohort, general population	JEM	Incidence	Ever exposed (calculated): OR=1.62 (1.19-2.21)
Matanoski 1993[33]	USA	Case-control, telephone workers	JEM	Mortality	Ever exposed (calculated): OR=1.69 (0.67-4.25)
Floderus 1993[34]	Sweden	Case-control, general population	JEM	Incidence	Ever exposed (calculated): RR=1.22 (0.96-1.55) Highest exposure: RR=1.70 (1.00-2.70) Longest exposure: RR=1.40 (0.80-2.30)
Tynes 1994[35]	Norway	Case-control, railway workers	JEM	Incidence	Ever exposed: OR=0.74 (0.35-1.55) Highest exposure: OR=1.07 (0.30-3.87)
Tynes 1994[36]	Norway	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=90 (45-160) Longest exposure: SIR=73 (20-187) (95% CI calculated) Highest exposure: SIR=104 (34-248) (95% CI calculated)

Thériault 1994[37]	Canada	Case-control, electricity companies	JEM	Incidence	Ever exposed: OR=1.54 (0.90-2.63) Highest exposure: OR=1.75 (0.77-3.96)
London 1994[38]	USA	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=1.26 (1.04-1.53) Longest exposure: OR=1.40 (1.00-2.00) Highest exposure: OR=1.40 (1.00-2.00)
Alfredsson 1996[39]	Sweden	Cohort, railway workers	Occupation	Incidence	Ever exposed (calculated): RR=1.28 (0.80-2.03)
Feychting 1997[4]	Sweden	Case-control, general population	JEM	Incidence	Ever exposed (calculated): RR=1.31 (1.02-1.68)
Floderus 1999[40]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.06 (0.99-1.12) Highest exposure (calculated): RR=1.10 (1.02-1.19)
Savitz 2000[41]	USA	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): RR=0.91 (0.65-1.27)
Harrington 2001[42]	UK	Cohort, electricity companies	JEM	Mortality	Ever exposed (calculated): RR=1.25 (0.93-1.68)
Bethwaite 2001[43]	New Zealand	Case-control, general population	JEM	Incidence	Ever exposed: OR=1.90 (1.00-3.80)
Blair 2001[44]	USA	Case-control, general population	JEM	Incidence	Ever exposed (calculated): RR=0.82 (0.64-1.04)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=0.82 (0.64-1.04) Highest exposure (calculated): RR=0.50 (0.30-1.00)
Willett 2003[46]	England	Case-control, general population	JEM	Incidence	Ever exposed: OR=0.97 (0.76-1.25)
Tynes 2003[6]	Norway	Case-control, general population	JEM	Incidence	Ever exposed: OR=1.10 (0.70-1.60)
Adegoke 2003[47]	China	Case-control, general population	JEM	Incidence	Ever exposed: OR=0.90 (0.70-1.20) Highest exposure: OR=1.20 (0.80-1.80)
Johansen 2007[48]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): OR=1.00 (0.63-1.60) Highest exposure: OR=1.04 (0.53-2.04)
Röösli 2007[49]	Switzerland	Cohort, railway workers	JEM	Incidence	Ever exposed (calculated): HR=1.24 (0.81-1.89)
Koeman 2014[50]	Netherlands	Cohort, general population	JEM	Incidence	Ever exposed (calculated): HR=1.27 (0.99-1.64) Highest exposure (calculated): HR=1.11 (0.76-1.64)

Huss 2018[51]	Switzerland	Cohort, general population	JEM	Mortality	Ever exposed (calculated): OR=1.04 (0.96-1.13) Highest exposure: OR=1.17 (0.97-1.42)

Abbreviations: HR: hazard rate; JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardised incidence ratio; SMR: standardised mortality ratio.
* In some cases the Committee has aggregated categories.

Table 9 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of leukaemia in general that were not included in the analysis

Reference	Reason for exclusion
Milham 1985[52]	PMR study
Törnqvist 1986[53]	Update in later publication
Linet 1988[54]	Broad job categories only
Garland 1990[55]	No exposure to ELF magnetic fields determined
Bastuji-Garin 1990[56]	Update in later publication
Balli-Antunes 1990[57]	Lymphomas and leukaemia combined
Robinson 1991[58]	PMR study
Floderus 1994[59]	The same data as Törnqvist 1991[28]
Dosemeci 1994[60]	No leukaemia patients
Savitz 1995[61]	Update in later publication
Fear 1996[62]	PRR study
Miller 1996[63]	Strong overlap with Thériault 1994[37]
Baris 1996[64]	The same data as in Theriault 1994[37]
Guénel 1996[65]	Strong overlap with Thériault 1994[37], electric field exposure only
Kelsh 1997[66]	The same population as Sahl 1993[31], mortality only
Johansen 1998[67]	Update in later publication
Pulsoni 1998[68]	Incomplete analysis
Pira 1999[69]	No exposure to ELF magnetic fields
Johansen 1999[70]	Paper in Danish
Kheifets 1999[71]	Reanalysis of 3 previous studies
Robinson 1999[72]	Exposure to ELF magnetic fields not analysed
Ronneberg 1999[73]	Unclear reference group
Villeneuve 2000[74]	Reanalysis of partial data from Thériault 1994[37]
Minder 2001[75]	Update in later publication
Van Wijngaarden 2001[76]	Previously described in Savitz 1995[61]
Bjork 2001[77]	1 type of CML only
Guénel 2002[78]	Partial data from Thériault 1994[37]
Groves 2002[79]	No exposure to ELF magnetic fields
Nichols 2005[80]	Update in later publication
Sorahan 2012[81]	Not a good study design
Sorahan 2014[82]	The same data with estimate of exposure in Harrington 2001[42]
Talibov 2015[83]	Data described in previous publications

Abbreviations: CML: chronic myeloid leukaemia; PMR: proportional mortality ratio; PRR: proportional registration ratio.

Table 10 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of AML that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Flodin 1986[84]	Sweden	Case-control, general population	Occupation	Incidence	Ever exposed: LRR=3.80 (1.50-9.50)
Juutilainen 1990[25]	Finland	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.38 (0.93-2.05)
Loomis 1990[26]	USA	Case-control, general population	Occupation	Mortality	Ever exposed: OR=1.10 (0.70-1.70)
Törnqvist 1991[28]	Sweden	Cohort, general population	Occupation	Incidence	Ever exposed (calculated): SMR=1.29 (0.99-1.69)
Pachocki 1991[27]	Poland	Case-control, general population	Occupation	Incidence	Ever exposed: OR=2.00 (0.78-5.14) (95% CI calculated)
Tynes 1992[29]	Norway	Cohort, general population	JEM	Incidence	Ever exposed: SIR=1.56 (1.06-2.26)
Richardson 1992[30]	France	Case-control, general population	JEM	Incidence	Ever exposed: OR=4.83 (1.48-15.80)
Floderus 1993[34]	Sweden	Case-control, general population	JEM	Incidence	Ever exposed (calculated): RR=0.99 (0.65-1.50) Highest exposure: RR=0.90 (0.40-2.10) Longest exposure: RR=0.40 (0.10-1.20)
Thériault 1994[37]	Canada	Case-control, electricity companies	JEM	Incidence	Ever exposed: OR=3.15 (1.20-8.27) Highest exposure: OR=2.68 (0.50-14.50)
Blair 2001[44]	USA	Case-control, general population	JEM	Incidence	Ever exposed (calculated): RR=0.68 (0.41-1.13)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=0.65 (0.48-0.89) Highest exposure (calculated): RR=0.83 (0.42-1.67)
Oppenheimer 2002[23]	USA	Case-control, general population	Occupation	Incidence	Ever exposed: OR=1.00 (0.80-1.50)
Willett 2003[46]	England	Case-control, general population	JEM	Incidence	Ever exposed: OR=0.91 (0.69-1.18)
Tynes 2003[6]	Norway	Case-control, general population	JEM	Incidence	Ever exposed: OR=0.80 (0.40-1.70)
Röösli 2007[49]	Switzerland	Cohort, railway workers	JEM	Incidence	Ever exposed (calculated): HR=3.98 (1.68-9.40)
Koeman 2014[50]	Netherlands	Cohort, general population	JEM	Incidence	Ever exposed (calculated): HR=1.51 (1.11-2.06) Highest exposure (calculated): HR=1.43 (0.90-2.29)
Sorahan 2014[82]	England	Cohort, electricity companies	Occupation	Incidence	Ever exposed: RR=0.99 (0.80-1.24)

Abbreviations: HR: hazard rate; JEM: job-exposure matrix; LRR: logistic rate ratio; OR: odds ratio; PRR: proportional registration ratio; RR: rate ratio; SIR: standardised incidence ratio; SMR: standardised mortality ratio.
* In some cases the Committee has aggregated categories.

Table 11 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of AML that were not included in the analysis

Reference	Reason for exclusion
Robinson 1991[58]	PMR study
Fear 1996[62]	Cross-sectional study

Abbreviations: PMR: proportional mortality ratio.

6.3 Breast cancer in women and residential exposure

Table 12 Studies that investigate the relationship between residential exposure to magnetic fields and risk of breast cancer in women that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Schreiber 1993[13]	Netherlands	Cohort, general population	Distance	Mortality	0-100 m: SMR=0.96 (0.31-2.23)
Verkasalo 1996[3]	Finland	Cohort, general population	Cumulative exposure	Incidence	Ever exposed (calculated): SIR=1.04 (0.98-1.10) Highest exposure: SIR=0.75 (0.48-1.13)
Li 1997[5]	Taiwan	Case-control, general population	Distance, average exposure	Incidence	0-50 m: OR=1.0 (0.8-1.3) Ever exposed (calculated): OR=1.10 (0.94-1.29) Highest exposure: OR=1.1 (0.9-1.3)
Feychting 1998[85]	Sweden	Case-control, general population	Distance, average field strength	Incidence	0-50 m: RR=0.8 (0.5-1.3) Ever exposed (calculated): OR=1.09 (0.83-1.44) Highest exposure: OR=1.00 (0.70-1.50)
Coogan 1998[86]	USA	Case-control, general population	Residing near a high-voltage power line or substation	Incidence	0-152 m ever: OR=1.5 (0.6-3.3) 0-152 m always: OR=1.4 (0.4-4.4)
Davis 2002[87]	USA	Case-control, general population	Wire code	Incidence	Ever exposed (calculated): OR=0.83 (0.69-1.01) Highest exposure: OR=0.90 (0.50-1.60)
Schoenfeld 2003[88]	USA	Case-control, general population	Wire code	Incidence	Ever exposed (calculated): OR=0.84 (0.68-1.04) Highest exposure: OR=0.90 (0.54-1.48)
London 2003[89]	USA	Case-control, general population	Wire code	Incidence	Ever exposed (calculated): OR=0.85 (0.65-1.12) Highest exposure: OR=0.84 (0.50-1.43)
Kliukiene 2004[90]	Norway	Case-control, general population	Residing near a high-voltage power line	Incidence	Ever exposed: OR=1.58 (1.30-1.92) Highest exposure: OR=1.38 (1.04-1.83)
Elliott 2013[8]	UK	Case-control, general population	Distance	Incidence	0-50 m: OR=1.07 (0.93-1.24) Ever exposed (calculated): OR=0.96 (0.84-1.01) Highest exposure: OR=1.08 (0.77-1.51)

Abbreviations: OR: odds ratio; SIR: standardised incidence ratio; SMR: standardised mortality ratio.
* In some cases the Committee has aggregated categories.

Table 13 Studies that investigate the relationship between electric bed warmer use and risk of breast cancer in women that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Vena 1991[91]	USA	Case-control, general population	Electric blanket use	Incidence	Ever exposed (calculated): OR=1.11 (0.81-1.54) Highest exposure: OR=1.46 (0.96-2.20) Longest exposure: OR=1.36 (0.77-2.40)
Vena 1994[92]	USA	Case-control, general population	Electric blanket use	Incidence	Ever exposed: OR=1.18 (0.83-1.68) Highest exposure: OR=1.43 (0.94-2.17) Longest exposure: OR=1.10 (0.59-2.05)
Coogan 1998[86]	USA	Case-control, general population	Electric blanket use	Incidence	Ever exposed (calculated): OR=0.95 (0.74-1.24) Highest exposure: OR=0.90 (0.60-1.30) Longest exposure: OR=1.50 (0.70-3.10)
Gammon 1998[93]	USA	Case-control, general population	Electric blanket, waterbed use	Incidence	Ever exposed: OR=1.01 (0.86-1.18) Highest exposure: OR=1.03 (0.88-1.22) Longest exposure: OR=0.96 (0.74-1.26)
Laden 2000[94]	USA	Cohort, general population	Electric blanket, waterbed use	Incidence	Ever exposed: OR=1.08 (0.95-1.24) Longest exposure: OR=1.11 (0.89-1.39)
Zheng 2000[95]	USA	Case-control, general population	Electric blanket use	Incidence	Ever exposed: OR=0.90 (0.70-1.10) Highest exposure: OR=0.90 (0.70-1.20) Longest exposure: OR=0.80 (0.60-1.10)
McElroy 2001[96]	USA	Case-control, general population	Electric blanket use	Incidence	Ever exposed: OR=0.93 (0.82-1.06) Longest exposure: OR=0.94 (0.77-1.15)
Davis 2002[87]	USA	Case-control, general population	Bed warmer use	Incidence	Ever exposed: OR=1.10 (0.80-1.30) Longest exposure: OR=1.20 (0.80-1.70)
Zhu 2003[97]	USA	Case-control, general population	Electric blanket, bed warmer, waterbed use	Incidence	Ever exposed: OR=1.40 (0.90-2.20) Highest exposure: OR=1.70 (1.00-3.00) Longest exposure: OR=4.90 (1.50-15.60)

Kabat 2003[98]	USA	Case-control, general population	Electric blanket, bed warmer, waterbed use	Incidence	Ever exposed (calculated): OR=1.08 (0.90-1.30) Highest exposure (calculated): OR=1.09 (0.81-1.47) Longest exposure (calculated): OR=0.97 (0.66-1.43)

Abbreviations: OR: odds ratio.
* In some cases the Committee has aggregated categories.

Table 14 Studies that investigate the relationship between residential exposure and risk of breast cancer in women that were not included in the analysis

Reference	Reason for exclusion
Davis 2007[99]	ELF exposure only in combination with medication

6.4 Breast cancer in women and occupational exposure

Table 15 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of breast cancer in women that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Guénel 1993[32]	Denmark	Cohort, general population	JEM	Incidence	Ever exposed (calculated): OR=0.96 (0.91-1.01)
Loomis 1994[100]	USA	Case-control, general population	Occupation	Mortality	Ever exposed: OR=1.38 (1.04-1.82)
Coogan 1996[101]	USA	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=1.06 (0.95-1.17) Highest exposure: OR=1.43 (0.99-2.09)
Petralia 1998[102]	China	Case-control, general population	JEM	Incidence	Ever exposed (calculated): SIR=1.00 (0.91-1.09) Highest exposure: SIR=1.00 (0.80-1.20)
Coogan 1998[86]	USA	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=0.96 (0.56-1.64) Highest exposure: OR=1.30 (0.30-6.00)
Kliukiene 1999[103]	Norway	Cohort, general population	Measurements, expert opinion	Incidence	Ever exposed (calculated): SIR=1.01 (0.99-1.02) Highest exposure: SIR=1.03 (0.97-1.09)
Floderus 1999[40]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.16 (1.12-1.19) Highest exposure: RR=1.10 (1.00-1.10)
Van Wijngaarden 2001[104]	USA	Case-control, general population	Measurements	Incidence	Ever exposed (calculated): OR=1.18 (1.02-1.37) Highest exposure: OR=1.20 (0.80-1.70)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=1.04 (0.94-1.16) Highest exposure: RR=1.10 (0.80-1.50)

Labrèche 2003[105]	Canada	Case-control, general population	Expert opinion	Incidence	Ever exposed: OR=1.06 (0.75-1.49) Longest exposure: OR=1.10 (0.71-1.71)
Kliukiene 2004[90]	Norway	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=1.04 (0.91-1.19) Highest exposure: OR=1.13 (0.91-1.40) Longest exposure: OR=1.16 (0.91-1.48)
Forssén 2005[106]	Sweden	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=1.00 (0.97-1.04) Highest exposure: OR=1.01 (0.93-1.10) Longest exposure: OR=1.00 (0.90-1.11)
Johansen 2007[48]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): OR=0.79 (0.58-1.07) Highest exposure: OR=1.04 (0.32-3.34)
Peplonska 2007[107]	Poland	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=1.26 (1.10-1.45) Highest exposure: OR=1.50 (1.10-2.00)
McElroy 2007[108]	USA	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=1.07 (1.01-1.14) Highest exposure: OR=1.17 (0.90-1.53)
Sorahan 2012[81]	UK	Cohort, railway workers	Occupation	Incidence	Ever exposed (calculated): SRR=1.08 (1.00-1.18)
Li 2013[109]	China	Case-control, textile workers	JEM	Incidence	Ever exposed (calculated): HR=1.06 (0.96-1.16) Highest exposure: HR=1.03 (0.87-1.21)
Koeman 2014[50]	Netherlands	Cohort, general population	JEM	Incidence	Ever exposed: HR=1.07 (0.94-1.23) Highest exposure: HR=1.03 (0.85-1.25)

Abbreviations: JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardised incidence ratio; SRR: standardised registration ratio.
* In some cases the Committee has aggregated categories.

Table 16 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of breast cancer in women that were not included in the analysis

Reference	Reason for exclusion
Dosemeci 1994[60]	Not an ELF study
Fear 1996[62]	PRR study
Johansen 1998[67]	Update in later publication
Forssén 2000[110]	Update in later publication
Rafnsson 2001[111]	No exposure to ELF magnetic fields
Kliukiene 2003[112]	Exposure to RF and ELF
Nichols 2005[80]	Update in later publication
Beniashvili 2005[113]	Lack of proper exposure assessment
Ray 2007[114]	Update in later publication
Milham 2008[115]	No exposure to ELF magnetic fields

Abbreviations: PRR: proportional registration ratio; RF: radio frequencies.

6.5 Breast cancer in men and residential exposure

Table 17 Studies that investigate the relationship between residential exposure to magnetic fields and risk of breast cancer in men that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Feychting 1998[85]	Sweden	Case-control, general population	Residing near a high-voltage power line	Incidence	Ever exposed: OR=2.1 (0.3-14.1)

6.6 Breast cancer in men and occupational exposure

Table 18 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of breast cancer in men that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Demers 1991[116]	USA	Case-control, general population	Occupation	Incidence	Ever exposed: OR=1.80 (1.00-3.70) Longest exposure: OR=2.10 (0.70-6.20)
Tynes 1992[29]	Norway	Cohort, general population	JEM	Incidence	Ever exposed: SIR=2.07 (1.76-3.61)
Tynes 1994[36]	Norway	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=1.37 (0.03-7.63)
Floderus 1994[59]	Sweden	Cohort, railway workers	JEM	Incidence	Ever exposed (calculated): RR=1.41 (0.69-2.92)
Rosenbaum 1994[117]	USA	Case-control, general population	Occupation	Incidence	Ever exposed: OR=0.60 (0.20-1.60)
Savitz 1995[61]	USA	Cohort, electricity companies	JEM	Mortality	Ever exposed (calculated): SMR =0.80 (0.29-1.74)
Stenlund 1997[118]	Sweden	Case-control, general population	Occupation	Incidence	Ever exposed (calculated): OR=1.08 (0.68-1.72) Highest exposure: OR=0.70 (0.20-2.30)
Cocco 1998[119]	USA	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=1.06 (0.75-1.50) Highest exposure: OR=1.00 (0.50-2.10)

Johansen 1998[67]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=0.50 (0.10-1.80)
Pollán 2001[120]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): OR=1.31 (1.05-1.63) Highest exposure: OR=0.92 (0.52-1.60)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=3.19 (0.86-11.84) Highest exposure: RR=3.80 (0.30-43.50)
Sorahan 2012[81]	UK	Cohort, railway workers	Occupation	Incidence	Ever exposed (calculated): SRR=1.16 (0.81-1.62)
Grundy 2016[121]	Canada	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=1.14 (0.72-1.81) Highest exposure: OR=1.80 (0.82-3.95) Longest exposure: OR=2.77 (0.98-7.82)

Abbreviations: JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardized incidence ratio; SMR: standardised mortality ratio; SRR: standardised registration ratio.
* In some cases the Committee has aggregated categories.

Table 19 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of breast cancer in men that were not included in the analysis

Reference	Reason for exclusion
Fear 1996[62]	PRR study
Floderus 1999[40]	Update in later publication
Koc 2001[122]	Not a good study design
Groves 2002[79]	No exposure to ELF magnetic fields
Milham 2004[123]	Cluster analysis
Nichols 2005[80]	Update in later publication

Abbreviations: PRR: proportional registration ratio.

6.7 Brain cancer and residential exposure

Table 20 Studies that investigate the relationship between residential exposure and risk of brain cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Verkasalo 1996[3]	Finland	Cohort, general population	Cumulative exposure	Incidence	Ever exposed (calculated): SIR=0.93 (0.83-1.05) Highest exposure: SIR=0.92 (0.37-1.89)
Feychting 1997[4]	Sweden	Case-control, general population	Average exposure	Incidence	Ever exposed (calculated): RR =1.08 (0.68-1.73) Highest exposure: RR=0.80 (0.40-1.60)
Li 1997[5]	Taiwan	Case-control, general population	Distance Average exposure	Incidence	0-50 m: OR=1.3 (0.8-2.1) Ever exposed (calculated): OR=1.04 (0.71-1.37) Highest exposure: OR=1.10 (0.80-1.60)
Wrensch 1999[124]	USA	Case-control, general population	Average exposure	Incidence	Ever exposed (calculated): OR=0.96 (0.72-1.27) Highest exposure: OR=1.70 (0.80-3.60)
Klaeboe 2005[125]	Norway	Case-control, general population	Average exposure	Incidence	Ever exposed (calculated): OR=1.27 (0.77-2.10) Highest exposure: OR=1.10 (0.50-2.40)
Marcilio 2011[7]	Brazil	Case-control, general population	Average exposure	Mortality	Ever exposed (calculated): OR=1.15 (0.71-1.86) Highest exposure: OR=1.16 (0.60-2.07)
Elliott 2013[8]	England	Case-control, general population	Distance, magnetic field	Incidence	Distance <50 m: OR=1.22 (0.88-1.69) Magnetic field: Ever exposed (calculated): OR=1.05 (0.84-1.32) Highest exposure: OR=1.02 (0.47-1.22)
Khan 2021[9]	Finland	Cohort, general population	Proximity of transformer in residential building	Incidence	Ever exposed: HR=1.47 (0.84-2.57)

Abbreviations: HR: hazard rate; OR: odds ratio; RR: rate ratio; SIR: standardised incidence ratio; SMR: standardised mortality ratio.
* In some cases the Committee has aggregated categories.

Table 21 Studies that investigate the relationship between residential exposure and risk of brain cancer that were not included in the analysis

Reference	Reason for exclusion
Feychting 1994[14]	Update in later publication
Feychting 1994[14]	Update in later publication
Mutnick 1997[126]	Incomplete data
Aldrich 2001[127]	No exposure to ELF magnetic fields
Li 2003[128]	No exposure to ELF magnetic fields
Kleinerman 2005[129]	Electrical equipment use

6.8 Brain cancer and occupational exposure

Table 22 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of brain cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Lin 1985[130]	USA	Case-control, general population	Occupation	Incidence	Ever exposed (calculated): OR=1.59 (1.23-2.06)
Speers 1988[131]	USA	Case-control, general population	Occupation	Mortality	Ever exposed: OR=3.94 (1.52-10.20)
Pearce 1989[24]	New Zealand	Case-control, general population	Occupation	Incidence	Ever exposed: OR=1.01 (0.56-1.82)
Schlehofer 1990[132]	Germany	Case-control, general population	Expert opinion	Incidence	Ever exposed: RR=1.87 (0.90-4.10) Longest exposure (calculated): RR=2.18 (0.61-7.79)
Juutilainen 1990[25]	Finland	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.29 (1.04-1.61)
Loomis 1990[26]	USA	Case-control, general population	Occupation	Mortality	Ever exposed: OR=1.40 (1.10-1.70) Longest exposure: OR=1.90 (1.30-2.70)
Törnqvist 1991[28]	Sweden	Cohort, general population	Occupation	Incidence	Ever exposed: SMR=1.30 (1.00-1.70)
Mack 1991[133]	USA	Case-control, general population	Occupation	Incidence	Ever exposed: OR=1.10 (0.60-1.80) Longest exposure: OR=1.30 (0.60-3.00)
Tynes 1992[29]	Norway	Cohort, general population	JEM	Incidence	Ever exposed: SIR=1.09 (0.90-1.41)
Guénel 1993[32]	Denmark	Cohort, general population	JEM	Incidence	Ever exposed (calculated): OR=0.98 (0.90-1.06) Longest exposure (calculated): OR=0.80 (0.56-1.16)
Sahl 1993[31]	USA	Case-control, general population	JEM	Incidence	Ever exposed: RR=1.09 (0.44-2.69)
Floderus 1993[34]	Sweden	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=1.29 (1.01-1.63) Highest exposure: OR=1.20 (0.70-2.10)
Tynes 1994[35]	Norway	Case-control, railway workers	JEM	Incidence	Ever exposed: OR=0.74 (0.35-1.55) Highest exposure: OR=1.07 (0.30-3.87)
Tynes 1994[36]	Norway	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=0.88 (0.47-1.50) Highest exposure: SIR=0.44 (0.05-1.59) Longest exposure: SIR=0.65 (0.13-1.90)
Thériault 1994[37]	Canada	Case-control, electricity companies	JEM	Incidence	Ever exposed: OR=1.54 (0.85-2.81) Highest exposure: OR=1.95 (0.76-5.00)

Grayson 1996[134]	USA	Case-control, general population	JEM	Incidence	Ever exposed: OR=1.28 (0.95-1.74)
Alfredsson 1996[39]	Sweden	Cohort, railway workers	Occupation	Incidence	Ever exposed (calculated): RR=0.97 (0.53-1.77)
Feychting 1997[4]	Sweden	Case-control, general population	JEM	Incidence	Ever exposed (calculated): RR=1.20 (0.90-1.59) Highest exposure: RR=1.20 (0.80-1.90)
Rodvall 1998[135]	Sweden	Case-control, general population	JEM	Incidence	Ever exposed: RR=1.90 (0.80-5.00) Longest exposure: RR=1.80 (0.70-5.10)
Savitz 2000[41]	USA	Cohort, electricity companies	JEM	Mortality	Ever exposed (calculated): RR=1.56 (1.10-2.21) Highest exposure: RR=2.50 (0.98-6.33)
Villeneuve 2002[136]	Canada	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=1.16 (0.89-1.51) Highest exposure: OR=1.33 (0.75-2.36)
Navas-Acién 2002[137]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.11 (1.04-1.18) Highest exposure: RR=1.07 (0.94-1.21)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=1.04 (0.87-1.25) Highest exposure (calculated): RR=1.04 (0.73-1.50)
Klaeboe 2005[125]	Norway	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=0.72 (0.47-1.10) Highest exposure: OR=0.60 (0.30-1.20)
Karipidis 2007[138]	Australia	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=0.78 (0.63-0.98) Highest exposure: OR=0.79 (0.53-1.18)
Johansen 2007[48]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): OR=0.81 (0.56-1.18) Highest exposure: OR=0.69 (0.38-1.25)
Röösli 2007[49]	Switzerland	Cohort, railway workers	JEM	Incidence	Ever exposed (calculated): OR=1.10 (0.64-1.90)
Coble 2009[139]	USA	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=0.97 (0.79-1.19) Highest exposure: OR=0.90 (0.60-1.30)
Baldi 2011[140]	France	Case-control, general population	JEM	Incidence	Ever exposed: OR=1.20 (0.66-2.17)
Sorahan 2012[81]	England, Wales	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SRR=0.99 (0.89-1.09)
Turner 2014[141]	Australia, Canada, France, Germany, New Zealand, UK, Israel	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=0.99 (0.91-1.08) Highest exposure: OR=1.00 (0.82-1.23)

Koeman 2014[50]	Netherlands	Cohort, general population	JEM	Incidence	Ever exposed (calculated): OR=0.99 (0.80-1.23) Highest exposure (calculated): OR=0.90 (0.62-1.31)

Abbreviations: JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardized incidence ratio. SMR: standardised mortality ratio; SRR: standardised registration ratio.
* In some cases the Committee has aggregated categories.

Table 23 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of brain cancer that were not included in the analysis

Reference	Reason for exclusion
Milham 1985[52]	PMR study
Thomas 1987[142]	No exposure to ELF magnetic fields
Preston-Martin 1989[143]	Update in later publication
Dosemeci 1994[60]	Not an EMF study
Savitz 1995[61]	Update in later publication
Guénel 1996[65]	No exposure to ELF magnetic fields
Baris 1996[64]	The same data as in Theriault 1994[37]
Beall 1996[144]	No exposure to ELF magnetic fields
Fear 1996[62]	PRR study
Johansen 1998[67]	Update in later publication
Floderus 1999[40]	Update in later publication
Ronneberg 1999[73]	Inconclusive analysis, low numbers
Harrington 1997[145]	Update in later publication
Cocco 1998[146]	Unclear whether ELF or RF exposure
Cocco 1999[147]	Unclear whether ELF or RF exposure
Santana 1999[148]	No exposure to ELF magnetic fields
Pira 1999[69]	No exposure to ELF magnetic fields
Minder 2001[75]	Update in later publication
Sorahan 2001[149]	Update in later publication
Groves 2002[79]	No exposure to ELF magnetic fields
Nichols 2005[80]	Update in later publication
Forssén 2006[150]	No brain tumour
Karipidis 2007[151]	Similar to parallel publication
Marsh 2013[152]	No distinction between ELF, RF and radar

Abbreviations: PMR: proportional mortality ratio; PRR: proportional registration ratio; RF: radio frequencies.

6.9 Testicular cancer and residential exposure

Table 24 Studies that investigate the relationship between residential exposure and risk of testicular cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Verreault 1990[153]	USA	Case-control, general population	Electric blankets	Incidence	Ever exposed: RR=1.00 (0.70-1.40) Highest exposure: RR=1.20 (0.70-1.90)
Verkasalo 1996[3]	Finland	Cohort, general population	Cumulative exposure	Incidence	Ever exposed (calculated): SIR=1.00 (0.78-1.29) Highest exposure: SIR=0.00 (0.00-5.51)

Abbreviations: RR: rate ratio; SIR: standardised incidence ratio.
* In some cases the Committee has aggregated categories.

6.10 Testicular cancer and occupational exposure

Table 25 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of testicular cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Törnqvist 1986[53]	Sweden	Cohort, general population	Occupation	Incidence	Ever exposed (calculated): SMR=1.76 (0.84-3.70)
Pearce 1989[24]	New Zealand	Case-control, general population	Occupation	Incidence	Ever exposed: OR=0.78 (0.41-1.47)
Swerdlow 1991[154]	England	Case-control, general population	Occupation	Incidence	Ever exposed: OR=0.74 (0.40-1.37)
Tynes 1992[29]	Norway	Case-control, railway workers	JEM	Incidence	Ever exposed: SIR=0.83 (0.59-1.12)
Stenlund 1997[118]	Sweden	Case-control, general population	Occupation	Incidence	Ever exposed (calculated): OR=1.34 (0.91-1.97) Highest exposure: OR=1.30 (0.80-4.40)
Johansen 1998[67]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=0.92 (0.70-1.20)
Floderus 1999[40]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.20 (1.07-1.35) Highest exposure: RR=1.10 (1.00-1.40)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=1.02 (0.81-1.29) Highest exposure: RR=0.70 (0.40-1.10)
Baumgard-Elms 2002[155]	Germany	Case-control, general population	Expert opinion	Incidence	Ever exposed (calculated): OR=0.91 (0.75-1.11)
Sorahan 2012[81]	England, Wales	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SRR=0.85 (0.67-1.05)

Abbreviations: JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardised incidence ratio.
* In some cases the Committee has aggregated categories.

Table 26 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of testicular cancer that were not included in the analysis

Reference	Reason for exclusion
Fear 1996[62]	PRR study
Pearce 1987[156]	No exposure to ELF magnetic fields
Van den Eeden 1991[157]	Only individual occupations studied
Knoke 1998[158]	Only individual occupations studied
Hardell 1998[159]	Only individual occupations studied
Pollán 2001[160]	Only individual occupations studied
Groves 2002[79]	No exposure to ELF magnetic fields
Nichols 2005[80]	Update in later publication

Abbreviations: PRR: proportional registration ratio.

6.11 Pancreatic cancer and residential exposure

Table 27 Studies that investigate the relationship between residential exposure and risk of pancreatic cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Schreiber 1993[13]	Netherlands	Cohort, general population	Distance	Mortality	0-100 m: SMR=124 (25-361)
Verkasalo 1996[3]	Finland	Cohort, general population	Cumulative exposure	Incidence	Ever exposed (calculated): SIR=1.04 (0.94-1.16) Highest exposure: SIR=0.83 (0.36-1.64)

Abbreviations: SIR: standardised incidence ratio; SMR: standardised mortality ratio.
* In some cases the Committee has aggregated categories.

6.12 Pancreatic cancer and occupational exposure

Table 28 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of pancreatic cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Törnqvist 1986[53]	Sweden	Cohort, general population	Occupation	Incidence	Ever exposed (calculated): SMR=0.93 (0.66-1.32)
Pearce 1989[24]	New Zealand	Case-control, general population	Occupation	Incidence	Ever exposed: OR=0.91 (0.51-1.62)
Tynes 1992[29]	Norway	Cohort, general population	JEM	Incidence	Ever exposed: SIR=1.19 (1.09-1.38)
Tynes 1994[36]	Norway	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=1.09 (0.66-1.70) Highest exposure: SIR=1.35 (0.65-2.48)
Savitz 1995[61]	USA	Cohort, electricity companies	JEM	Mortality	Ever exposed: SMR=0.84 (0.74-0.95)
Johansen 1998[67]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SIR=1.18 (0.95-1.46)
Ji 1999[161]	China	Case-control, general population	JEM	Incidence	Ever exposed (calculated): OR=1.08 (0.85-1.37) Highest exposure (calculated): OR=2.35 (1.05-5.23)

Floderus 1999[40]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.08 (1.02-1.14) Highest exposure (calculated): RR=1.07 (0.99-1.16)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=0.80 (0.65-1.00) Highest exposure: RR=1.20 (0.80-1.90)
Weiderpass 2003[162]	Finland	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.14 (1.00-1.29) Highest exposure: RR=1.82 (1.18-2.81)
Sorahan 2012[81]	England, Wales	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SRR=0.85 (0.77-0.94)

Abbreviations: JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardized incidence ratio; SMR: standardised mortality ratio; SRR: standardised registration ratio.
* In some cases the Committee has aggregated categories.

Table 29 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of pancreatic cancer that were not included in the analysis

Reference	Reason for exclusion
Baris 1996[64]	The same data as in Theriault 1994[37]
Fear 1996[62]	PRR study
Pira 1999[69]	No exposure to ELF magnetic fields
Nichols 2005[80]	Update in later publication

Abbreviations: PRR: proportional registration ratio.

6.13 Lung cancer and residential exposure

Table 30 Studies that investigate the relationship between residential exposure and risk of lung cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Schreiber 1993[13]	Netherlands	Cohort, general population	Distance	Mortality	0-100 m: SMR=114 (65-185)
Verkasalo 1996[3]	Finland	Cohort, general population	Average exposure	Incidence	Ever exposed (calculated): SIR=0.92 (0.85-1.00) Highest exposure: SIR=0.91 (0.62-1.29)

Abbreviations: SIR: standardised incidence ratio; SMR: standardised mortality ratio.
* In some cases the Committee has aggregated categories.

6.14 Lung cancer and occupational exposure

Table 31 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of lung cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Törnqvist 1986[53]	Sweden	Cohort, general population	Occupation	Incidence	Ever exposed (calculated): SMR=0.70 (0.55-0.90)
Pearce 1989[24]	New Zealand	Case-control, general population	Occupation	Incidence	Ever exposed: OR=0.88 (0.69-1.11)
Tynes 1992[29]	Norway	Cohort, general population	JEM	Incidence	Ever exposed: SIR=1.09 (1.00-1.19)
Tynes 1994[36]	Norway	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=1.11 (0.86-1.40) Highest exposure: SIR =1.29 (0.88-1.82)
Theriault 1994[37]	Canada, France	Case-control, electricity companies	JEM	Incidence	Ever exposed: OR=1.00 (0.67-2.51)
Alfredsson 1996[39]	Sweden	Cohort, railway workers	Occupation	Incidence	Ever exposed: RR=0.70 (0.50-1.00)
Savitz 1997[163]	USA	Cohort, electricity companies	JEM	Incidence	Ever exposed: SMR=0.91 (0.87-0.95) Highest exposure: SMR=1.25 (1.02-1.52)
Johansen 1998[67]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SIR=1.14 (1.10-1.19)
Floderus 1999[40]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.24 (1.21-1.28) Highest exposure (calculated): RR=1.29 (1.24-1.34)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=1.11 (0.97-1.22) Highest exposure (calculated): RR=1.09 (0.88-1.35)
Röösli 2007[49]	Switzerland	Cohort, railway workers	JEM	Incidence	Ever exposed (calculated): OR=1.05 (0.89-1.24)
Sorahan 2012[81]	England, Wales	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SRR=0.83 (0.79-0.86)
Koeman 2014[50]	Netherlands	Cohort, general population	JEM	Incidence	Ever exposed: HR=1.2 (0.91-1.15) Highest exposure: HR=0.98 (0.86-1.12)

Abbreviations: HR: hazard rate; JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardized incidence ratio; SMR: standardised mortality ratio; SRR: standardised registration ratio.
* In some cases the Committee has aggregated categories.

Table 32 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of lung cancer that were not included in the analysis

Reference	Reason for exclusion
Savitz 1995[61]	Update in later publication
Fear 1996[62]	PRR study
Baris 1996[64]	The same data as in Theriault 1994[37]
Pira 1999[69]	No exposure to ELF magnetic fields
Minder 2001[75]	Update in later publication
Nichols 2005[80]	Update in later publication
Yenugadhati 2009[164]	Only individual occupations studied

Abbreviations: PRR: proportional registration ratio.

6.15 Prostate cancer and residential exposure

Table 33 Studies that investigate the relationship between residential exposure and risk of prostate cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Verkasalo 1996[3]	Finland	Cohort, general population	Cumulative exposure	Incidence	Ever exposed (calculated): SIR=0.99 (0.91-1.07) Highest exposure: SIR=1.22 (0.77-1.85)
Zhu 1999[165]	USA	Case-control, general population	Electric blanket, waterbed use	Incidence	Ever exposed: OR=1.4 (0.9-2.2) Highest exposure: OR=1.70 (0.70-3.90)

Abbreviations: OR: odds ratio; SIR: standardised incidence ratio.
* In some cases the Committee has aggregated categories.

6.16 Prostate cancer and occupational exposure

Table 34 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of prostate cancer that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate*
Törnqvist 1986[53]	Sweden	Cohort, general population	Occupation	Incidence	Ever exposed (calculated): SMR=1.02 (0.93-1.13)
Pearce 1989[24]	New Zealand	Case-control, general population	Occupation	Incidence	Ever exposed: OR=0.96 (0.71-1.29)
Tynes 1992[29]	Norway	Cohort, general population	JEM	Incidence	Ever exposed: SIR=1.02 (0.94-1.10)
Tynes 1994[36]	Norway	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=1.08 (0.86-1.32) Highest exposure: SIR=1.08 (0.78-1.47) Longest exposure: SIR=1.06 (0.79-1.39)
Theriault 1994[37]	Canada, France	Case-control, electricity companies	JEM	Incidence	Ever exposed: OR=1.18 (0.70-2.00)
Johansen 1998[67]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SIR=1.07 (0.90-1.20)
Floderus 1999[40]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.10 (1.06-1.14) Highest exposure: RR=1.10 (1.00-1.20)

Charles 2003[166]	USA	Cohort, general population	JEM	Incidence	Ever exposed (calculated): OR=1.16 (0.97-1.39) Highest exposure: OR=1.60 (1.07-2.40)
Sorahan 2012[81]	England, Wales	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SRR=1.07 (1.03-1.11)

Abbreviations: JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SIR: standardised incidence ratio; SMR: standardised mortality ratio; SRR: standardised registration ratio.
* In some cases the Committee has aggregated categories.

Table 35 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of prostate cancer that were not included in the analysis

Reference	Reason for exclusion
Savitz 1995[61]	Update in later publication
Fear 1996[62]	PRR study
Guénel 1996[65]	No exposure to ELF magnetic fields
Pira 1999[69]	No exposure to ELF magnetic fields
Nichols 2005[80]	Update in later publication

Abbreviations: PRR: proportional registration ratio.

6.17 Skin melanomas and residential exposure

Table 36 Studies that investigate the relationship between residential exposure and risk of skin melanomas that were included in the analysis

Reference	Country, period	Type of study	Exposure criterion	Determination of disease	Risk estimate
Verkasalo 1996[3]	Finland	Cohort, general population	Cumulative exposure	Incidence	Ever exposed (calculated): SIR=1.00 (0.88-1.14) Highest exposure: SIR=1.19 (0.48-2.46)
Tynes 2003	Norway	Case-control, general population	Average exposure	Incidence	Ever exposed (calculated): OR=1.86 (1.39-2.50) Highest exposure: OR=1.87 (1.23-2.83)
Elliott 2013[8]	England	Case-control, general population	Distance, magnetic field	Incidence	Distance <50 m: OR=0.82 (0.61-1.11) Magnetic field: Ever exposed (calculated): OR=0.88 (0.70-1.10) Highest exposure: OR=0.84 (0.47-1.51)
Khan 2021[167]	Finland	Cohort, general population	Proximity of transformer in residential building	Incidence	Ever exposed: HR=0.88 (0.57-1.35)

Abbreviations: HR: hazard rate; OR: odds ratio; SIR: standardised incidence ratio.
* In some cases the Committee has aggregated categories.

6.18 Skin melanomas and occupational exposure

Table 37 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of melanoma that were included in the analysis

Reference	Country, period	Study control type	Exposure criterion	Determination of disease	Risk estimate*
Tynes 1994[36]	Norway	Cohort, electricity companies	JEM	Incidence	Ever exposed: SIR=112 (67-175)
Johansen 1998[67]	Denmark	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SIR=115 (94-141)
Floderus 1999[40]	Sweden	Cohort, general population	JEM	Incidence	Ever exposed (calculated): RR=1.39 (1.32-1.47) Highest exposure (calculated): RR=1.31 (1.20-1.42)
Tynes 2003[168]	Norway	Cohort	JEM	Incidence	Ever exposed (calculated): OR=1.11 (0.87-1.41) Highest exposure: OR=1.22 (0.80-1.82)
Håkansson 2002[45]	Sweden	Cohort, welders	JEM	Incidence	Ever exposed (calculated): RR=0.88 (0.77-1.01) Highest exposure (calculated): RR=0.66 (0.47-0.92)
Sorahan 2012[81]	England, Wales	Cohort, electricity companies	JEM	Incidence	Ever exposed (calculated): SRR=1.04 (0.93-1.16)

Abbreviations: JEM: job-exposure matrix; OR: odds ratio; RR: rate ratio; SRR: standardised registration ratio.
* In some cases the Committee has aggregated categories.

Table 38 Studies that investigate the relationship between occupational exposure to magnetic fields and risk of melanoma that were not included in the analysis

Reference	Reason for exclusion
Nichols 2005[80]	Update in later publication
Behrens 2010[169]	Only melanoma of the eye

7 Meta-analyses performed by the Committee

The Committee used the program RStudio, version 1.4.1106, to perform meta-analyses of the data from the available studies. Random effect analyses were used because the populations studied can differ from study to study. This chapter sets out the results of the Committee's meta-analyses.

With regard to residential exposure, sufficient data on risks is only available in relation to some types of cancer. It was possible to analyse the relationship to magnetic field strength for breast cancer in women, leukaemia and brain cancer. The relationship to distance to high-voltage power lines could only be analysed for breast cancer in women and leukaemia. The relationship to electric bed warmer use was also analysed for breast cancer in women.

In the case of occupational exposure, the main analysis compared the risks for employees who are exposed at work to a level of magnetic fields above background level and employees who are only exposed to the background level, caused by the electricity system and electrical equipment present in virtually every workplace, such as lighting, computers and household appliances. A distinction was made between studies of occupational exposure in the general population (such as case-control studies and cohort studies in the general population) and studies in subjects from specific industries, such as electricity company employees (these are usually cohort studies). Where possible, a number of subanalyses were carried out for each of these two types of study. Firstly, a distinction was made between studies where a subject's disease was diagnosed by a physician soon after it manifested itself, compared to studies where the subject's disease was determined on the basis of information on the death certificate. Secondly, studies in which exposure was actually measured, calculated or estimated based on a job-exposure matrix (JEM) were compared with studies in which ever practising a profession was used as the sole measure of exposure. The third subanalysis distinguished between studies with a complete and studies with an incomplete occupational history. Subanalyses were also carried out of highest and longest exposure, once again where possible.

7.1 Leukaemia in general

7.1.1 Leukaemia and residential distance to high-voltage power lines

The main analysis for residing at a distance of 0-50 metres from a high-voltage power line shows a statistically significantly increased risk (figure 2).

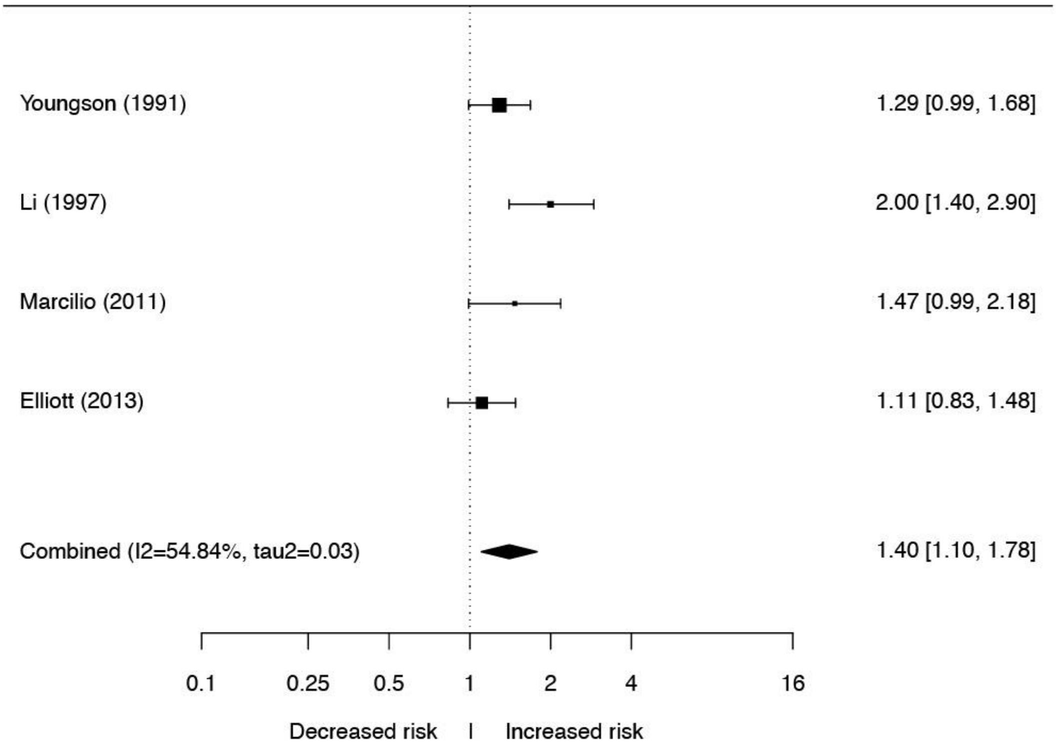


Figure 2 Meta-analysis of data on leukaemia and residing next to a high-voltage power line; risk estimate for main analysis of 0 and 50 metres versus more than 50 metres

7.1.2 Leukaemia and residential exposure to magnetic fields

For studies on residential exposure and leukaemia, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 3).

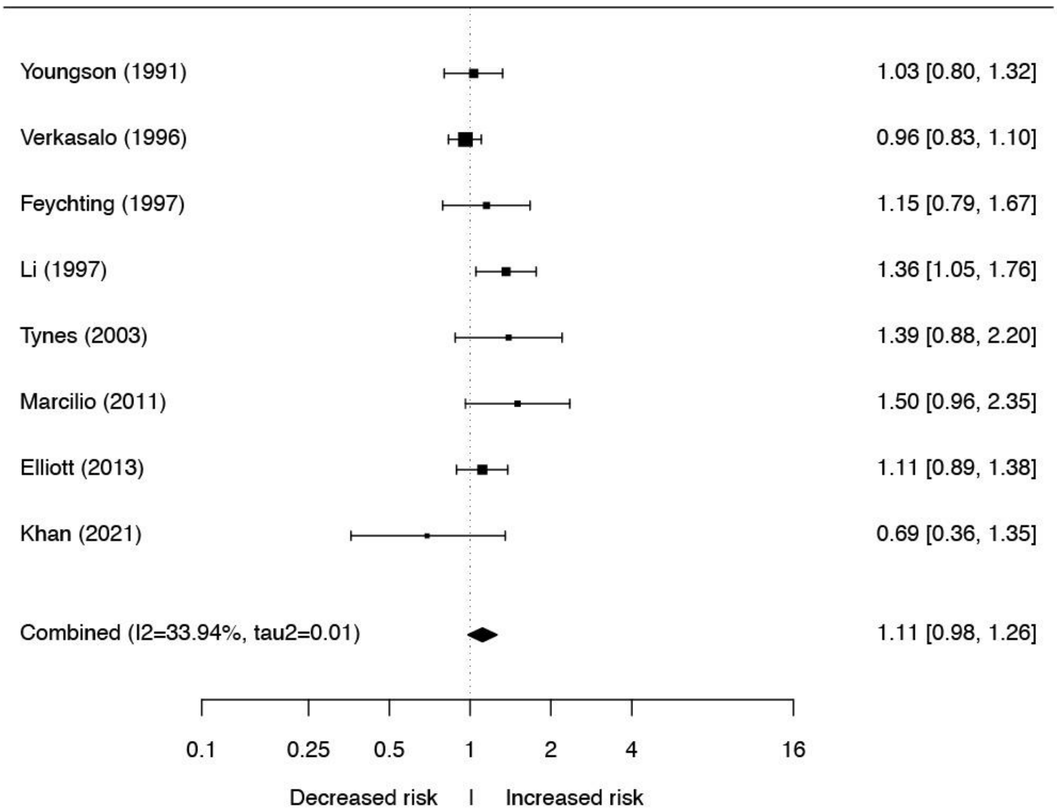


Figure 3 Meta-analysis of data on leukaemia and residential exposure to magnetic fields; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to highest exposure shows a statistically significantly increased risk (figure 4).

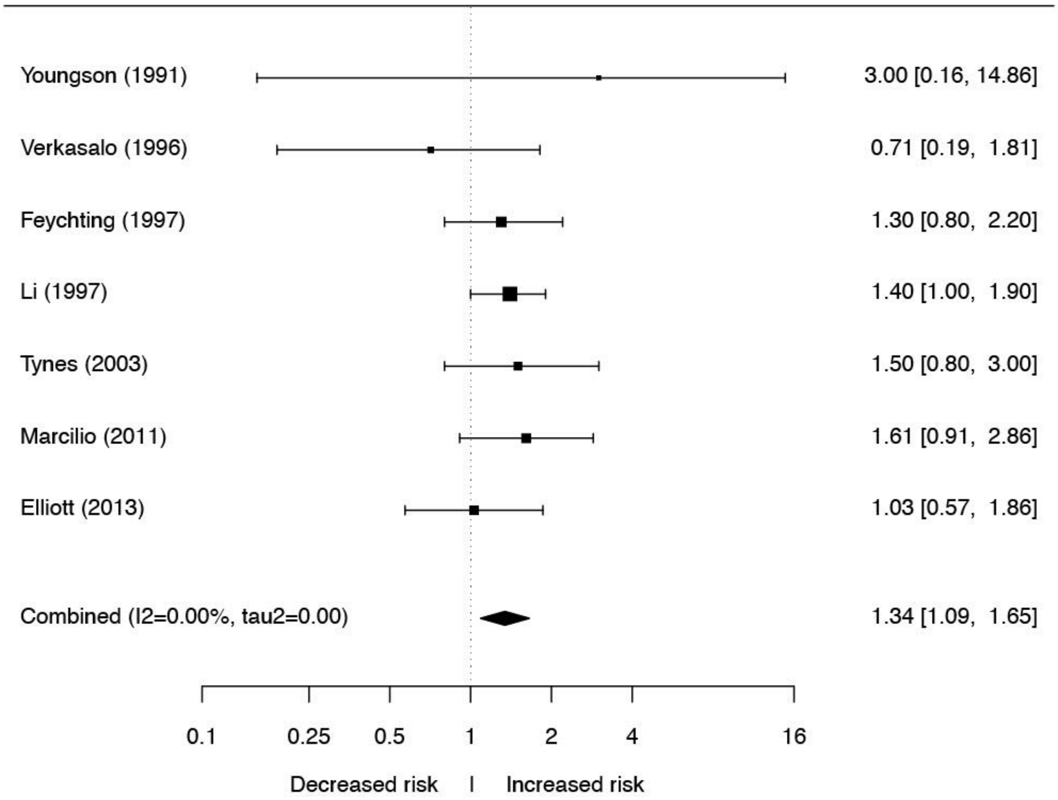


Figure 4 Meta-analysis of data on leukaemia and residential exposure to magnetic fields; risk estimate for subanalysis of highest exposure versus background exposure

Other subanalyses were not possible due to the low number of studies in the subcategories.
Table 39 summarises the results of the meta-analyses.

Table 39 Analysis of data on the relationship between residential exposure to magnetic fields and risk of leukaemia

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Hetero-geneity
Distance	0-50 metres to high-voltage power line	**1.40**	**1.10-1.78**	4	54.8%
Main analysis	Exposure above background levels	1.11	0.98-1.26	8	33.9%
	Highest exposure	**1.34**	**1.09-1.65**	7	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.1.3 Leukaemia and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 5).

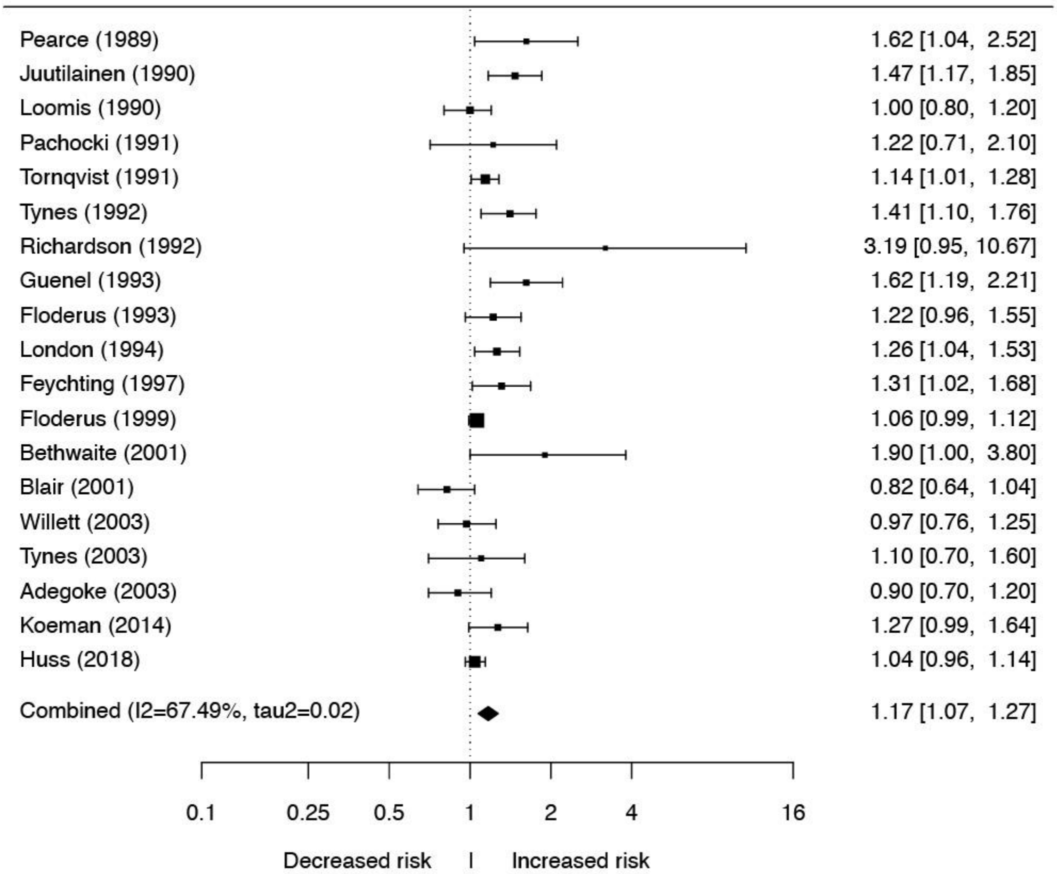


Figure 5 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnosis versus information from the death certificate) is only possible for diagnosis. This shows a statistically significantly increased risk (figure 6).

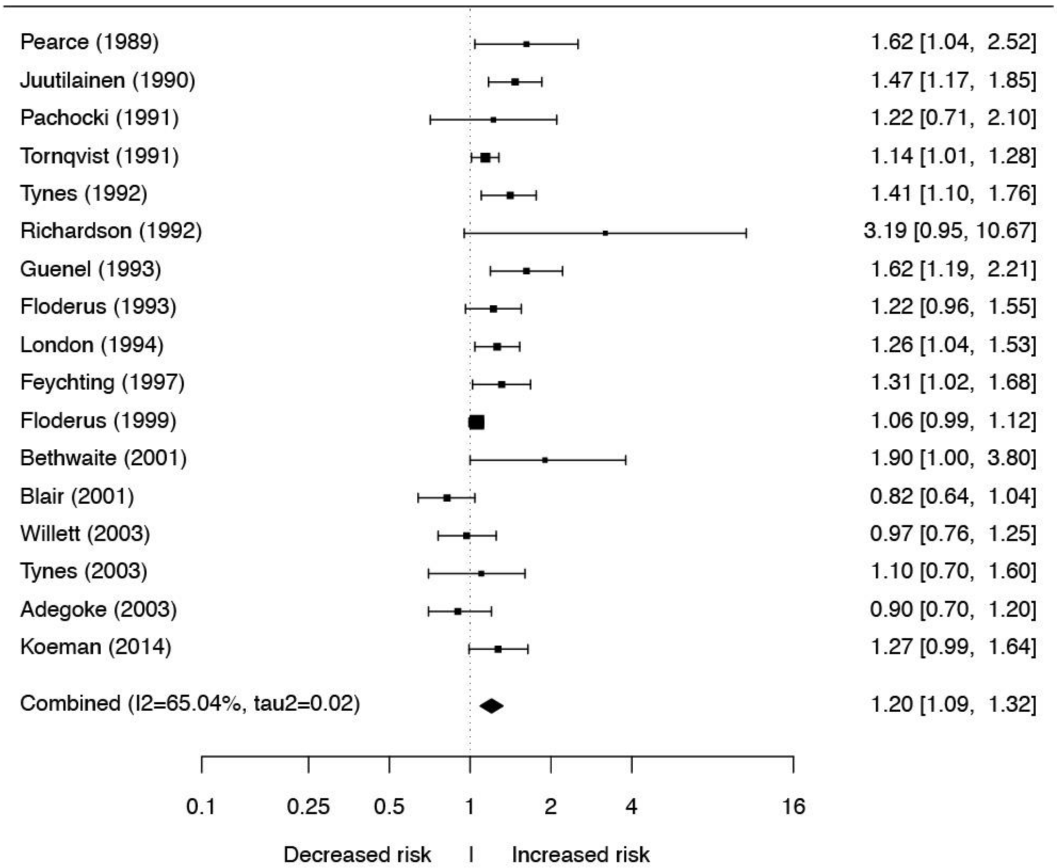


Figure 6 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of diagnosis alone

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). The risk estimates for both subcategories overlap each other entirely (figure 7).

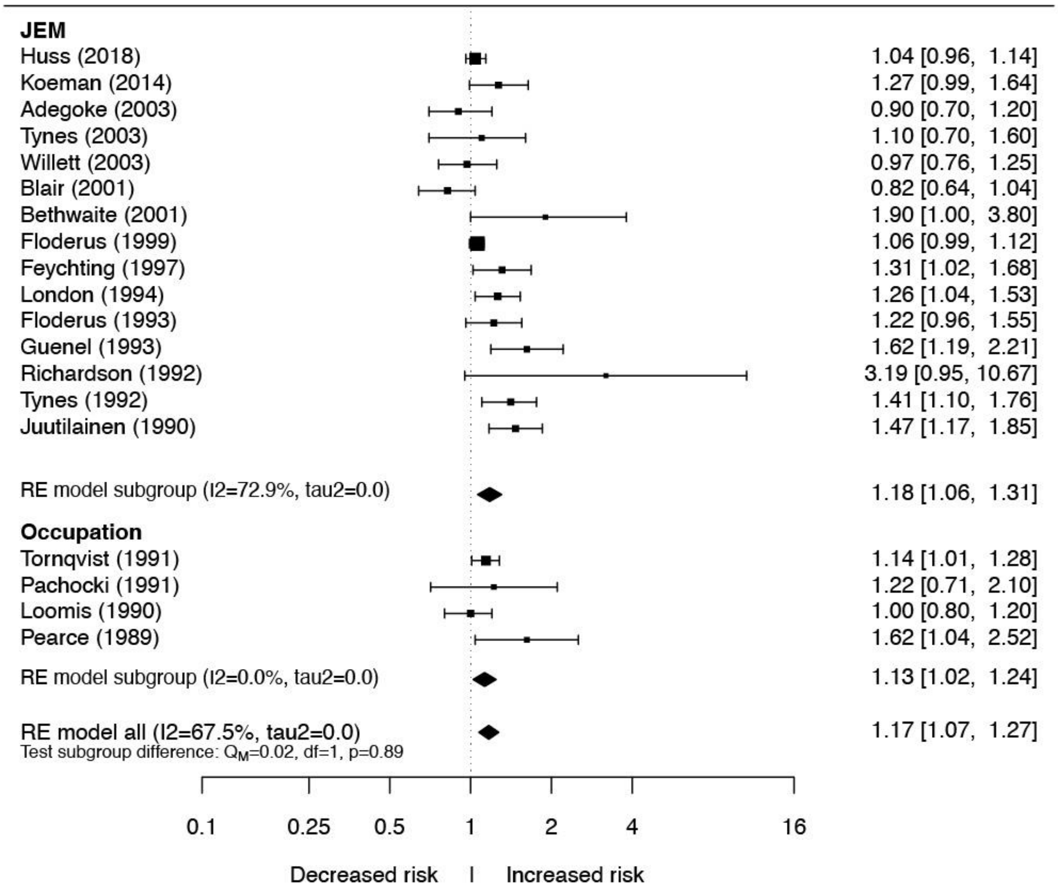


Figure 7 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) versus job title (Occupation)

In the subanalysis according to studies with a complete occupational history versus studies with an incomplete occupational history, only the risk estimate for incomplete occupational history was statistically significantly increased (figure 8).

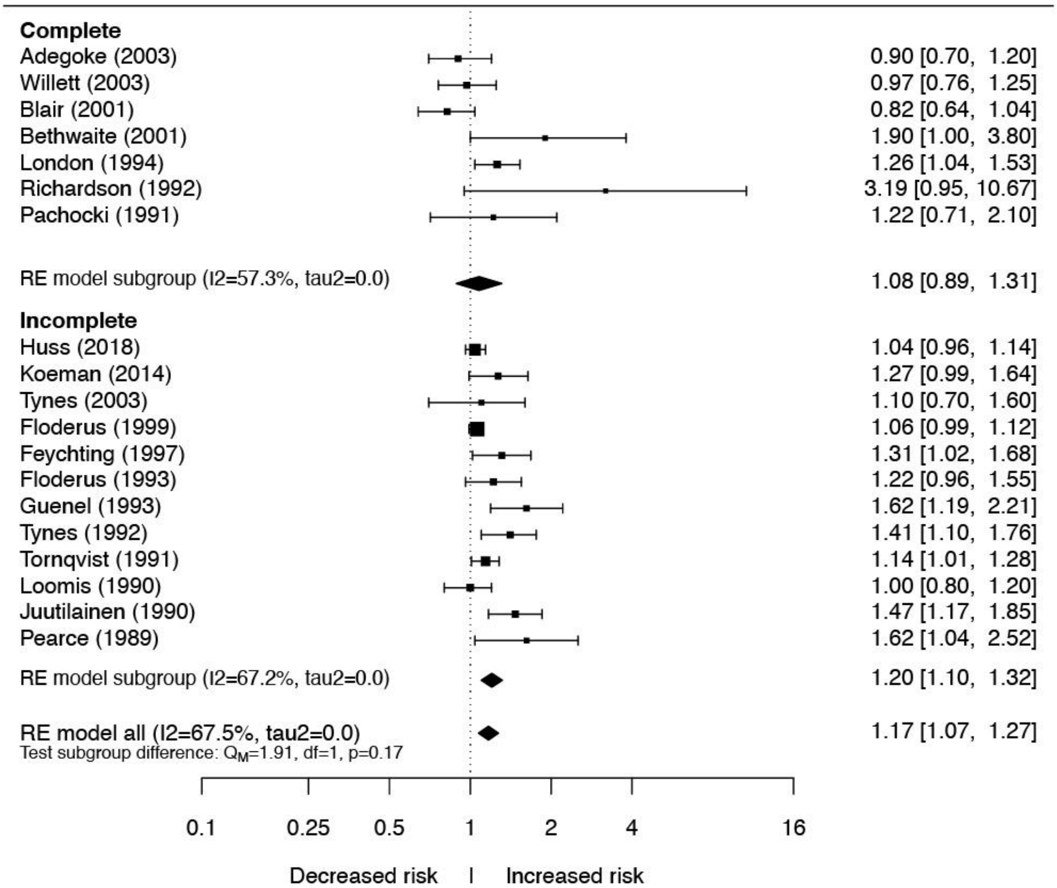


Figure 8 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of complete versus incomplete occupational history

The subanalysis of highest exposure versus background exposure shows a statistically significantly increased risk (figure 9).

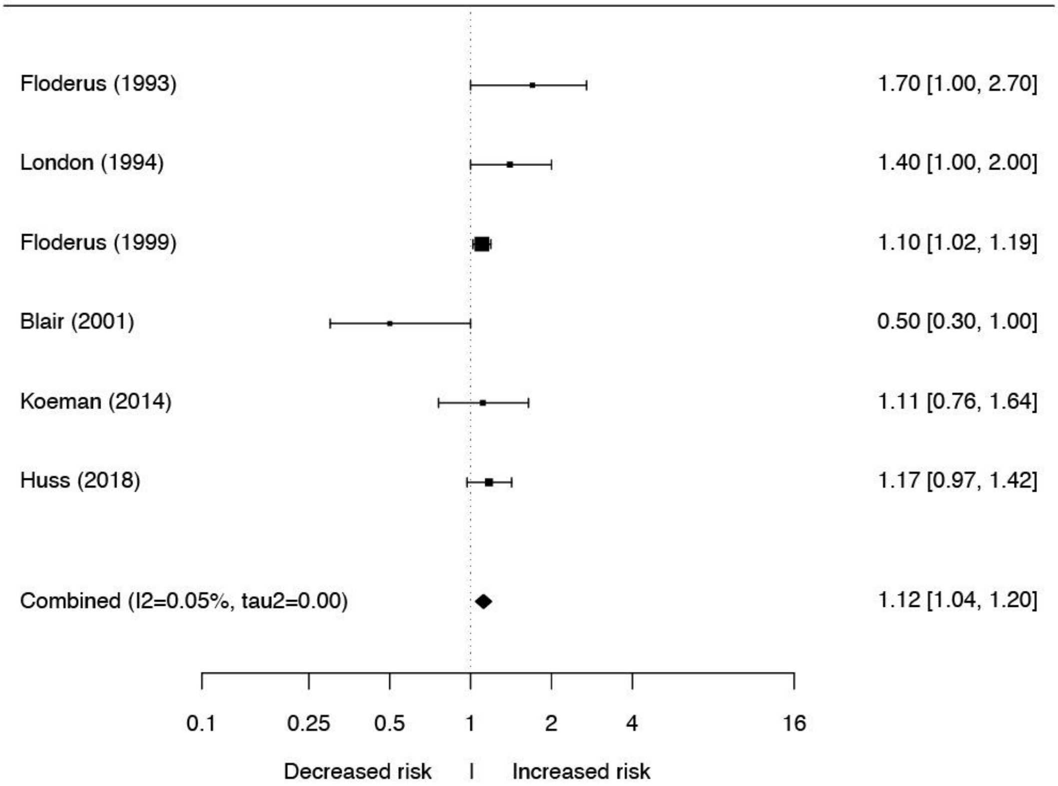


Figure 9 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of highest exposure versus background exposure

The subanalysis of longest exposure versus background exposure shows no statistically significantly increased risk (figure 10).

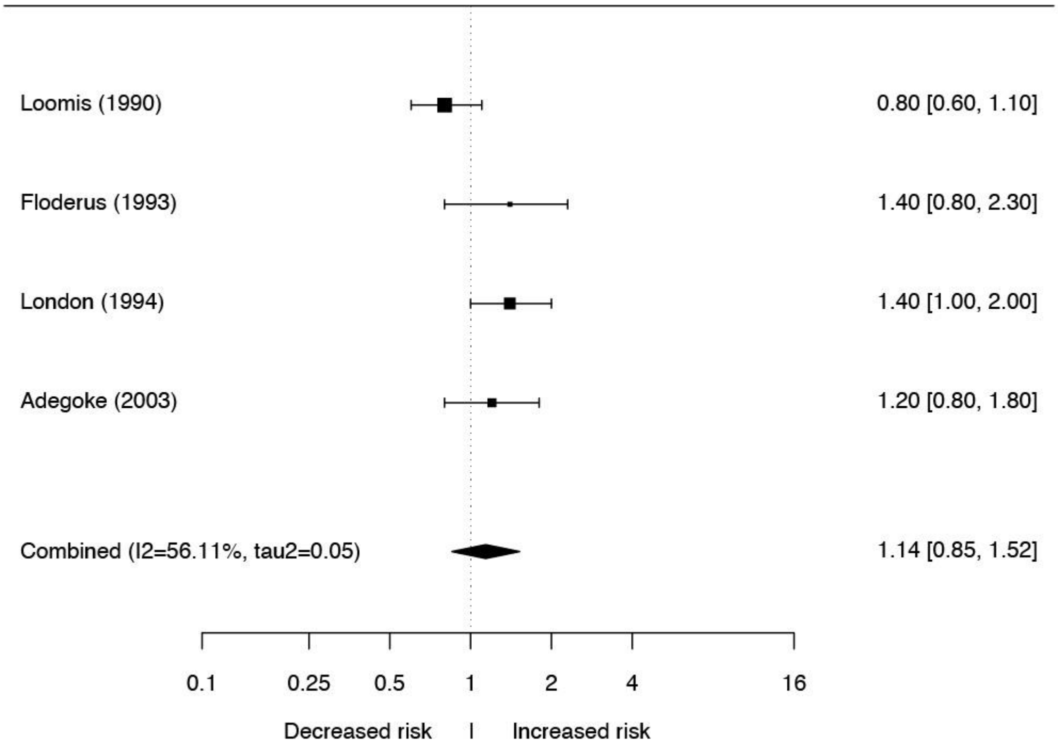


Figure 10 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of longest exposure versus background exposure

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 11).

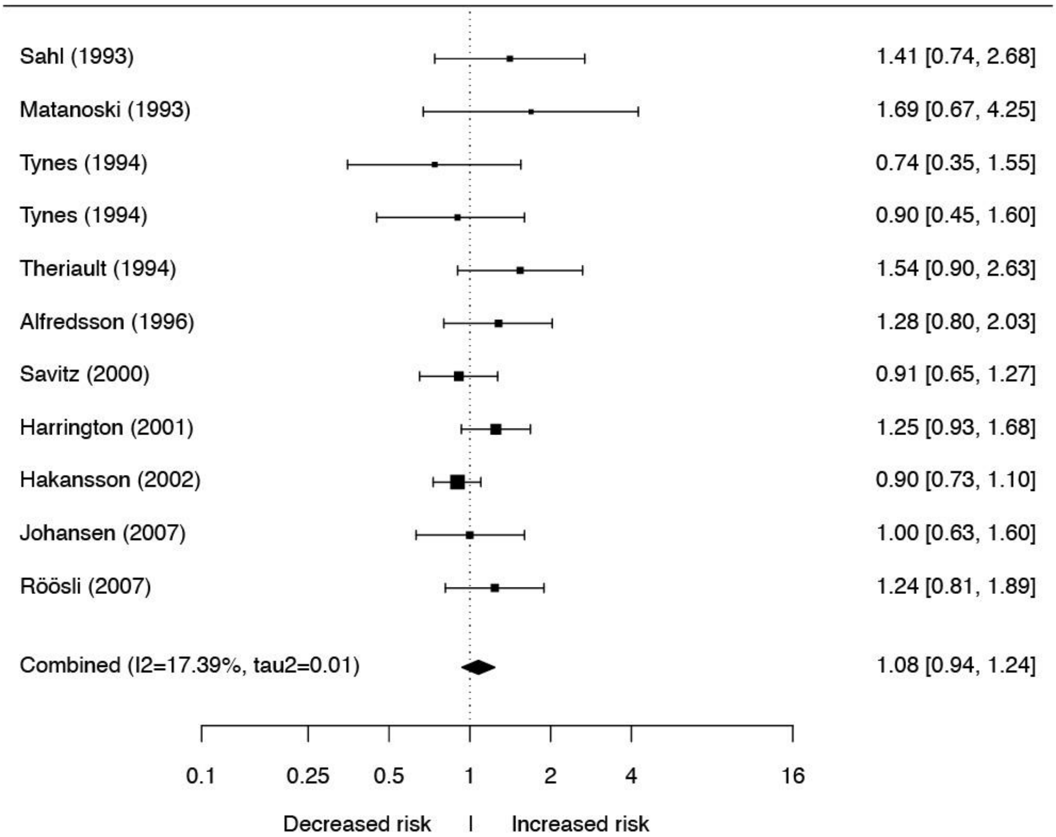


Figure 11 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - industrial populations; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to accuracy of the exposure assessment can only be carried out for studies in which exposure was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM). The risk estimate is not statistically significantly increased (figure 12)

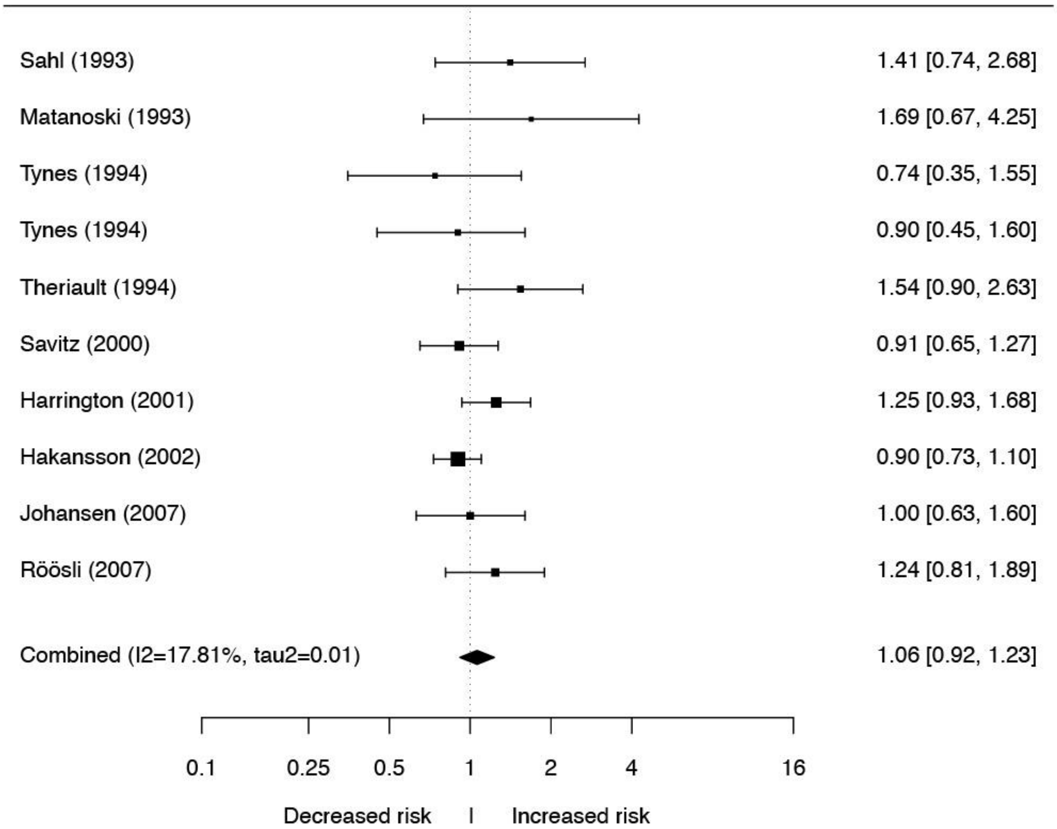


Figure 12 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - industrial populations; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone

In the subanalysis according to studies with a complete occupational history versus studies with an incomplete occupational history, the risk estimates were not statistically significantly increased (figure 13).

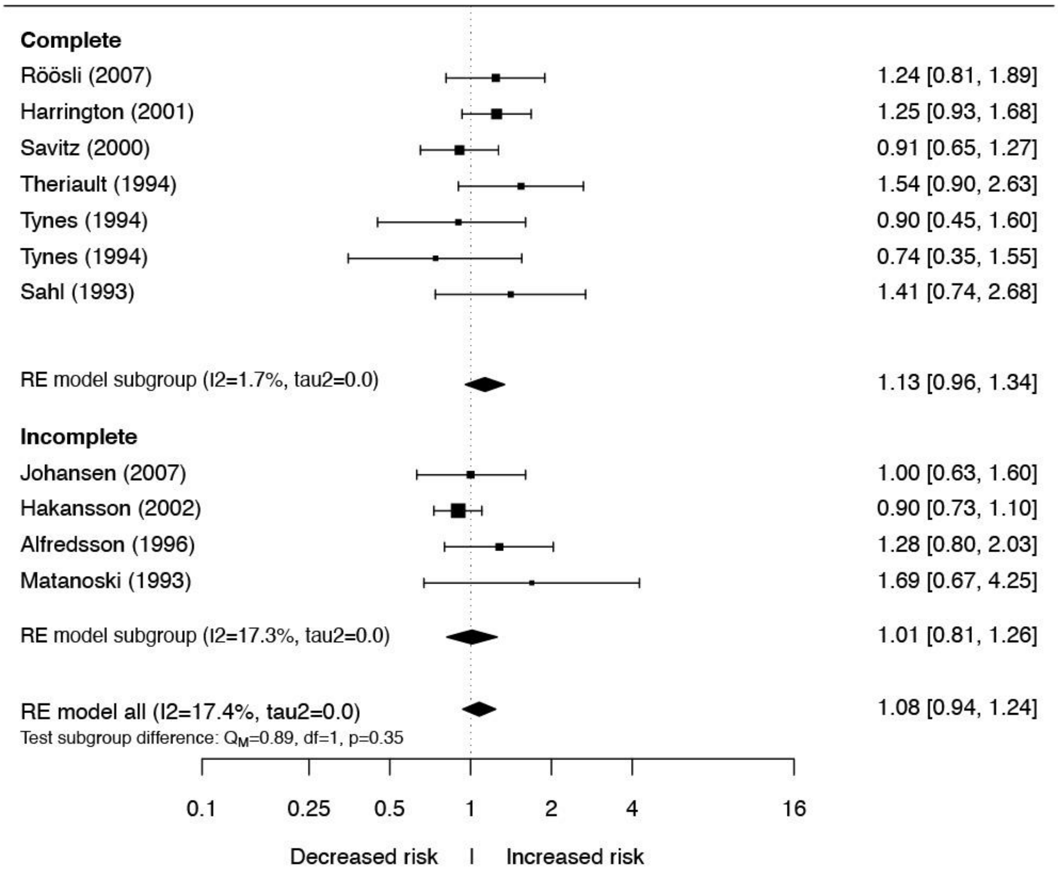


Figure 13 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - industrial populations; risk estimate for subanalysis of complete versus incomplete occupational history

Other subanalyses were not possible due to the low number of studies in the subcategories.

The subanalysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 14).

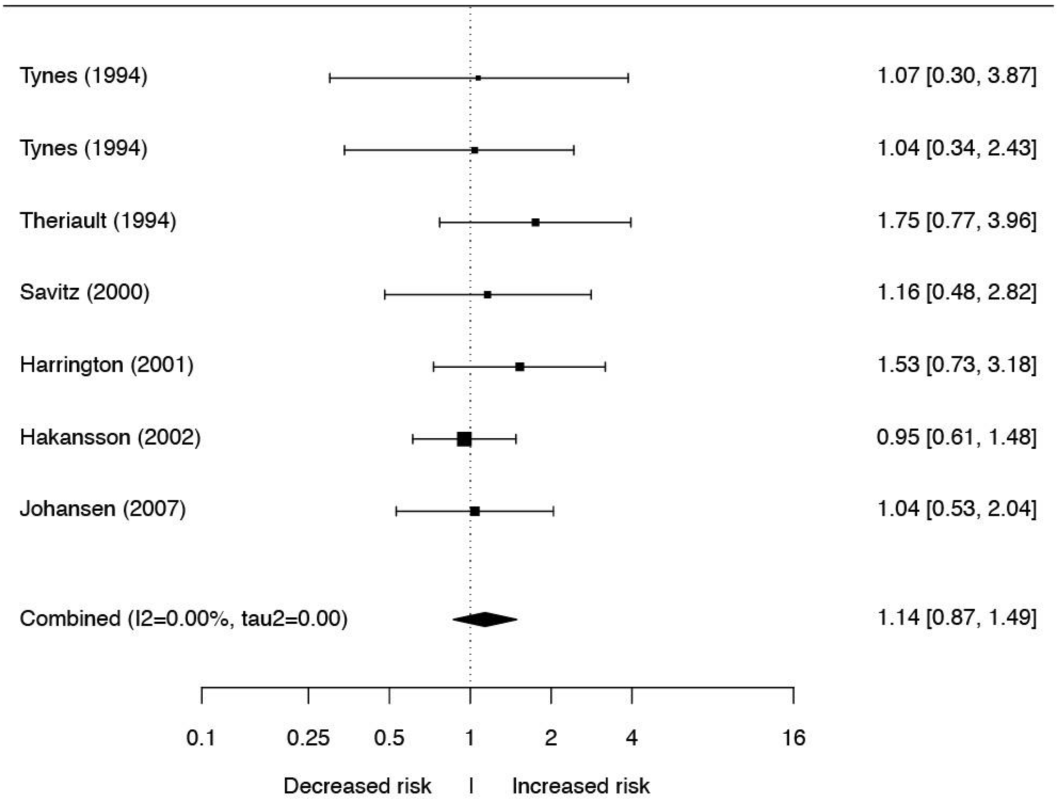


Figure 14 Meta-analysis of data on leukaemia and occupational exposure to magnetic fields - industrial populations; risk estimate for subanalysis of highest exposure versus background exposure

An analysis of longest exposure versus background exposure was not possible as the number of studies was too low.

Table 40 summarises the results of the meta-analyses.

Table 40 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of leukaemia

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Hetero-geneity
Main analysis of general population	Exposure above background levels	**1.17**	**1.07-1.27**	19	67.5%
Subanalysis 1: recording of disease	Diagnosis	**1.20**	**1.09-1.32**	17	65.0%
	Mortality	--	--	2	--
Subanalysis 2: exposure assessment	Calculated / measured	**1.18**	**1.06-1.31**	15	72.9%
	Occupation	**1.13**	**1.02-1.24**	4	0.0%
Subanalysis 3: occupational history	Incomplete	**1.20**	**1.10-1.32**	12	67.2%
	Complete	1.08	0.89-1.31	7	57.3%
Subanalysis 4	Highest exposure	1.12	1.04-1.20	6	0.0%
Subanalysis 5	Longest exposure	1.14	0.85-1.52	3	56.1%
Main analysis of industrial populations	Exposure above background levels	1.08	0.94-1.24	11	17.4%
Subanalysis 1: exposure assessment	Calculated / measured	**1.06**	**0.92-1.23**	10	17.8%
	Occupation	**--**	**--**	1	--
Subanalysis 2: occupational history	Incomplete	**1.01**	**0.81-1.26**	4	17.3%
	Complete	**1.13**	**0.96-1.34**	7	1.7%
Subanalysis 3	Highest exposure	1.14	0.87-1.49	7	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.2 Acute myeloid leukaemia (AML)

7.2.1 AML and residential distance to high-voltage power lines

No studies were found that investigate the relationship between distance to high-voltage power lines and risk of AML.

7.2.2 AML and residential exposure to magnetic fields

For studies on residential exposure and AML, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 15).

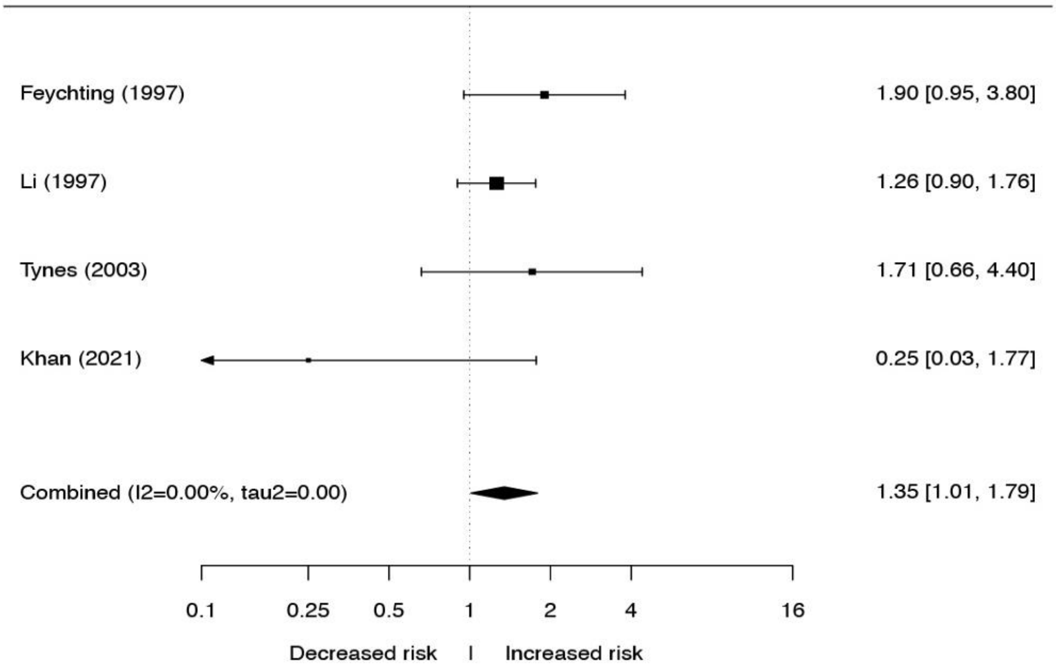


Figure 15 Meta-analysis of data on AML and residential exposure to magnetic fields; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to highest exposure shows a statistically significantly increased risk (figure 16).

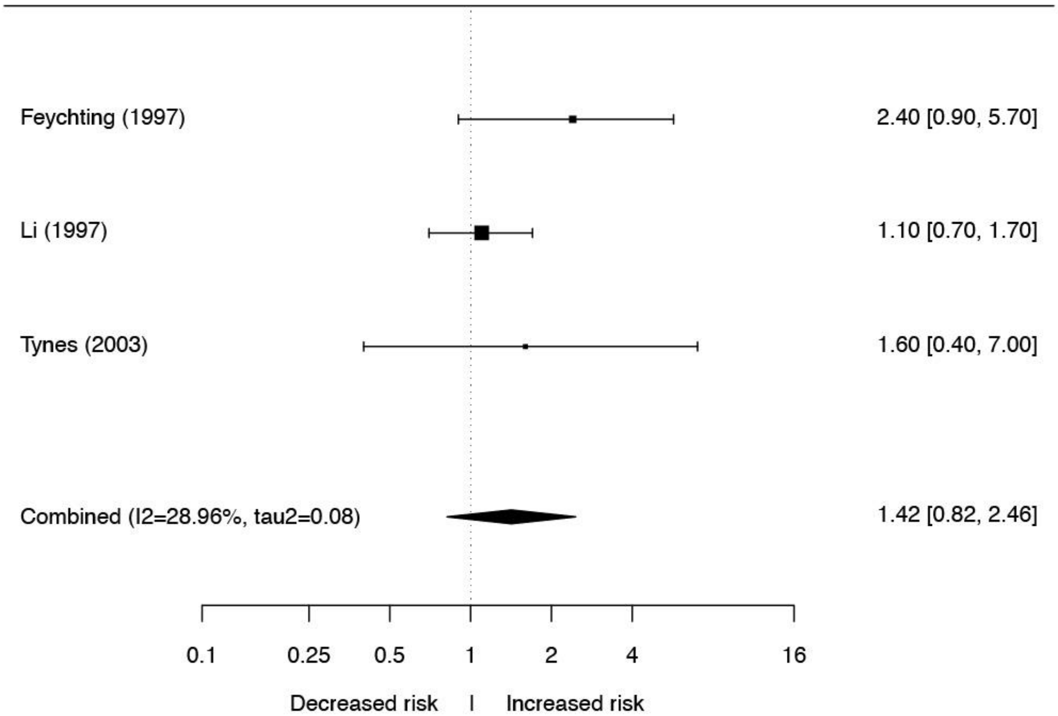


Figure 16 Meta-analysis of data on AML and residential exposure to magnetic fields; risk estimate for subanalysis of highest exposure versus background exposure

Table 41 summarises the results of the meta-analyses.

Table 41 Analysis of data on the relationship between residential exposure to magnetic fields and risk of AML

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis	Exposure above background levels	**1.35**	**1.01-1.79**	4	0.0%
	Highest exposure	**1.42**	**0.82-2.46**	3	29.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.2.3 AML and electric bed warmer use

Two studies were found that investigate the relationship between electric bed warmer use and the occurrence of AML. In the first study, a risk estimate of 0.9 (0.5-1.6) was found.[22] In the second study, the risk estimate was also 0.9 (0.7-1.2).[23]

7.2.4 AML and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 17).

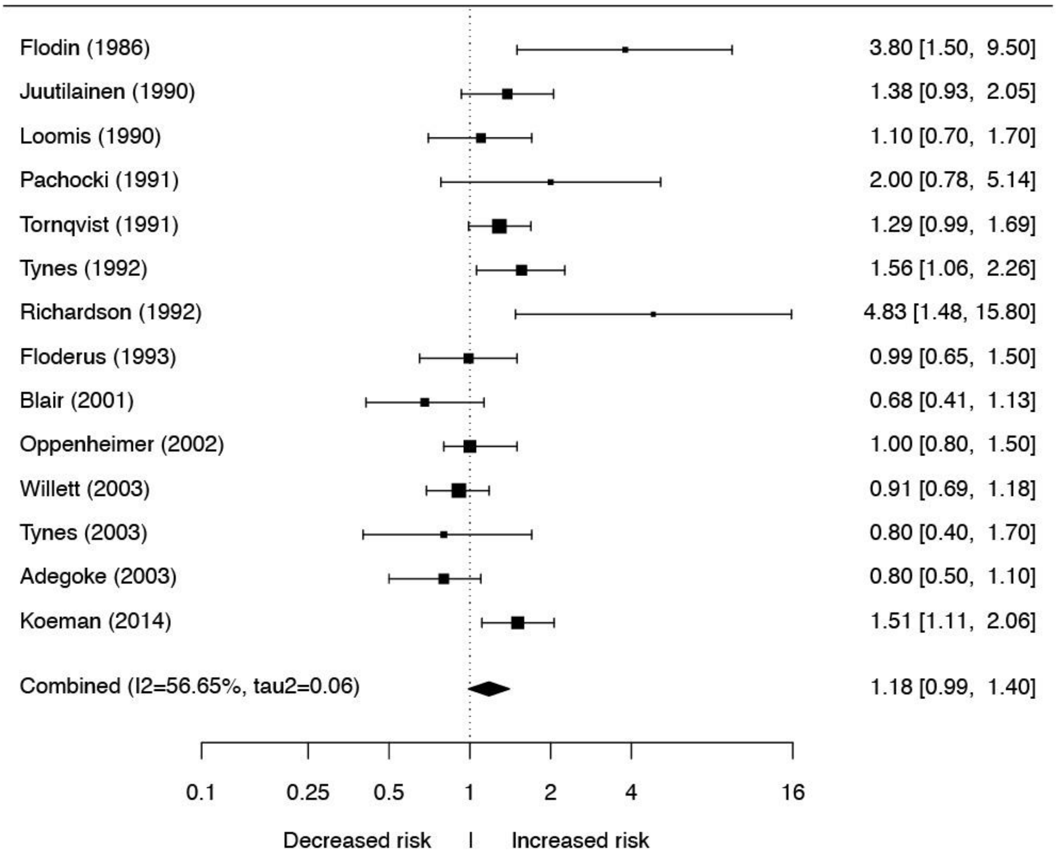


Figure 17 Meta-analysis of data on AML and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnosis versus information from the death certificate) is only possible for diagnosis. This shows no statistically significantly increased risk (figure 18).

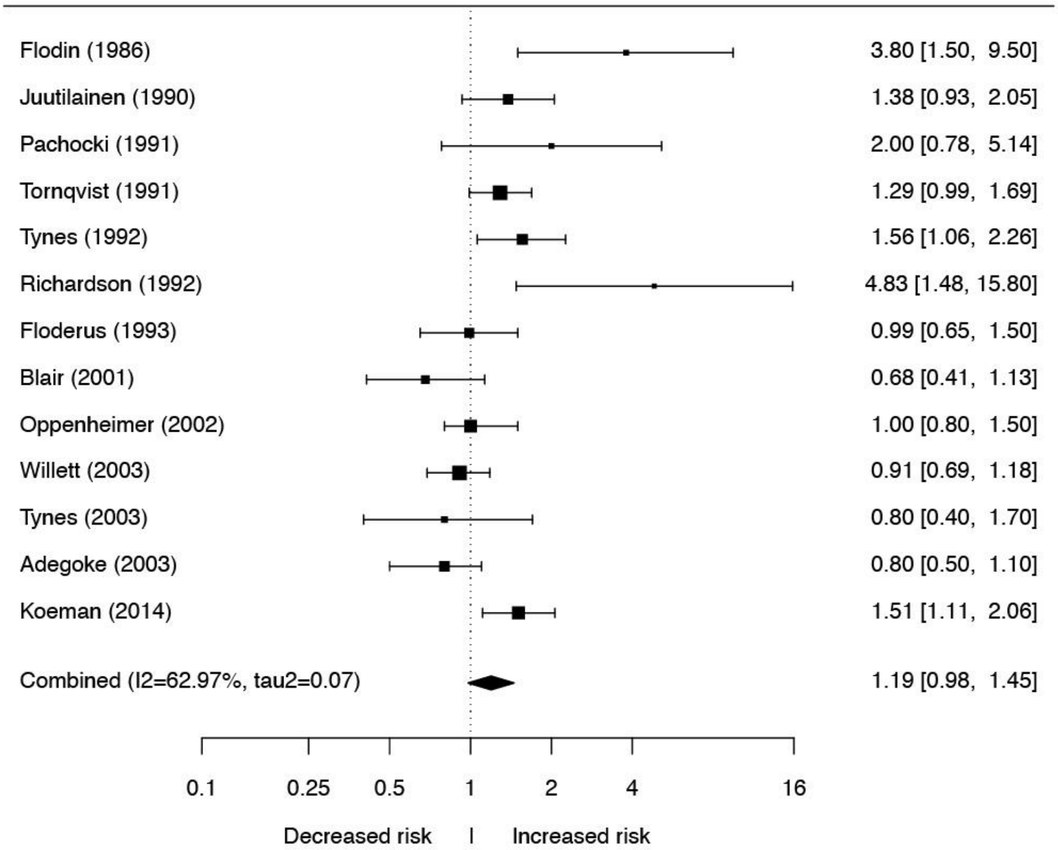


Figure 18 Meta-analysis of data on AML and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of diagnosis alone

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). In both subcategories, the risk estimate is not statistically significantly increased (figure 19).

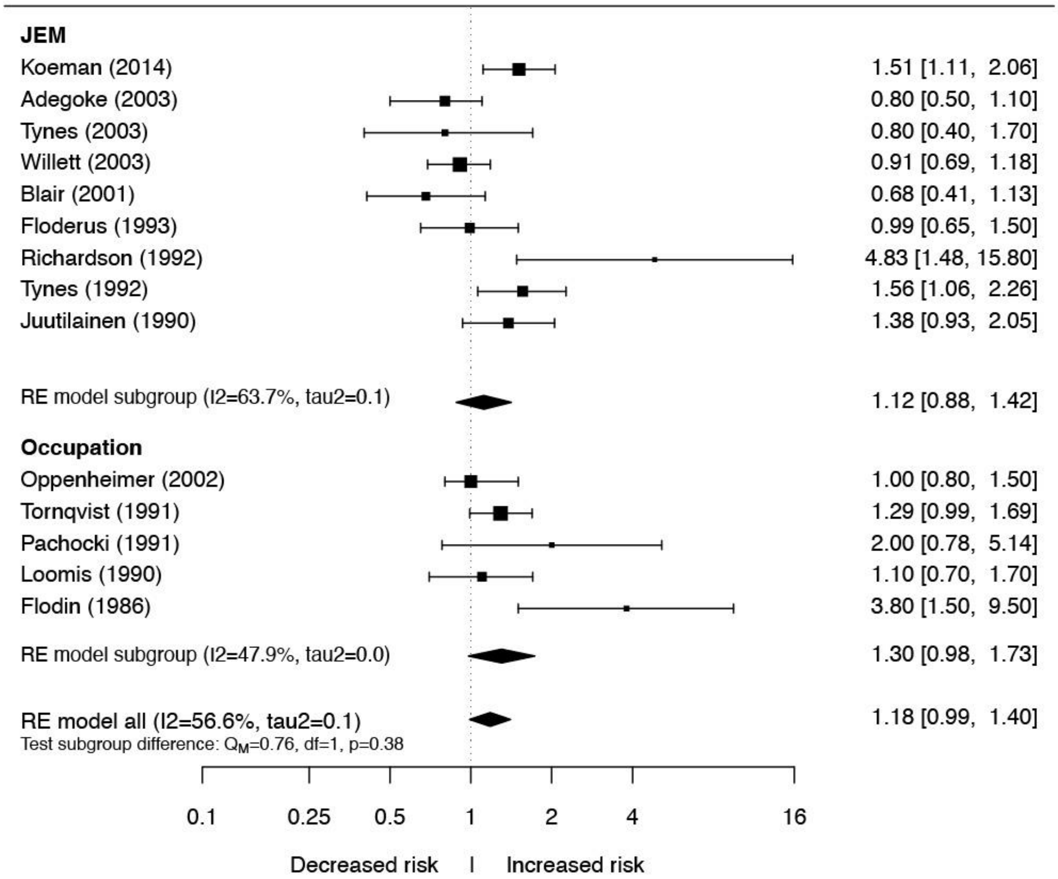


Figure 19 Meta-analysis of data on AML and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) versus job title (Occupation)

In the subanalysis according to completeness of the occupational history, the risk estimate is statistically significantly increased in the subcategory of incomplete occupational history. This was not the case in the subcategory of complete occupational history (figure 20).

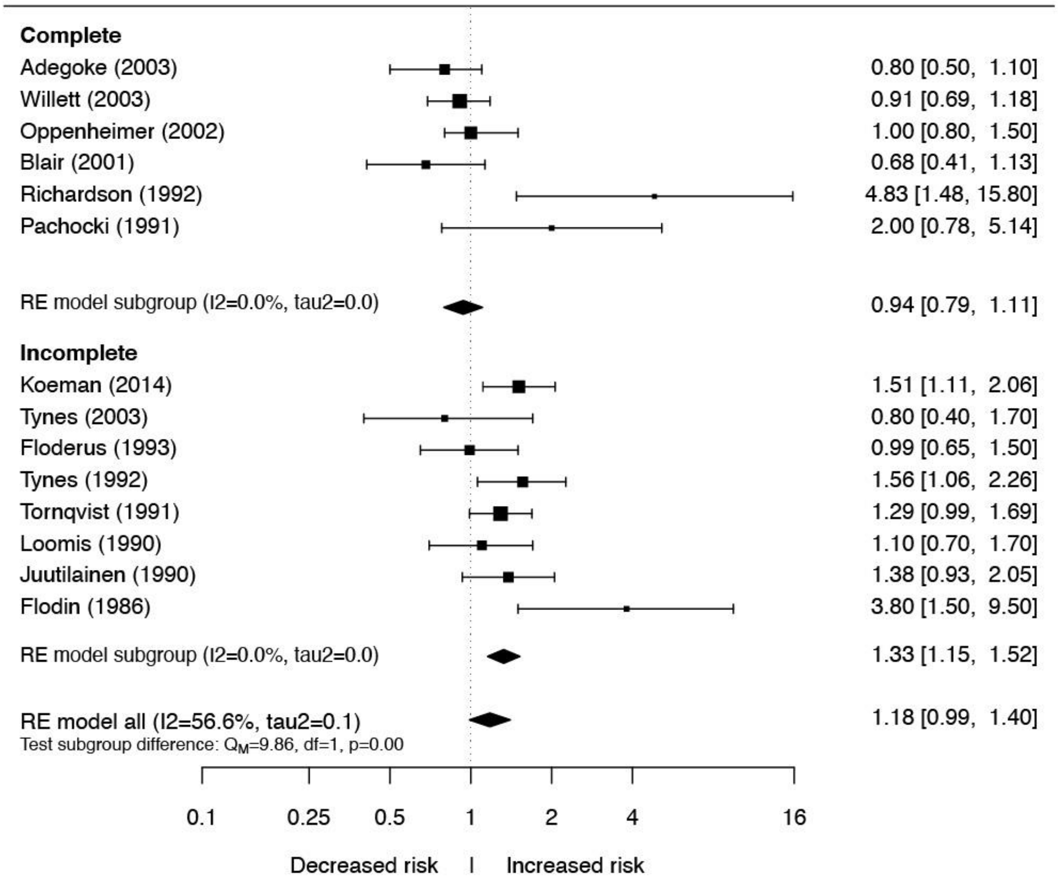


Figure 20 Meta-analysis of data on AML and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of complete versus incomplete occupational history

No other subanalyses were possible as the number of studies in one of the subcategories was too low.

The analysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 21).

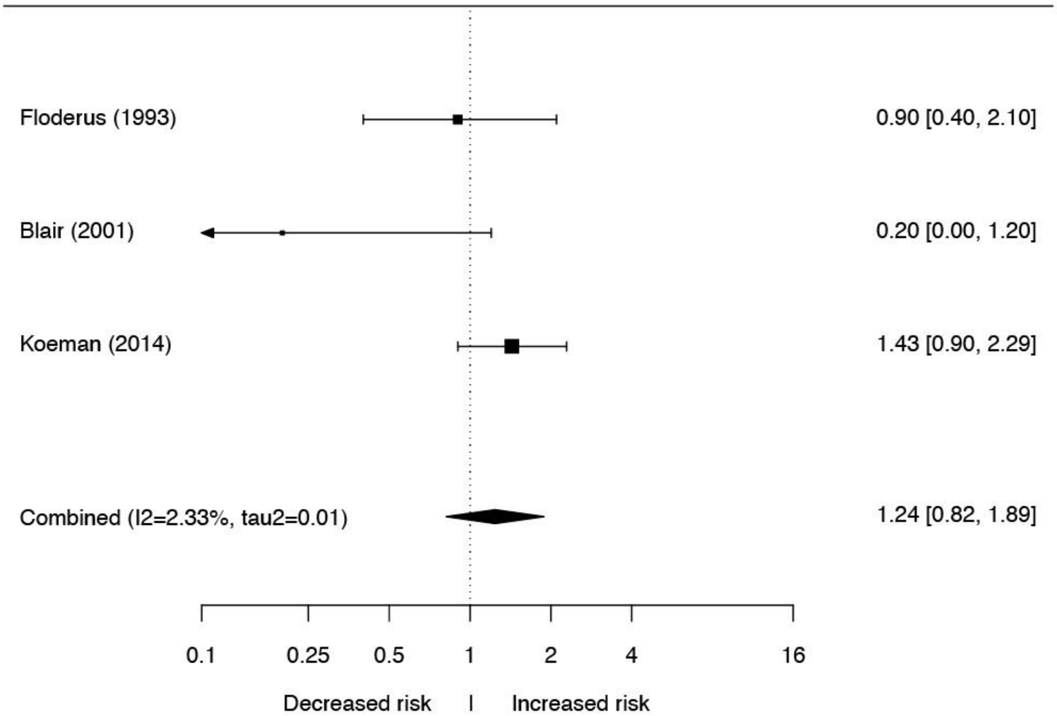


Figure 21 Meta-analysis of data on AML and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of highest exposure versus background exposure

An analysis of longest exposure versus background exposure was not possible as the number of studies was too low.

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 22).

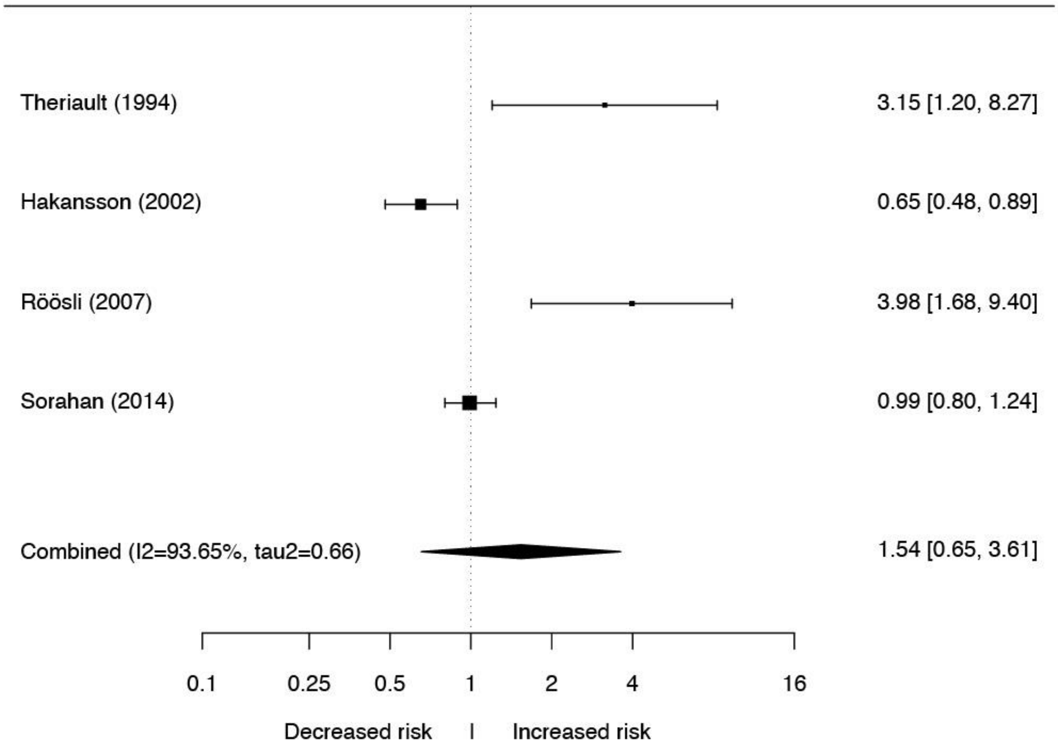


Figure 22 Meta-analysis of data on AML and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

The subanalysis according to accuracy of the exposure assessment is only possible for studies in which exposure was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM). The risk estimate is not statistically significantly increased (figure 23).

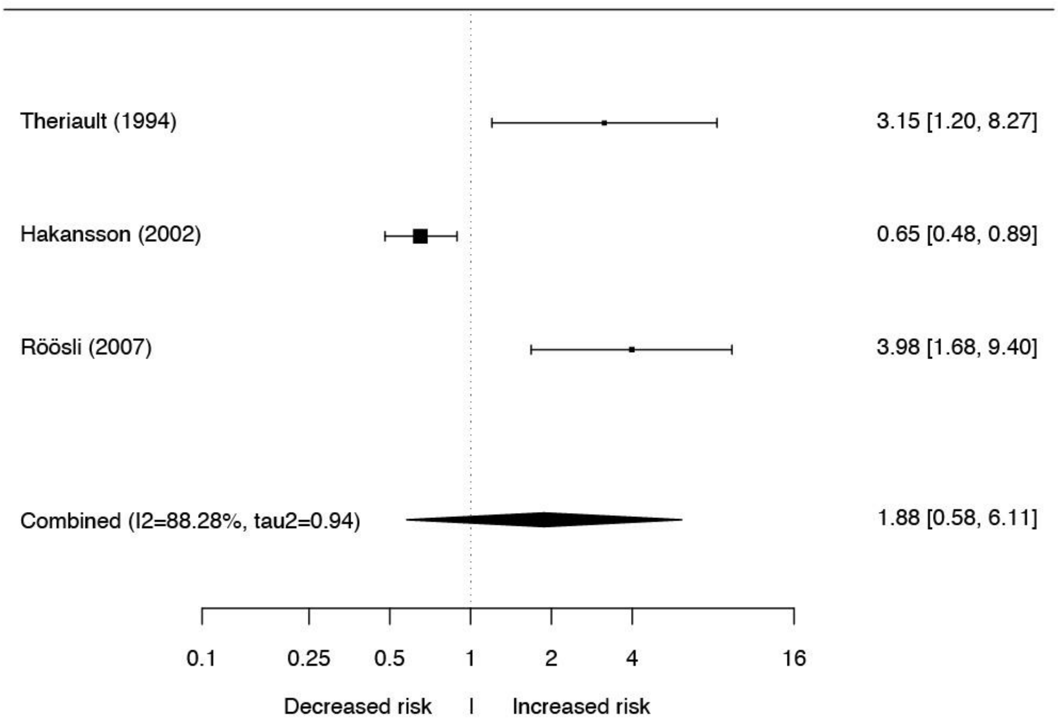


Figure 23 Meta-analysis of data on AML and occupational exposure to magnetic fields - industrial populations; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone

The subanalysis according to completeness of occupational history is only possible for studies with a complete occupational history. The risk estimate is not statistically significantly increased (figure 24).

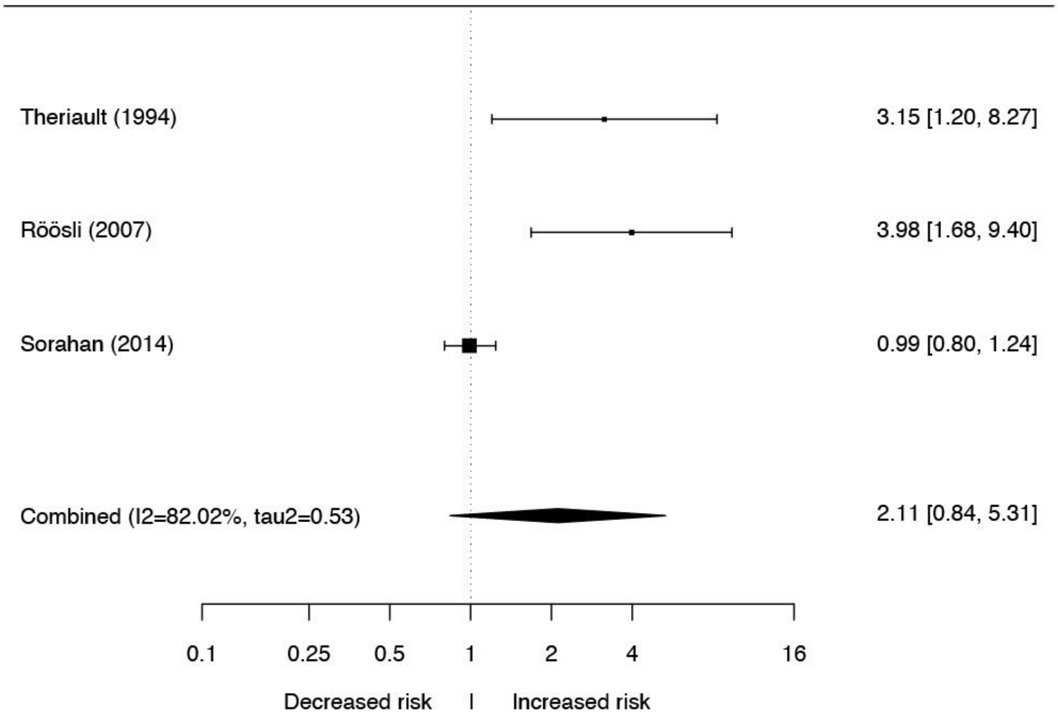


Figure 24 Meta-analysis of data on AML and occupational exposure to magnetic fields - industrial populations; risk estimate for subanalysis of complete occupational history alone

Other subanalyses were not possible due to the low number of studies in the subcategories.

Table 42 summarises the results of the meta-analyses.

Table 42 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of AML

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Hetero-geneity
Main analysis of general population	Exposure above background levels	1.18	0.99-1.40	14	56.6%
Subanalysis 1	Diagnosis	1.19	0.98-1.45	13	63.0%
	Mortality	--	--	1	--
Subanalysis 2: exposure assessment	Calculated / measured	1.12	0.88-1.42	9	63.7%
	Occupation	1.30	0.98-1.73	5	47.9%
Subanalysis 3: occupational history	Incomplete	**1.33**	**1.15-1.52**	8	0.0%
	Complete	0.94	0.79-1.11	6	0.0%
Subanalysis 4	Highest exposure	1.24	0.82-1.89	3	2.3%
Main analysis of industrial populations	Exposure above background levels	1.54	0.65-3.61	4	93.7%
Subanalysis 1: exposure assessment	Calculated / measured	1.88	0.58-6.11	3	88.3%
	Occupation	--	--	1	--
Subanalysis 2: occupational history	Incomplete	--	--	1	--
	Complete	2.11	0.84-5.31	3	82.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.3 Breast cancer in women

7.3.1 Breast cancer in women and residential distance to high-voltage power lines

Five studies investigate the relationship between distance to high-voltage power lines and risk of breast cancer in women. The analysis shows no significantly increased risk (figure 25).

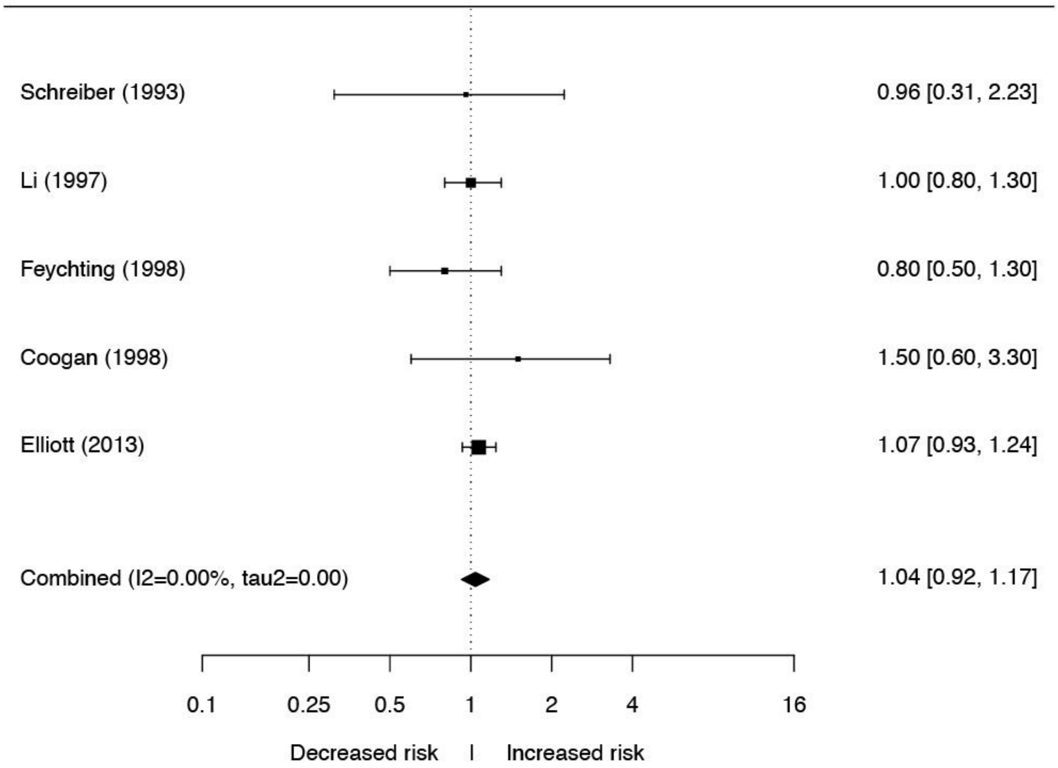


Figure 25 Meta-analysis of data on breast cancer in women and distance to high-voltage power lines

7.3.2 Breast cancer in women and residential exposure to magnetic fields

For studies on residential exposure and breast cancer in women, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 26).

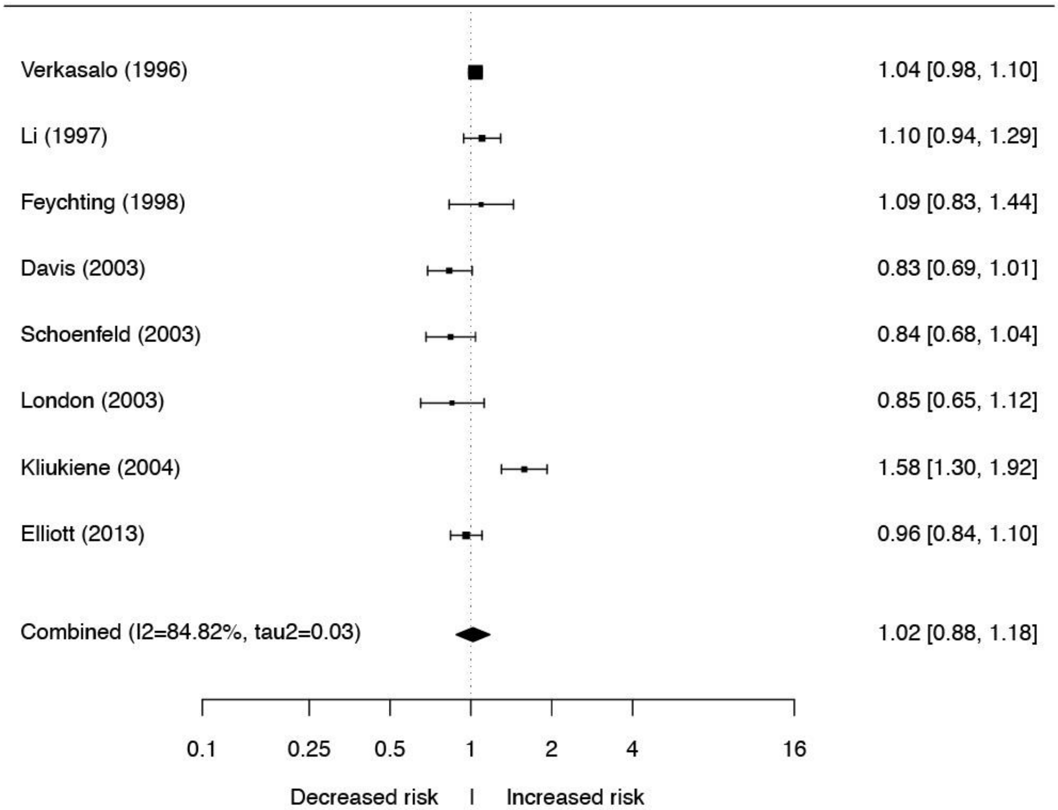


Figure 26 Meta-analysis of data on breast cancer in women and residential exposure; main analysis of exposure above background levels versus background exposure

The subanalysis according to highest residential exposure shows no statistically significantly increased risk of breast cancer in women (figure 27).

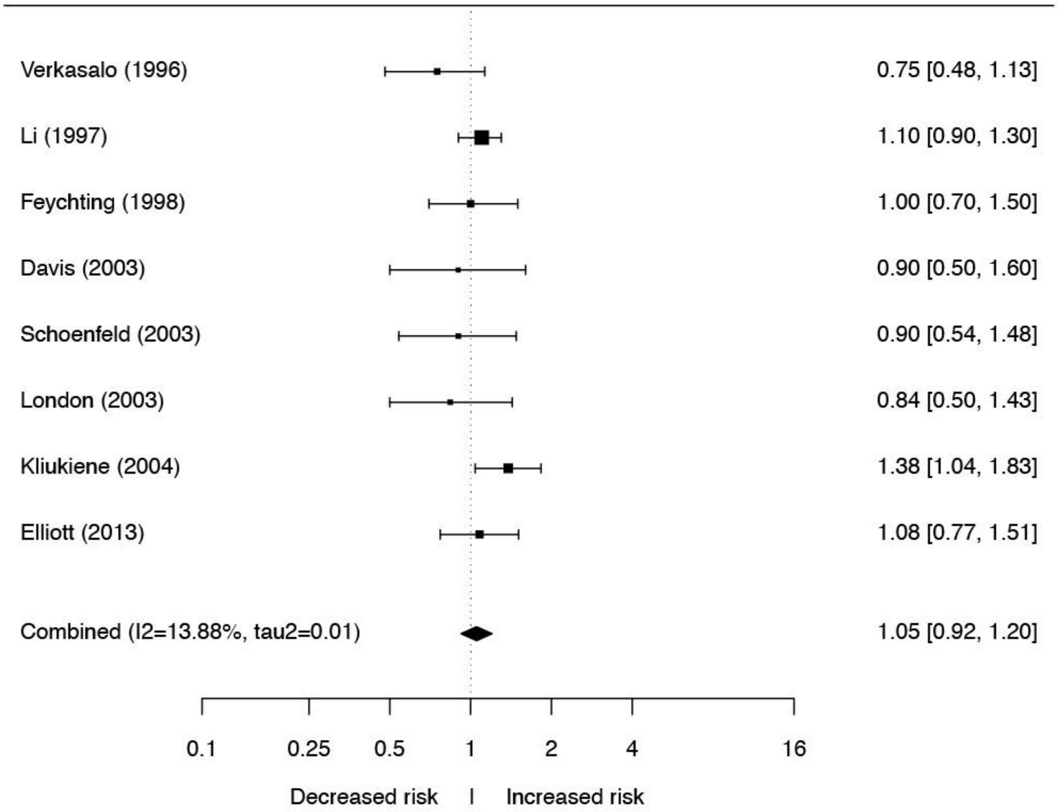


Figure 27 Meta-analysis of data on breast cancer in women and residential exposure; subanalysis of highest exposure

There is not enough data for a subanalysis according to longest exposure.

7.3.3 Breast cancer in women and electric bed warmer use

The main analysis of ever used electric bed warmers versus never used shows no statistically significantly increased risk of breast cancer in women (figure 28).

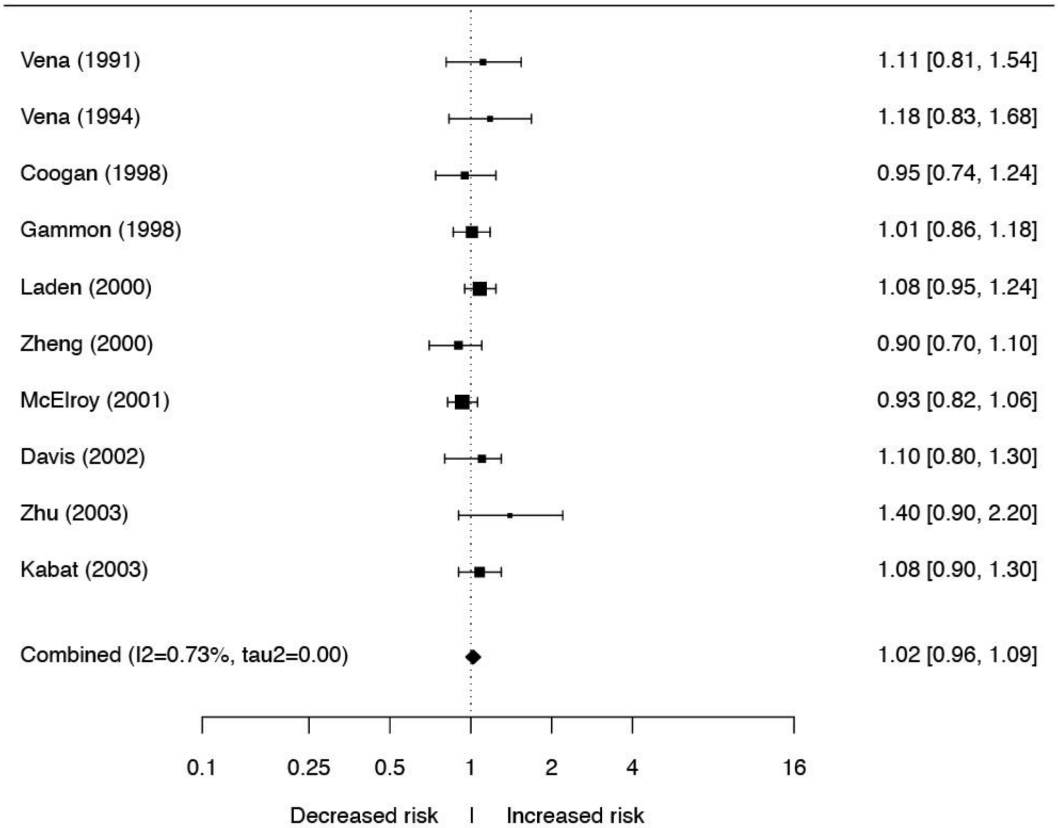


Figure 28 Meta-analysis of data on breast cancer in women and electric bed warmer use; main analysis of ever used versus never used

The subanalysis according to highest electric bed warmer use shows no statistically significantly increased risk of breast cancer in women (figure 29).

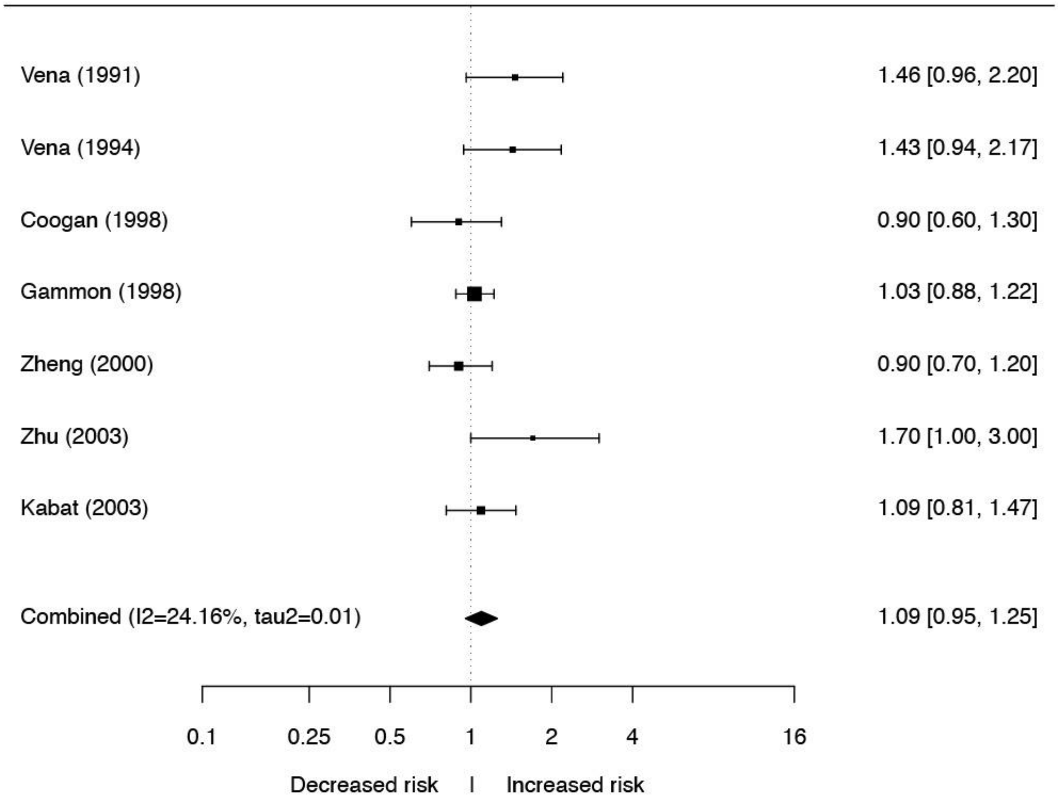


Figure 29 Meta-analysis of data on breast cancer in women and electric bed warmer use; subanalysis of highest use

The subanalysis according to longest use of electric bed warmers shows no statistically significantly increased risk of breast cancer in women (figure 30).

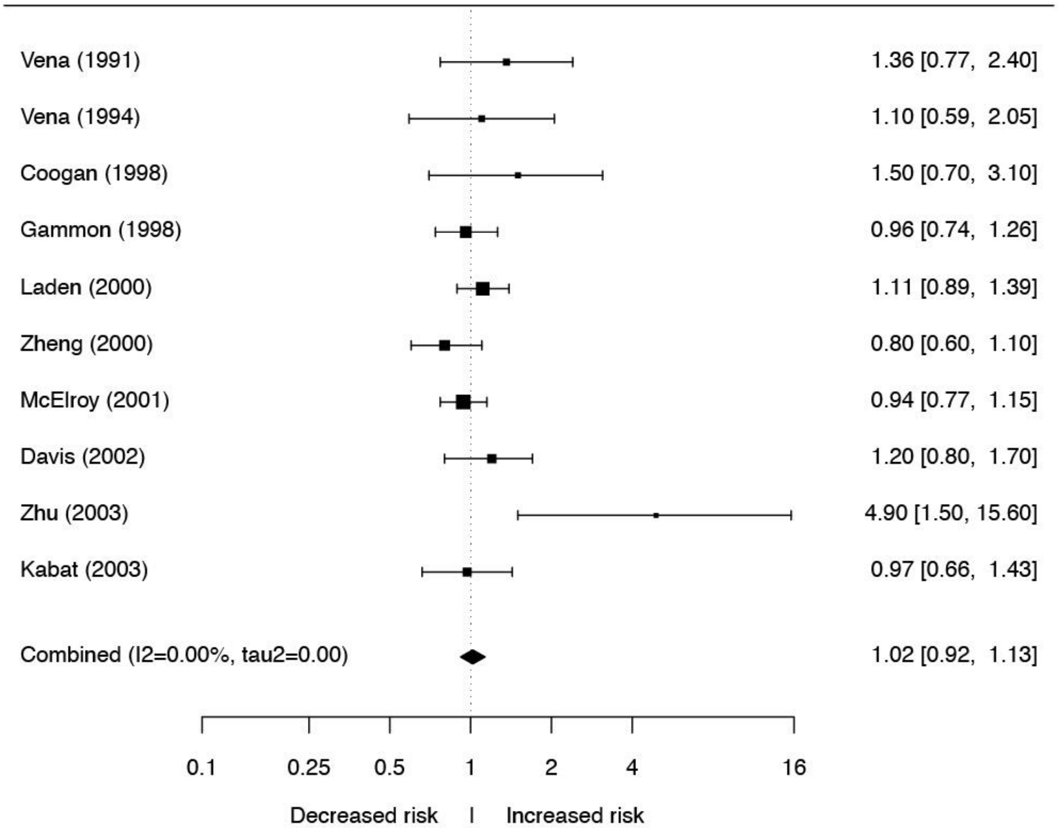


Figure 30 Meta-analysis of data on breast cancer in women and electric bed warmer use; subanalysis of longest use

Table 43 summarises the results of the meta-analyses.

Table 43 Analysis of data on the relationship between residential exposure to magnetic fields and risk of breast cancer in women

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Hetero-geneity
Main analysis of distance to high-voltage power lines	0-50 to 0-100 m	1.04	0.92-1.17	53	0.0%
Main analysis of exposure to magnetic fields	Above background levels	1.02	0.88-1.18	8	84.8%
Subanalysis 1	Highest exposure	1.05	0.92-1.20	8	13.9%
Main analysis electric bed warmers	Ever used	1.02	0.96-1.09	10	0.7%
Subanalysis 1	Highest use	1.09	0.95-1.25	7	24.2%
Subanalysis 2	Longest use	1.02	0.92-1.13	10	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.3.4 Breast cancer in women and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 31).

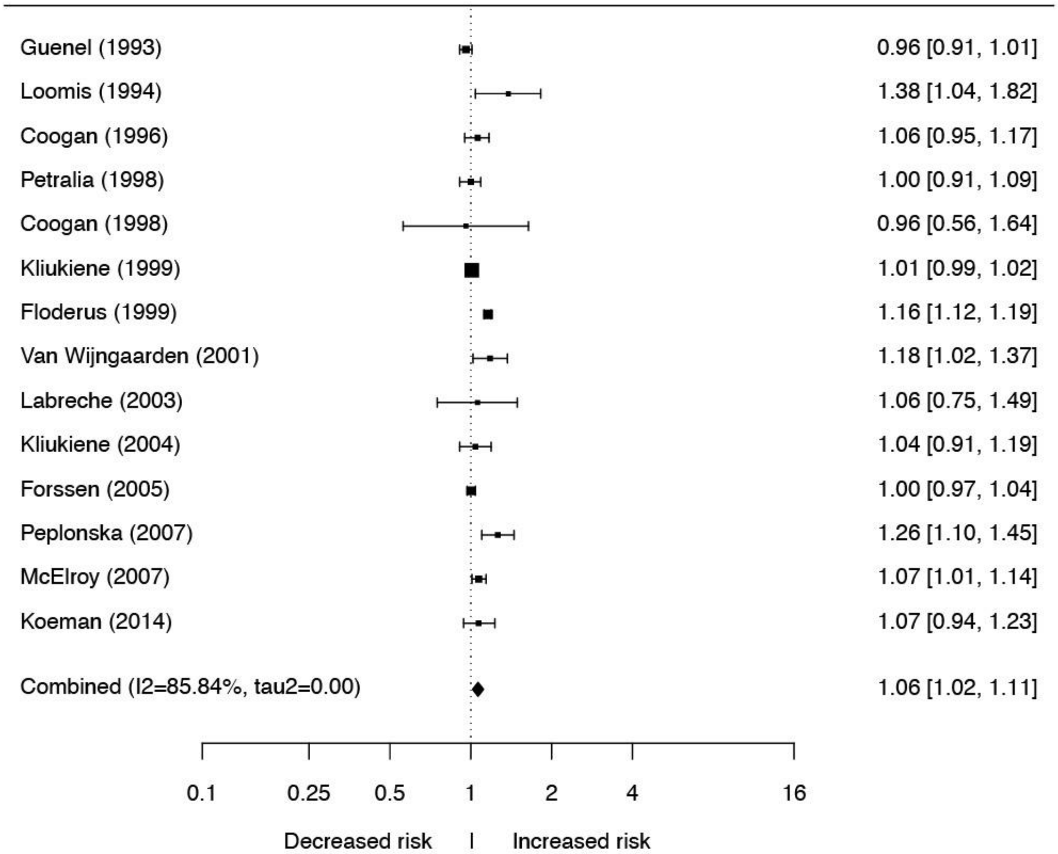


Figure 31 Meta-analysis of data on breast cancer in women and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is not possible because all studies use diagnosis.

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). The latter subcategory contains only one study and therefore cannot be used. The risk estimate for the first subcategory is statistically significantly increased (figure 32).

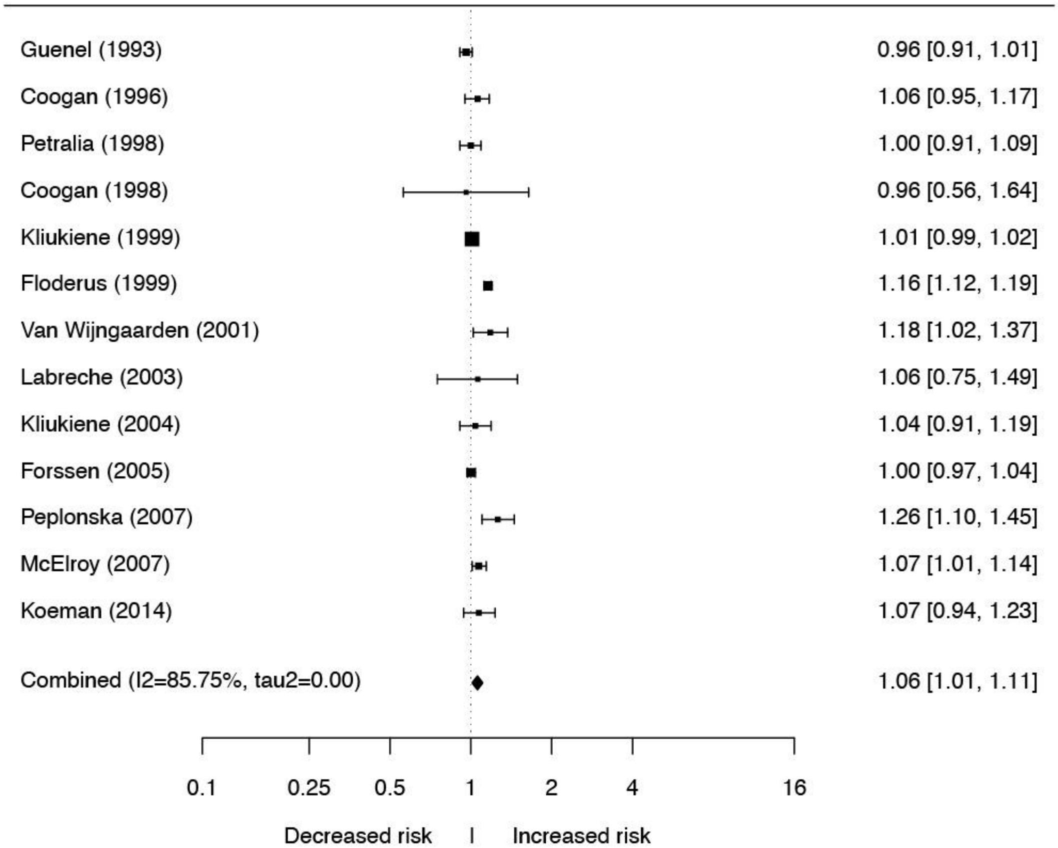


Figure 32 Meta-analysis of data on breast cancer in women and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone

In the subanalysis according to studies with a complete occupational history versus studies with an incomplete occupational history, only the risk estimate for the latter subcategory was statistically significantly increased (figure 33).

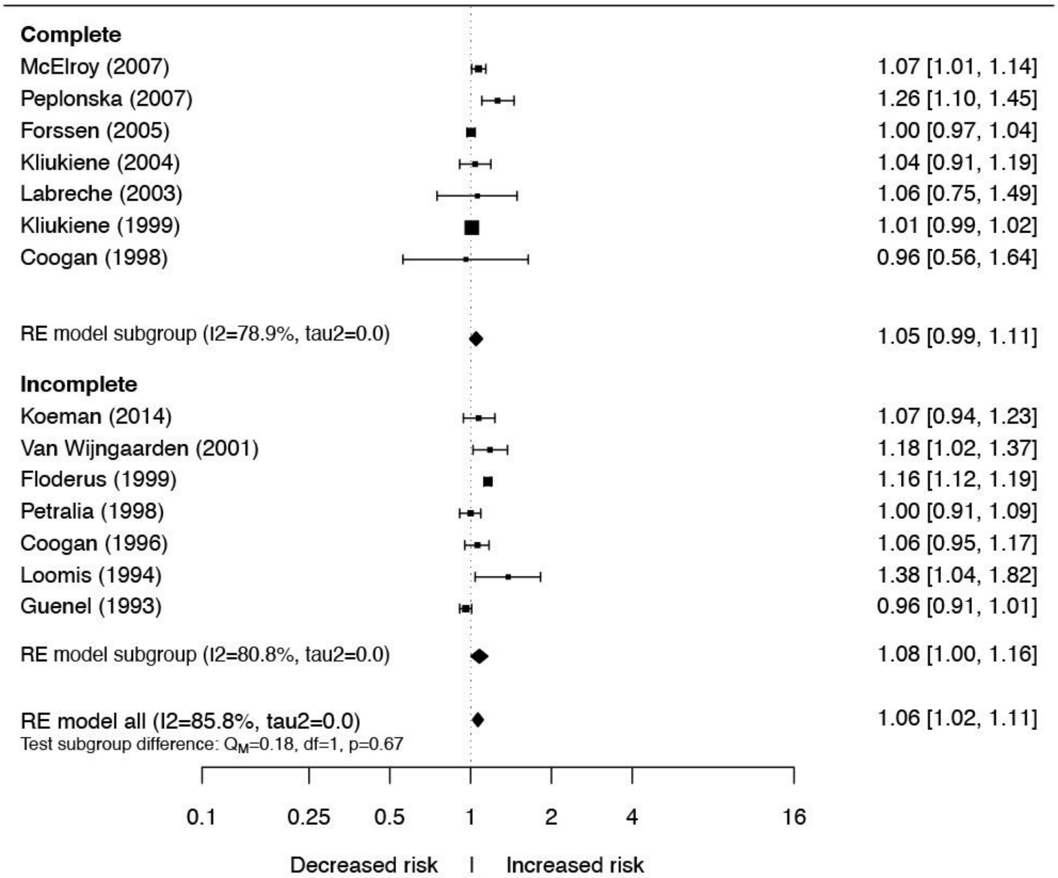


Figure 33 Meta-analysis of data on breast cancer in women and occupational exposure to magnetic fields - general population; risk estimates for subanalysis of complete versus incomplete occupational history

The subanalysis of highest exposure versus background exposure shows a statistically significantly increased risk (figure 34).

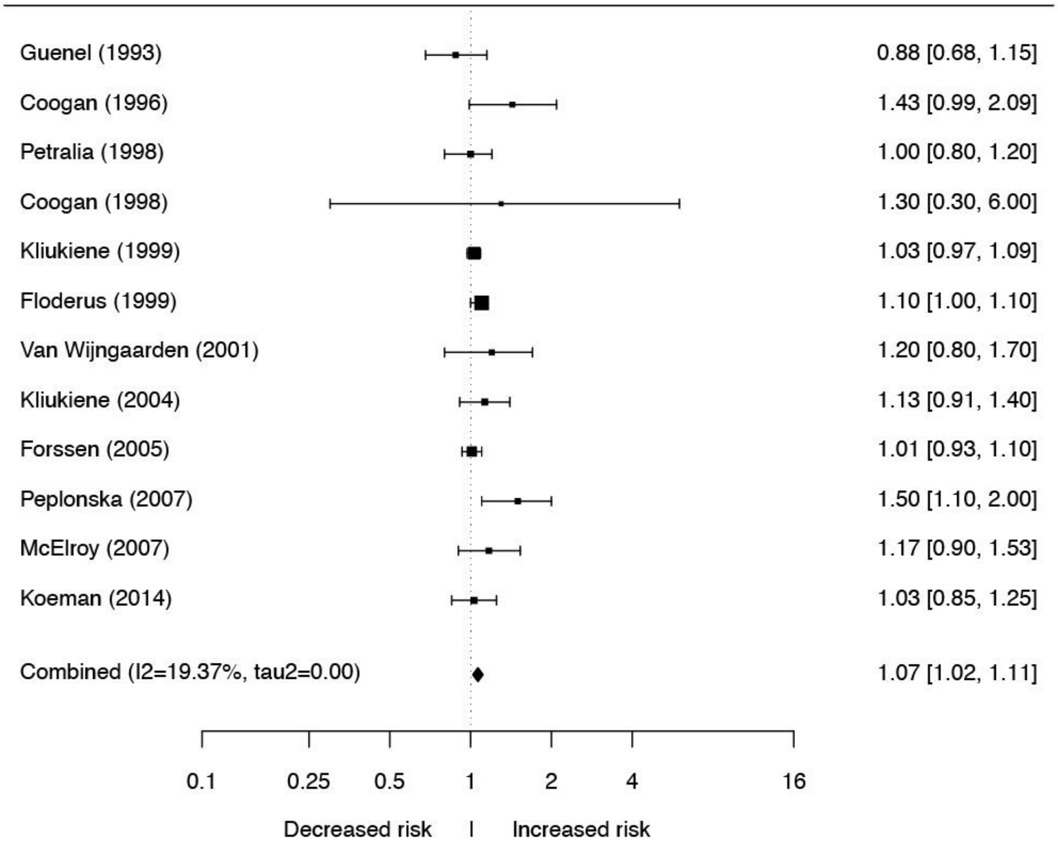


Figure 34 Meta-analysis of data on breast cancer in women and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of highest exposure versus background exposure

The analysis of longest exposure versus background exposure shows no statistically significantly increased risk (figure 35).

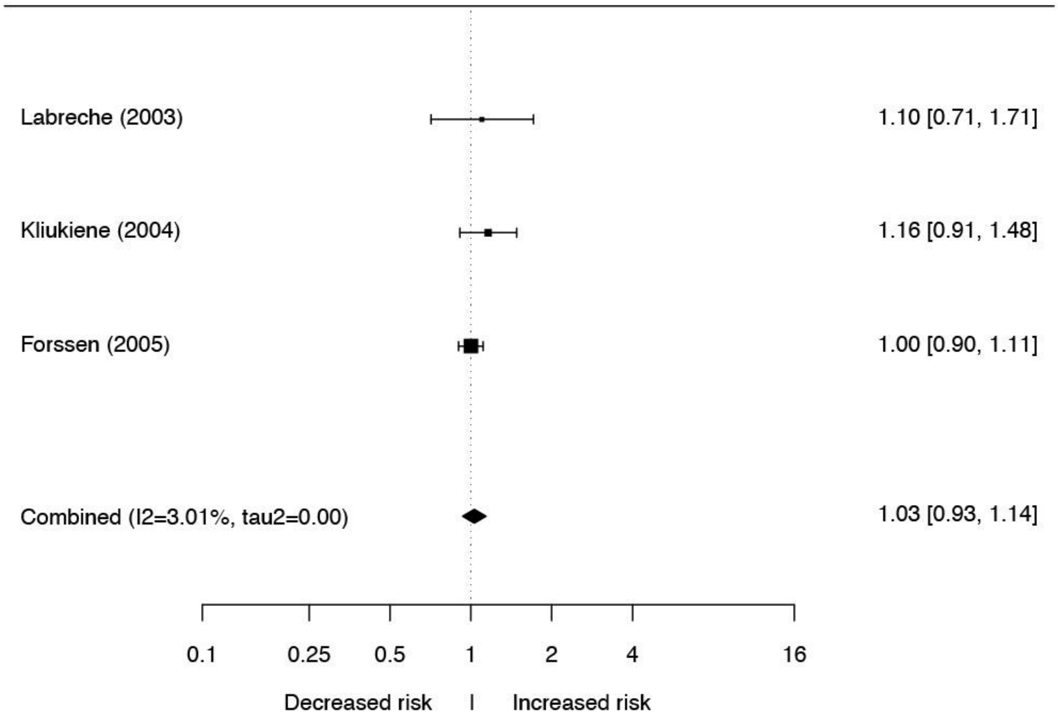


Figure 35 Meta-analysis of data on breast cancer in women and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of longest exposure versus background exposure

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 36).

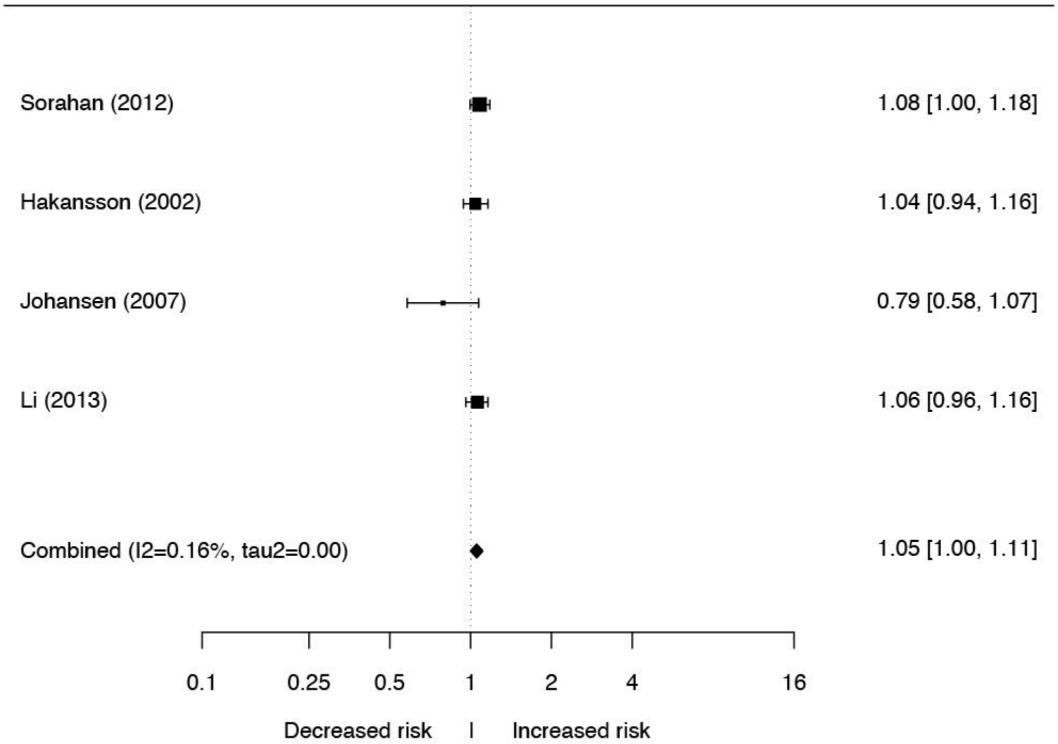


Figure 36 Meta-analysis of data on breast cancer in women and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

Subanalyses were not possible due to the low number of studies in the subcategories.

For the studies in subjects from specific industries, the analysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 37).

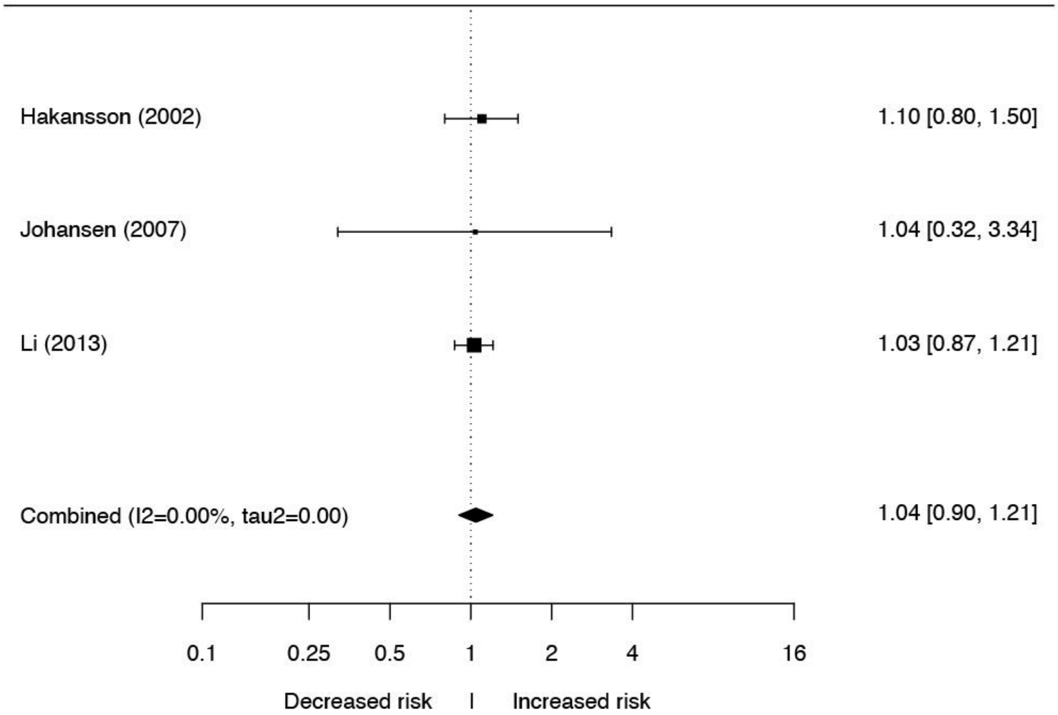


Figure 37 Meta-analysis of data on breast cancer in women and occupational exposure to magnetic fields - industrial populations highest exposure versus background exposure

The analysis of longest exposure versus background exposure was not possible due to the low number of studies.

Table 44 summarises the results of the meta-analyses.

Table 44 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of breast cancer in women

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Hetero-geneity
Main analysis of general population	Exposure above background levels	**1.06**	**1.02-1.11**	14	85.8%
Subanalysis 1: exposure assessment	Calculated / measured	**1.06**	**1.01-1.11**	13	85.7%
	Occupation	--	--	1	--
Subanalysis 2: occupational history	Incomplete	**1.08**	**1.00-1.16**	7	80.8%
	Complete	**<u>1.05</u>**	**<u>0.99-1.11</u>**	7	78.9%
Subanalysis 3	Highest exposure	**1.07**	**1.02-1.11**	12	19.4%
Subanalysis 4	Longest exposure	1.03	0.93-1.14	3	3.0%
Main analysis of industrial populations	Ever	**<u>1.05</u>**	**<u>1.00-1.11</u>**	4	0.2%
Subanalysis 1	Highest exposure	1.04	0.90-1.21	3	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.4 Breast cancer in men

7.4.1 Breast cancer in men and residential distance to high-voltage power lines

There is no data on breast cancer in men in relation to residential distance to high-voltage power lines.

7.4.2 Breast cancer in men and residential exposure to magnetic fields

A single study was found that investigates the relationship between residential exposure and the occurrence of breast cancer in men. For exposure to magnetic fields with a field strength of 0.2 µT or higher, the risk estimate was 2.1 (0.3-14.1).[85]

7.4.3 Breast cancer in men and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 38).

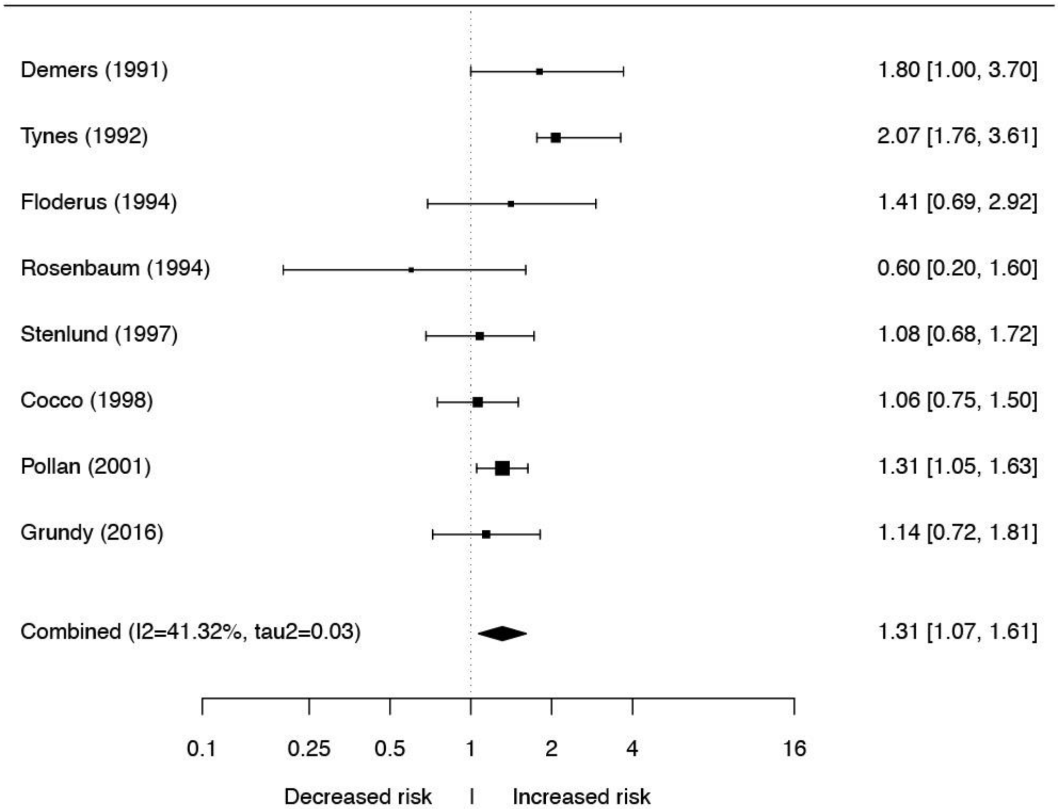


Figure 38 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is only possible for the studies that use diagnosis. These show a statistically significantly increased risk (figure 39).

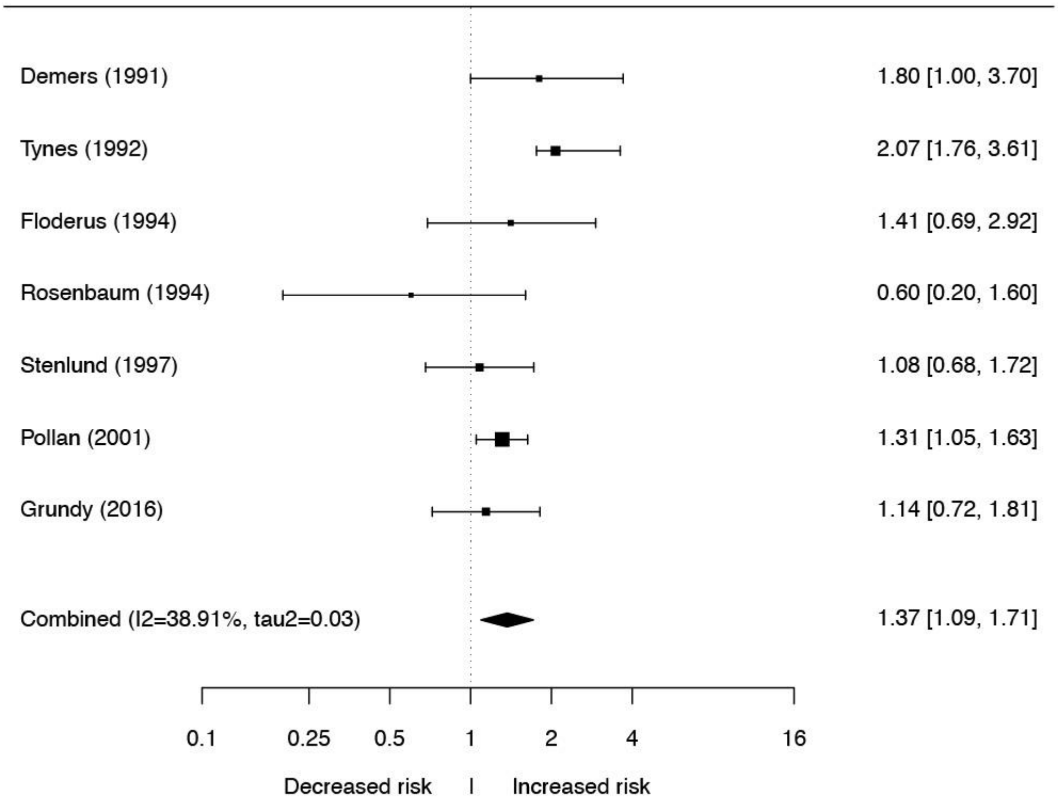


Figure 39 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of diagnosis alone

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). The risk estimates for both subcategories are statistically significantly increased (figure 40).

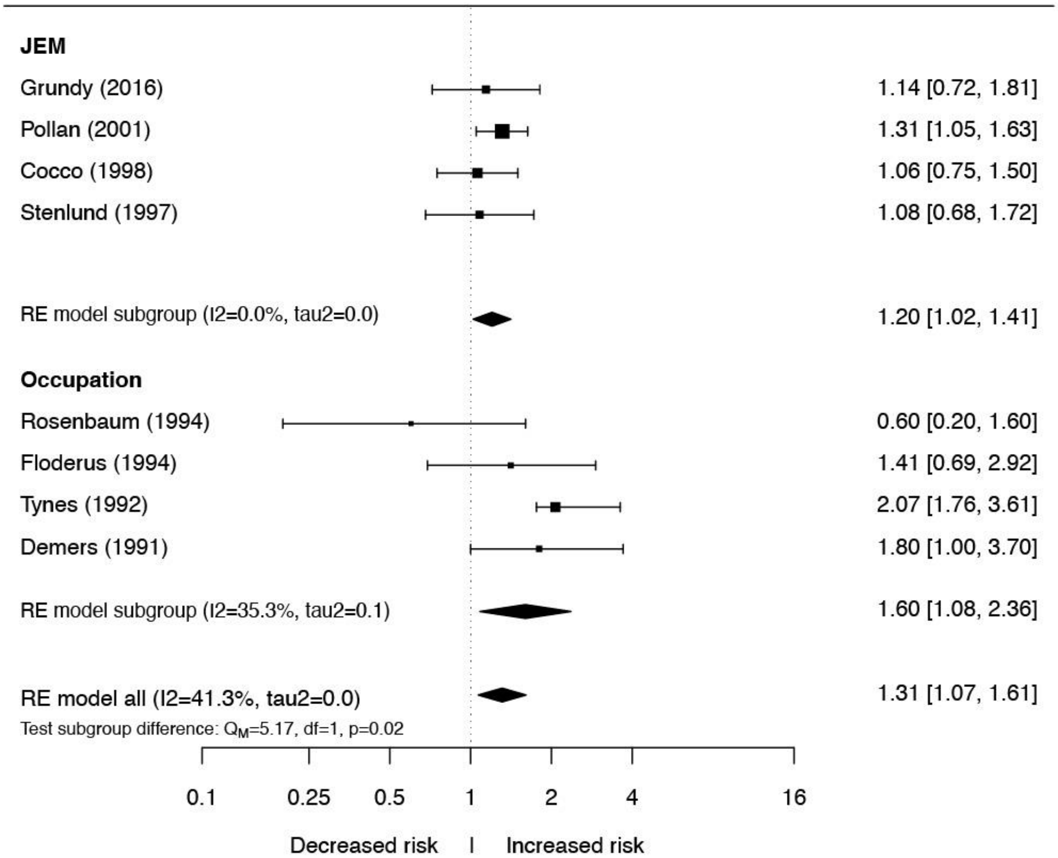


Figure 40 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) versus job title (Occupation)

The subanalysis according to completeness of occupational history is only possible for the studies involving an incomplete occupational history, as the number of studies with a complete occupational history is too low. The risk estimate for an incomplete occupational history is statistically significantly increased (figure 41).

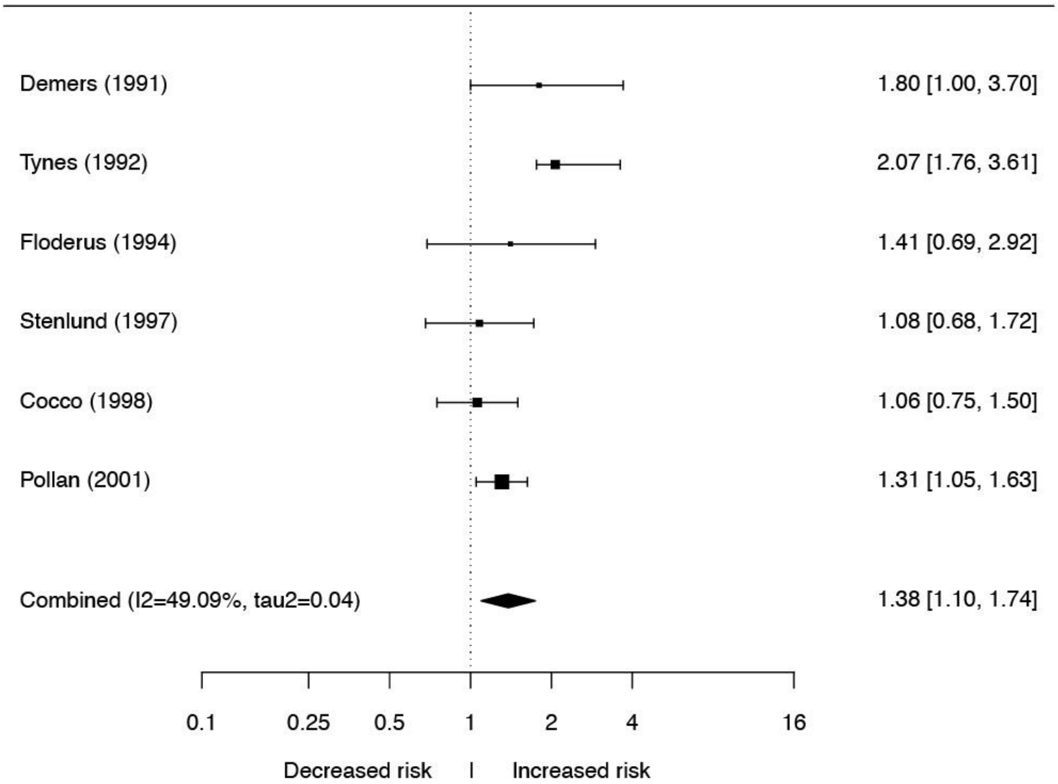


Figure 41 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of incomplete occupational history alone

The subanalysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 42).

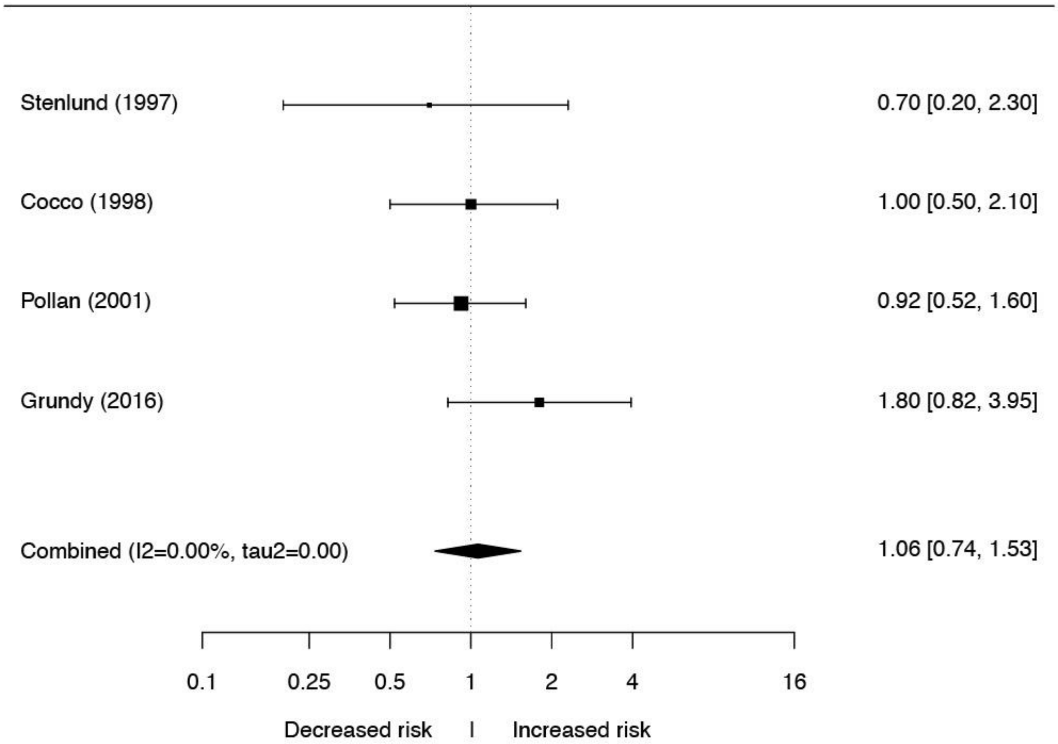


Figure 42 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of highest exposure versus background exposure

An analysis of longest exposure versus background exposure was not possible as the number of studies was too low.

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 43).

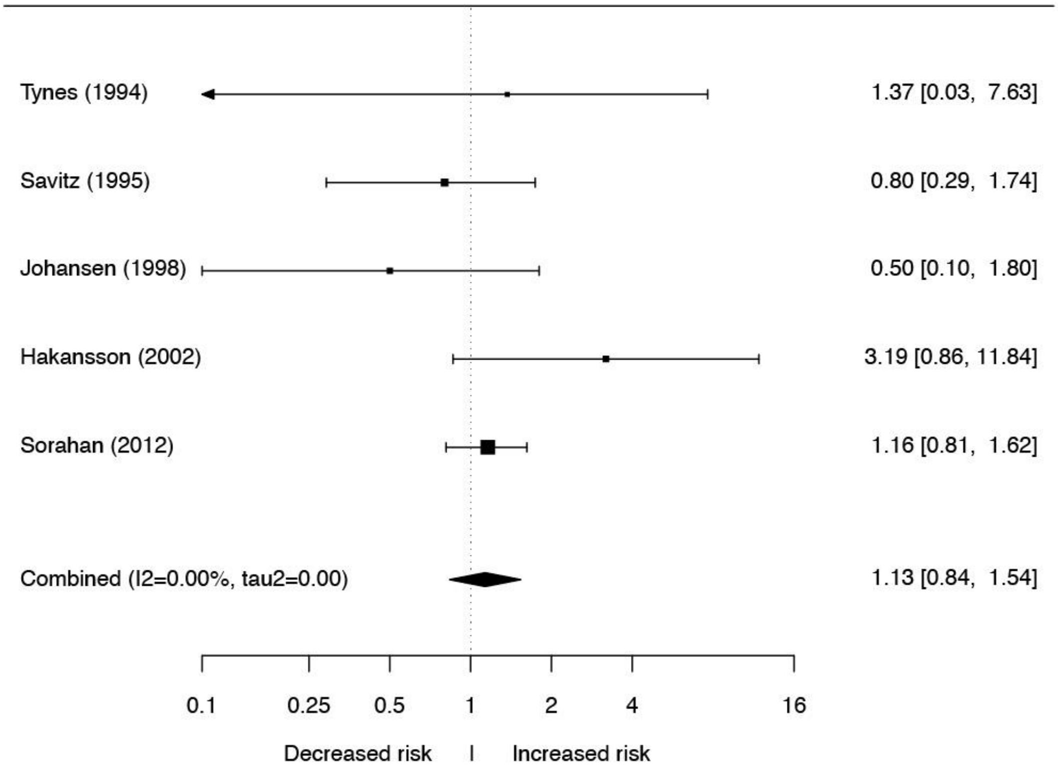


Figure 43 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnosis versus information from the death certificate) is only possible for diagnosis. This shows no statistically significantly increased risk (figure 44).

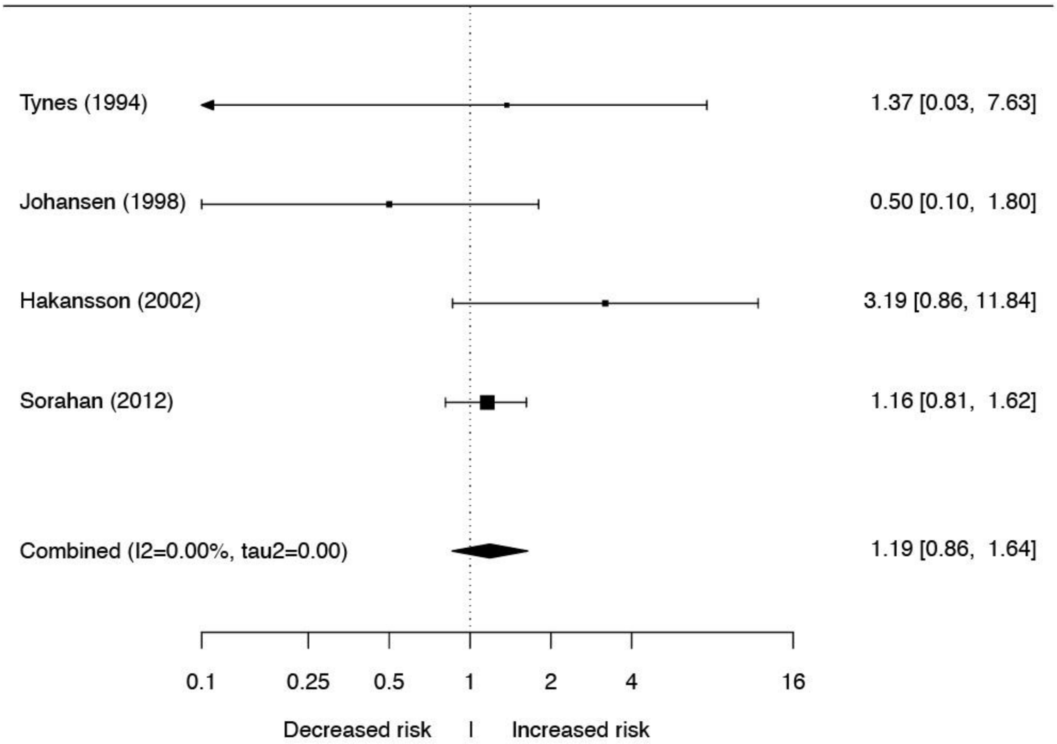


Figure 44 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - industrial populations; subanalysis of diagnosis alone

The subanalysis according to accuracy of the exposure assessment is only possible for studies in which exposure was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM). The risk estimate is not statistically significantly increased (figure 45).

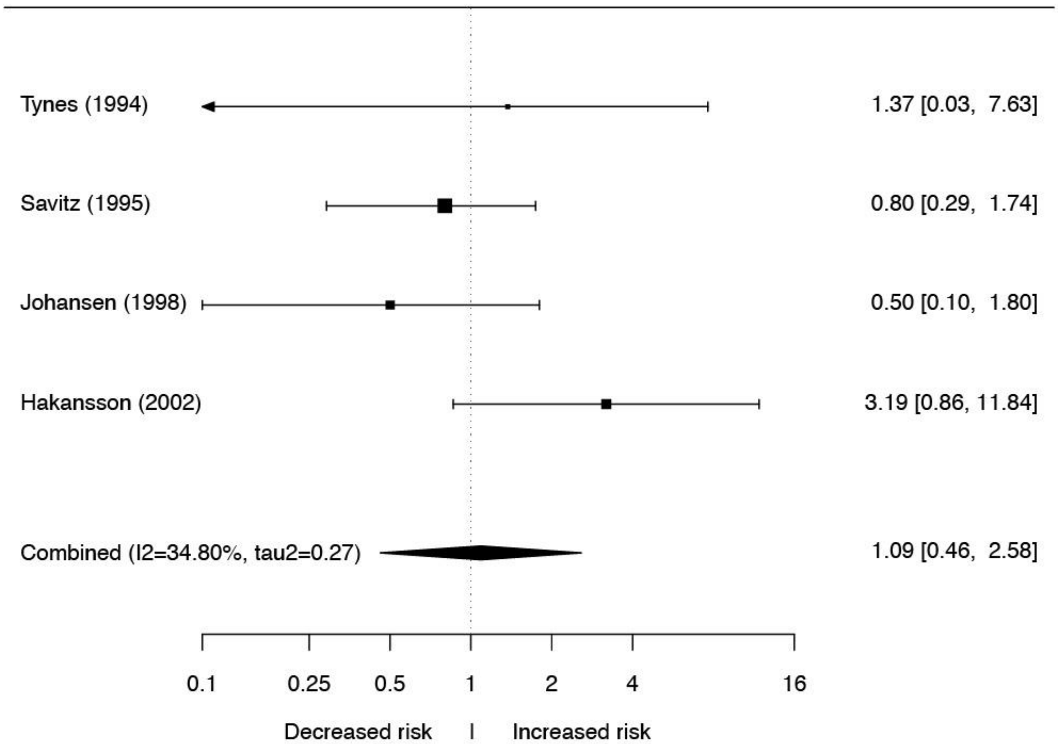


Figure 45 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - industrial population; subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) versus job title (Occupation)

The subanalysis according to completeness of occupational history is only possible for studies with a complete occupational history. The risk estimate is not statistically significantly increased (figure 46).

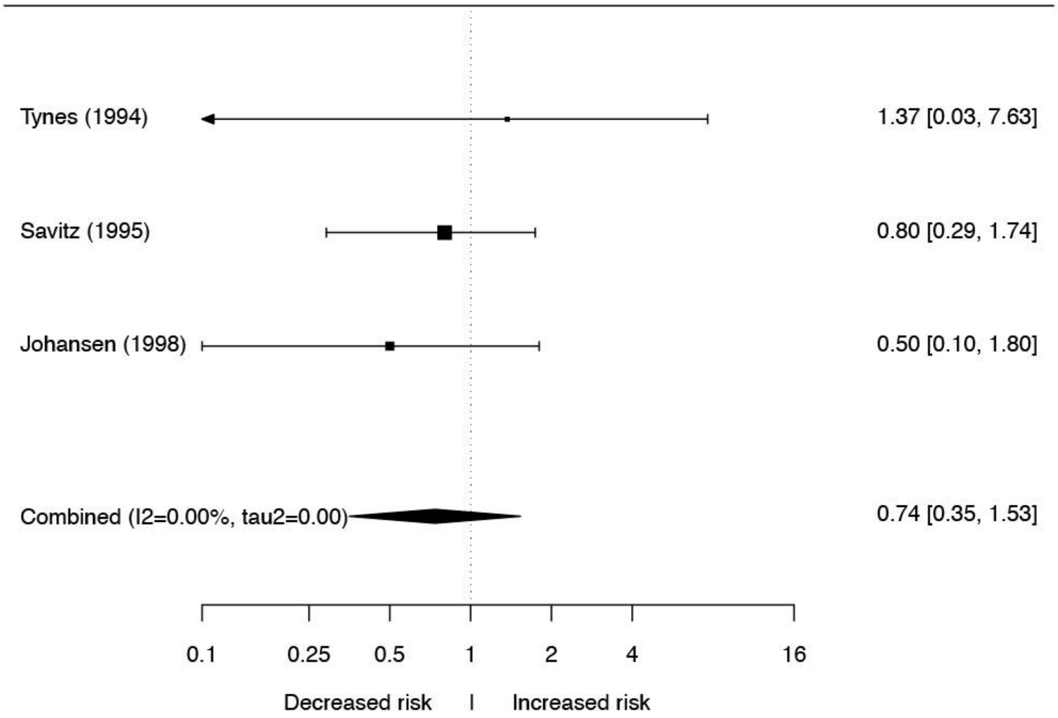


Figure 46 Meta-analysis of data on breast cancer in men and occupational exposure to magnetic fields - industrial populations; subanalysis of complete occupational history alone

The analyses of highest or longest exposure versus background exposure cannot be carried out due to the low number of studies.

Table 45 summarises the results of the meta-analyses.

Table 45 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of breast cancer in men

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Hetero-geneity
Main analysis of general population	Exposure above background levels	**1.31**	**1.07-1.61**	8	41.3%
Subanalysis 1: recording of disease	Diagnosis	**1.37**	**1.09-1.71**	7	38.9%
	Mortality	--	--	1	--
Subanalysis 2: exposure assessment	Calculated / measured	1.20	1.02-1.41	4	0.0%
	Occupation	**1.60**	**1.08-2.36**	4	35.3%
Subanalysis 3: occupational history	Incomplete	**1.38**	**1.10-1.74**	6	49.1%
	Complete	--	--	2	--
Subanalysis 4	Highest exposure	1.06	0.74-1.53	4	0.48%
Main analysis of industrial populations	Ever	1.13	0.84-1.54	5	0.0%
Subanalysis 1: recording of disease	Diagnosis	1.19	0.86-1.64	4	0.0%
	Mortality	**--**	**--**	1	--
Subanalysis 2: exposure assessment	Calculated / measured	1.09	0.46-2.58	4	34.8%
	Occupation	**--**	**--**	1	--
Subanalysis 3: occupational history	Incomplete	**--**	**--**	2	--
	Complete	0.74	0.35-1.53	3	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.5 Brain cancer

7.5.1 Brain cancer and residential distance to high-voltage power lines

Two studies were found that investigate the relationship between distance to high-voltage power lines and the occurrence of brain cancer. In the first study, the risk estimate for residing at a distance of 0-50 metres from a high-voltage power line is 1.22 (0.88-1.69).[8] In the second study, the risk estimate is 1.3 (0.8-2.1) [5]

7.5.2 Brain cancer and residential exposure to magnetic fields

For studies on residential exposure and brain cancer, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 47).

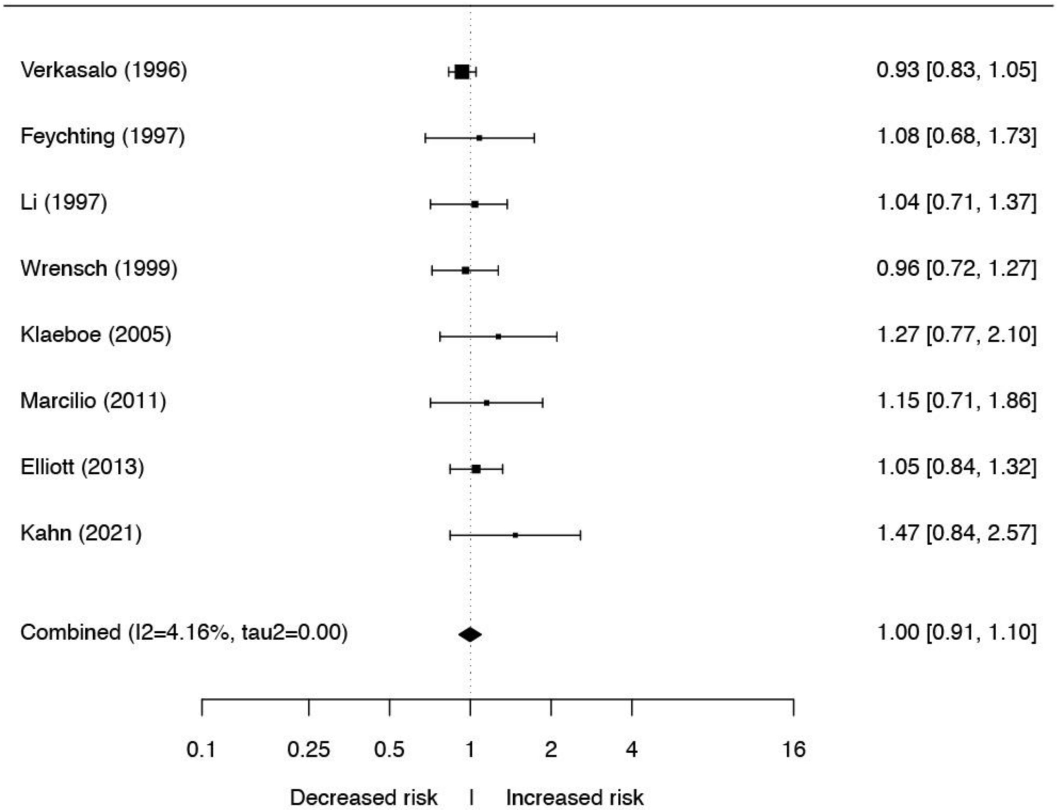


Figure 47 Meta-analysis of data on brain cancer and residential exposure to magnetic fields; main analysis of exposure above background levels versus background exposure

The subanalysis according to highest exposure shows no statistically significantly increased risk (figure 48).

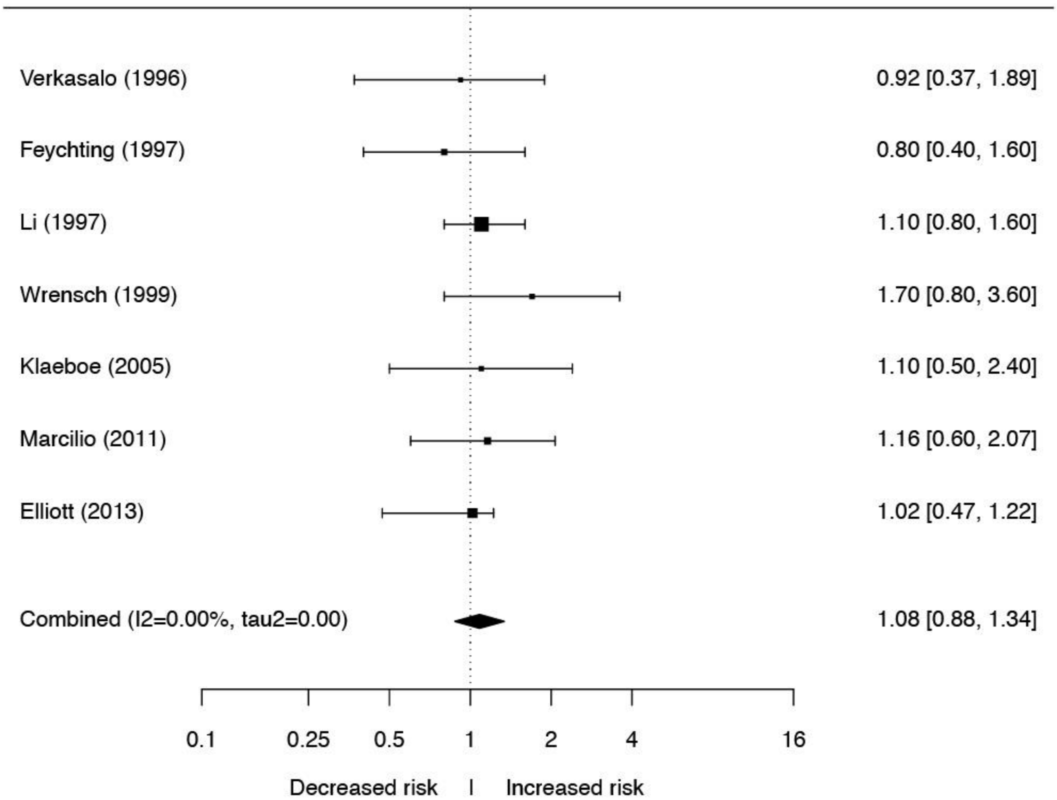


Figure 48 Meta-analysis of data on brain cancer and residential exposure to magnetic fields; risk estimate for subanalysis of highest exposure versus background exposure

Other subanalyses were not possible due to the low number of studies.

Table 46 summarises the results of the meta-analyses.

Table 46 Analysis of data on the relationship between residential exposure to magnetic fields and risk of brain cancer

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Hetero-geneity
Main analysis	Exposure above background levels	1.00	0.91-1.10	8	4.2%
Subanalysis	Highest exposure	1.08	0.88-1.34	7	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.5.3 Brain cancer and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 49).

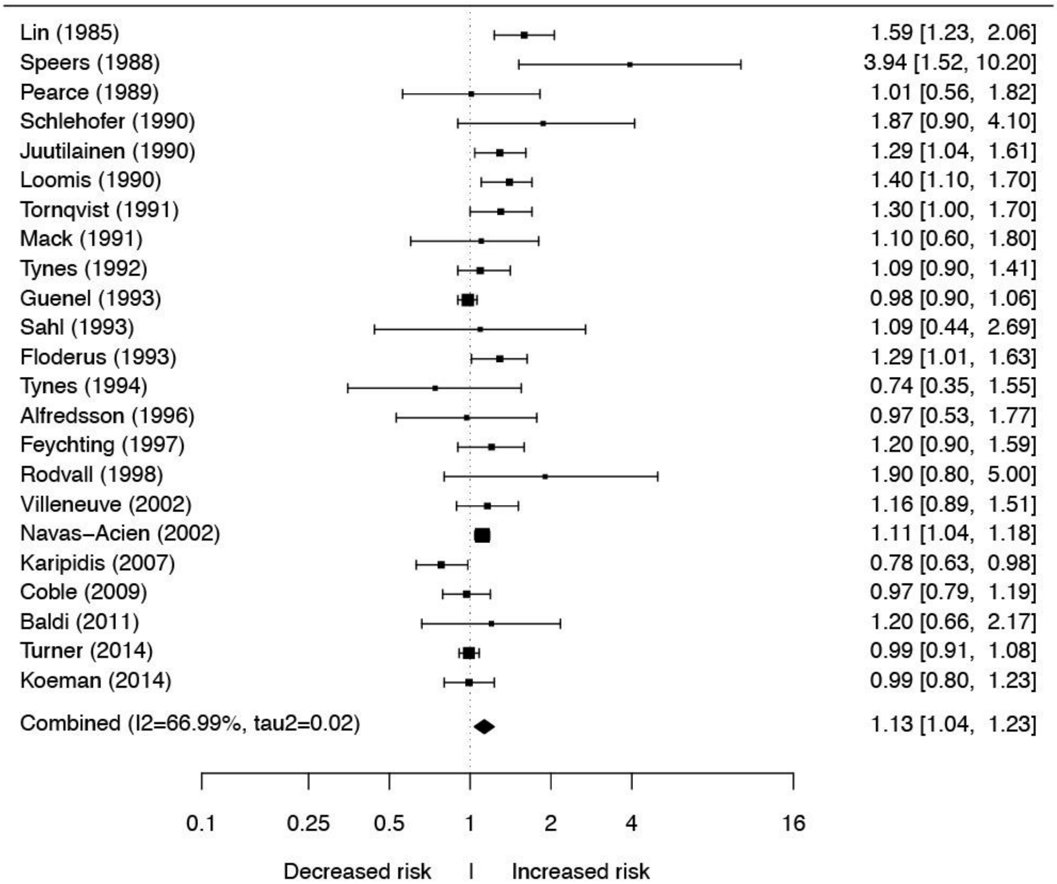


Figure 49 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is only possible for the studies that use diagnosis. These show a statistically significantly increased risk (figure 50).

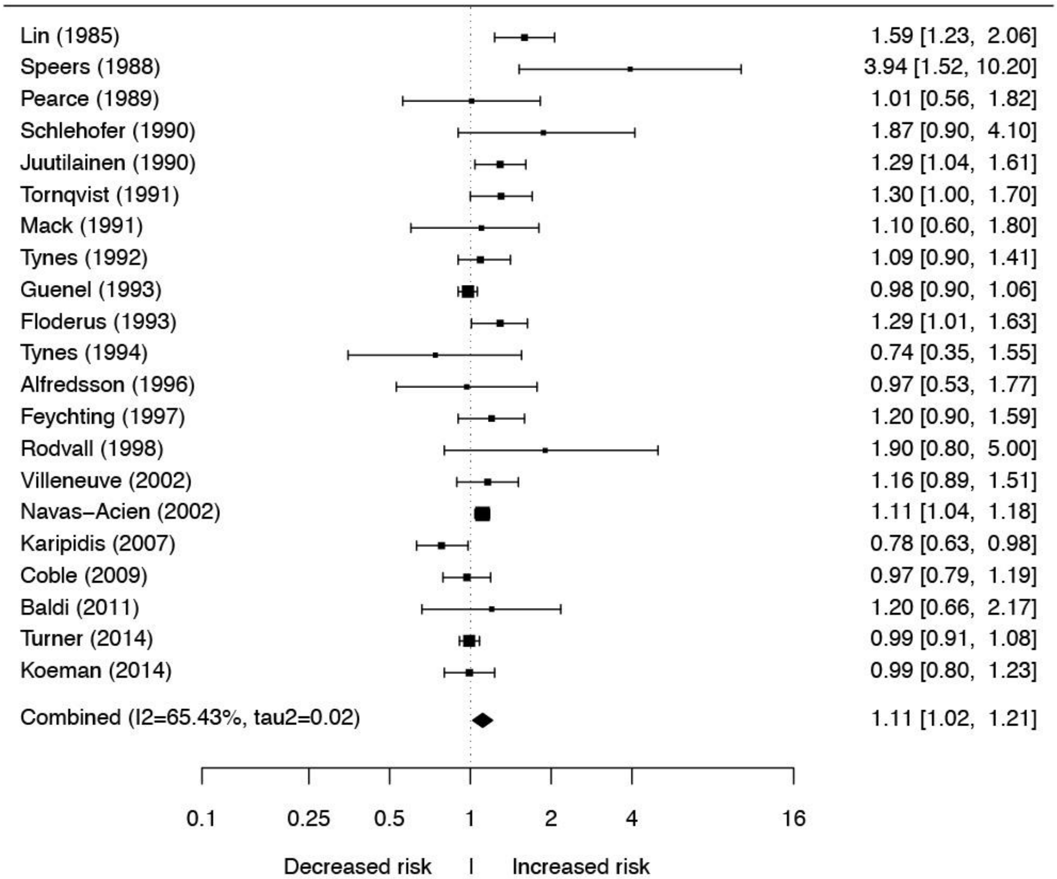


Figure 50 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of diagnosis alone

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). Only the risk estimate for the latter subcategory is statistically significantly increased (figure 51).

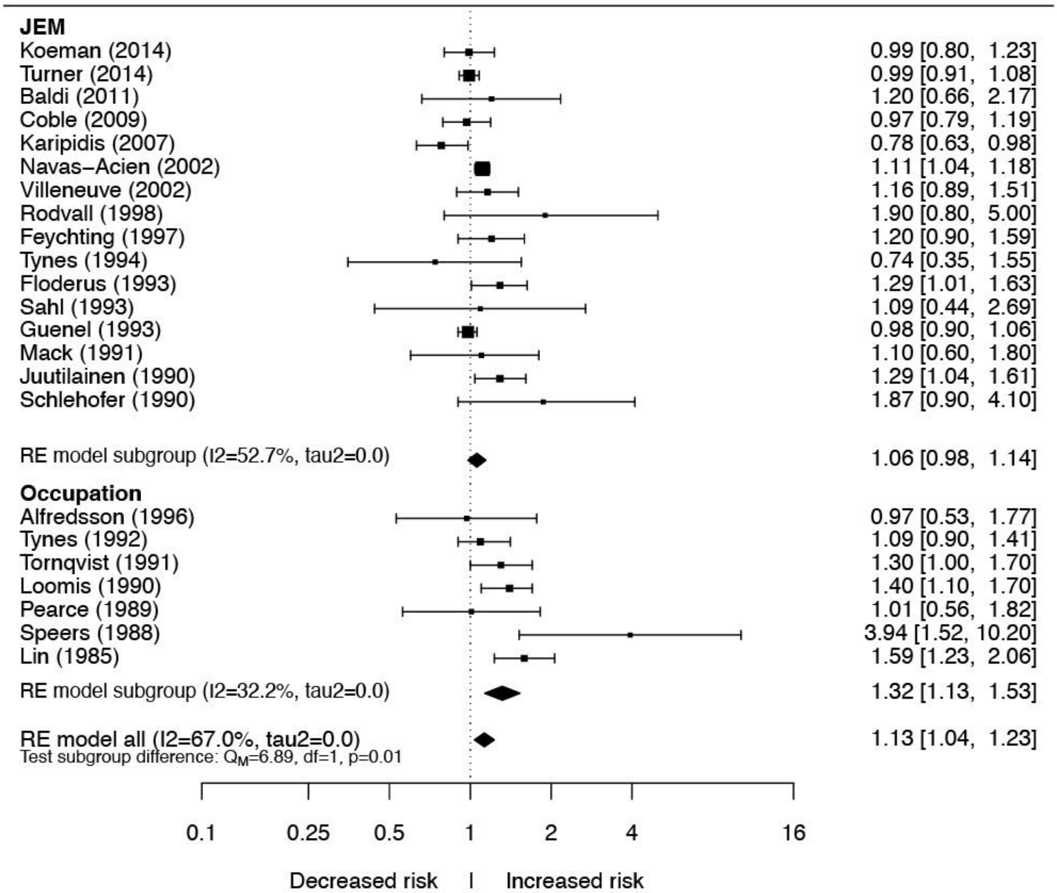


Figure 51 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) versus job title (Occupation)

The subanalysis according to completeness of occupational history only shows a statistically significantly increased risk for studies involving an incomplete occupational history (figure 52).

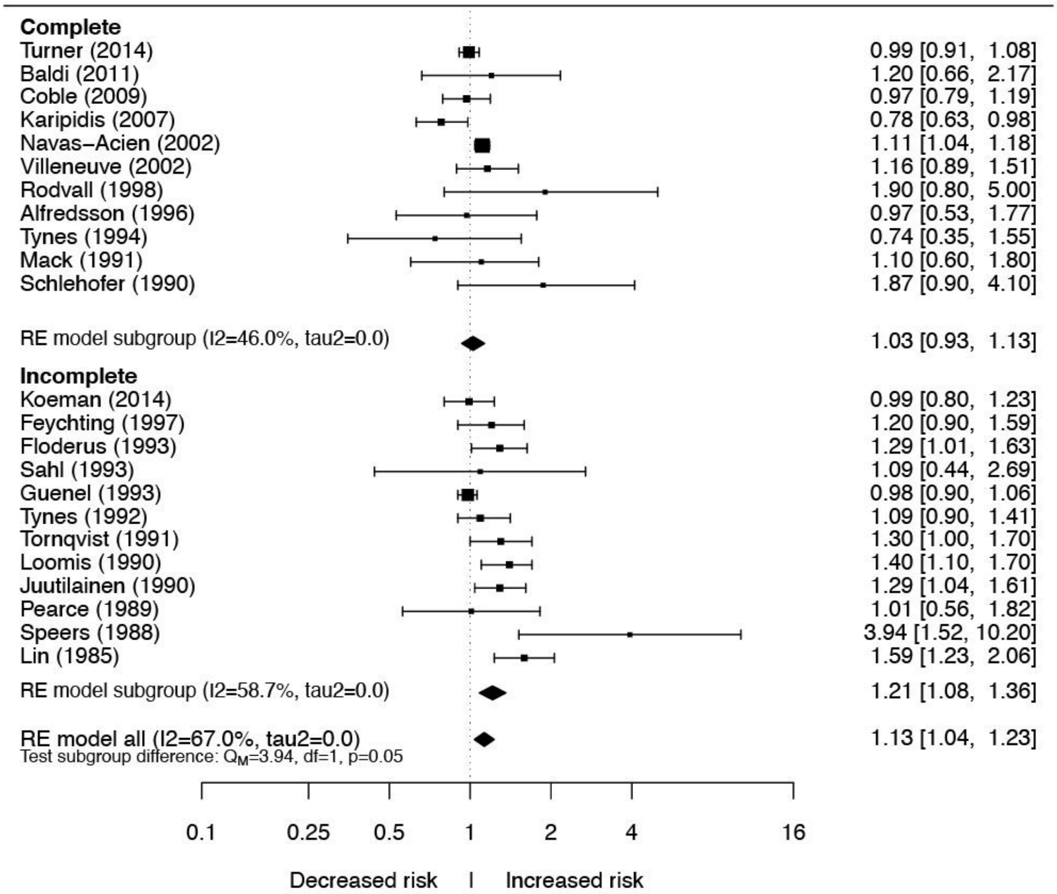


Figure 52 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of complete versus incomplete occupational history

The subanalysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 53).

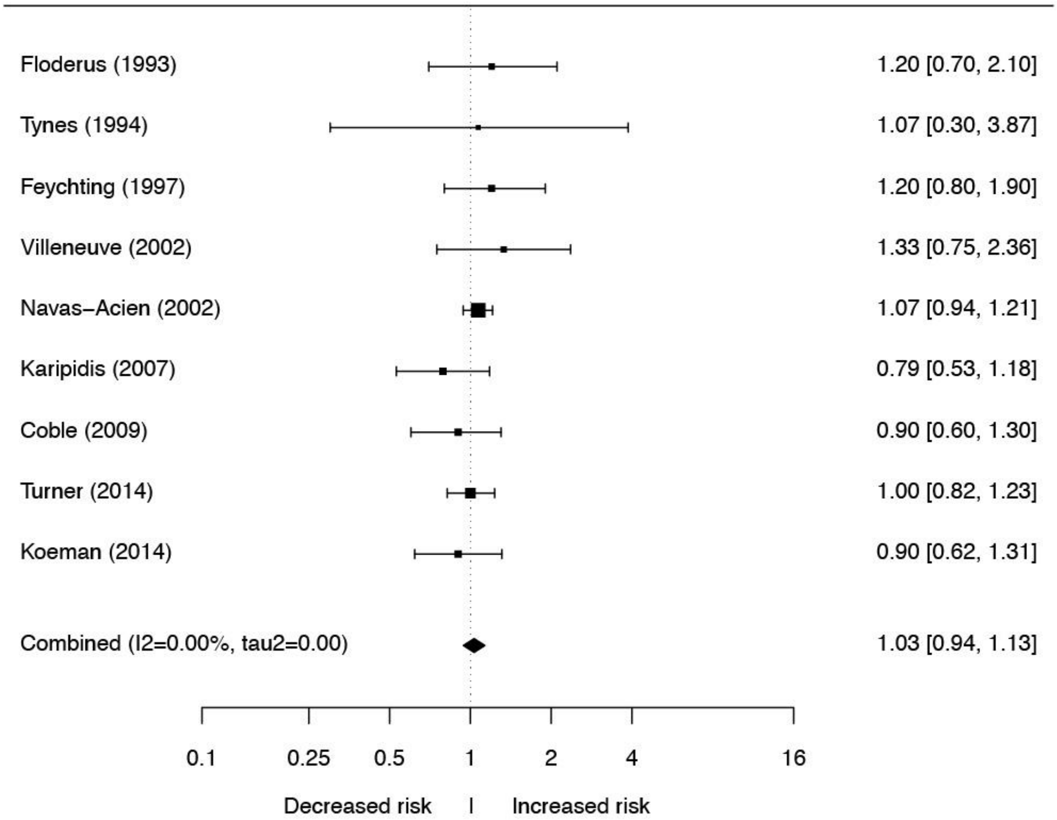


Figure 53 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of highest exposure versus background exposure

The subanalysis of longest exposure versus background exposure shows no statistically significantly increased risk (figure 54).

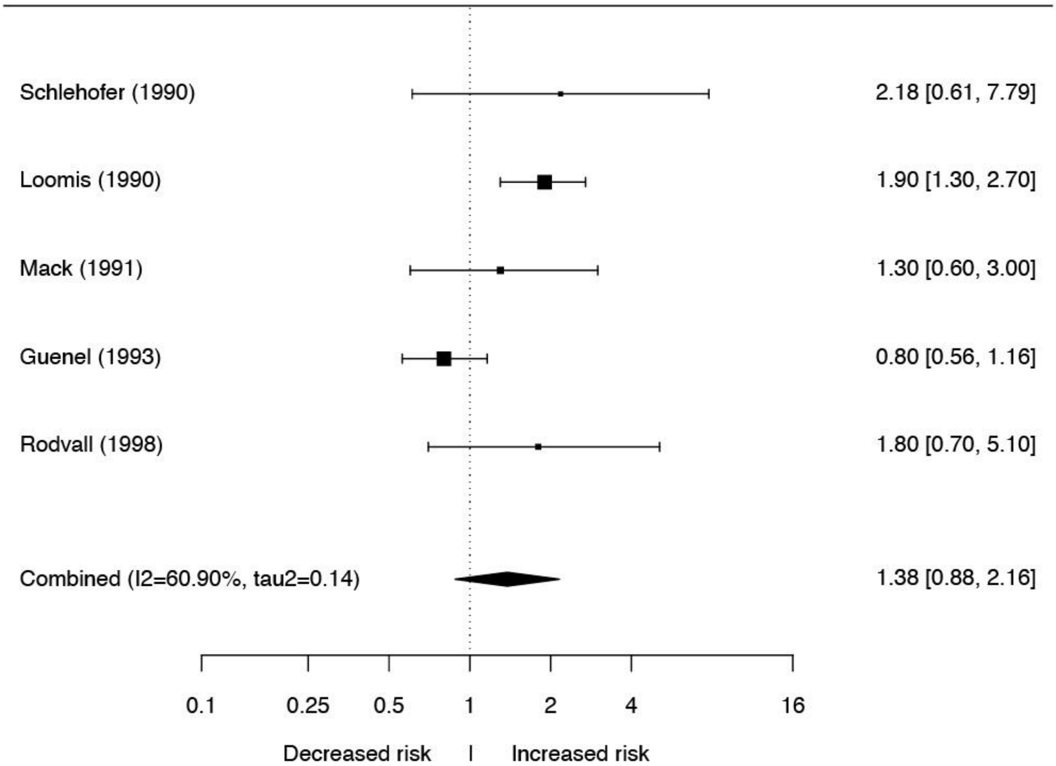


Figure 54 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of longest exposure versus background exposure

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 55).

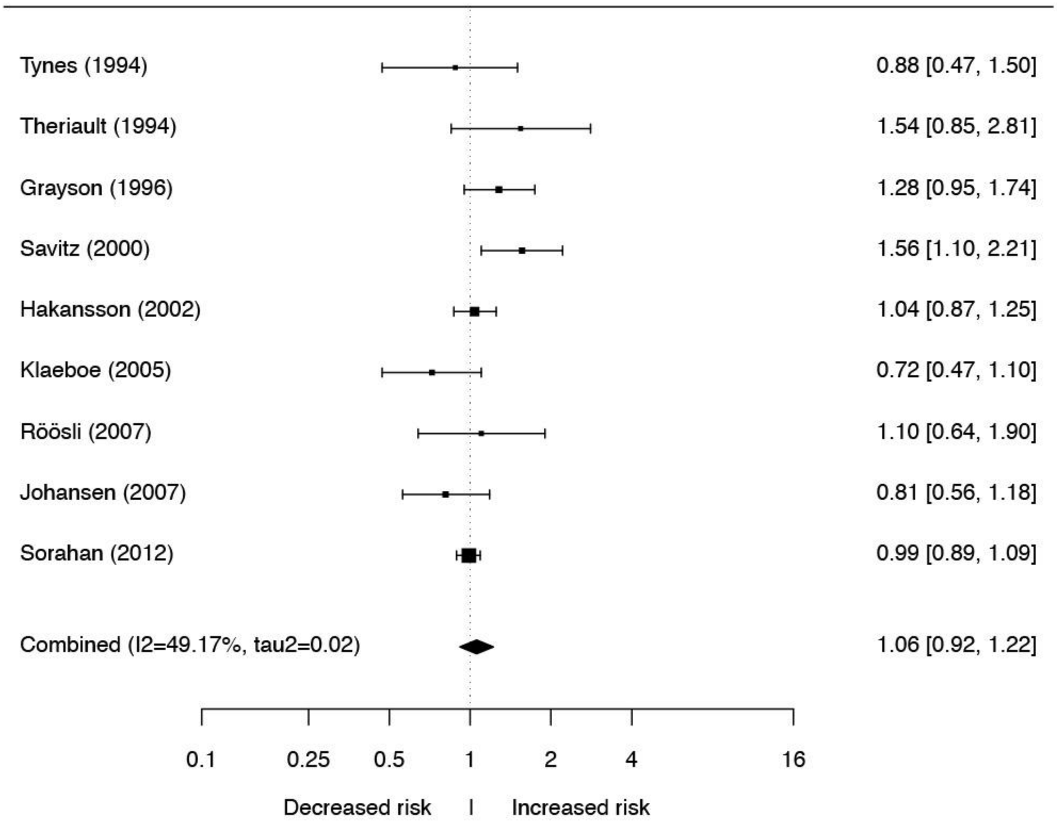


Figure 55 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnosis versus information from the death certificate) is only possible for diagnosis. This shows no statistically significantly increased risk (figure 56).

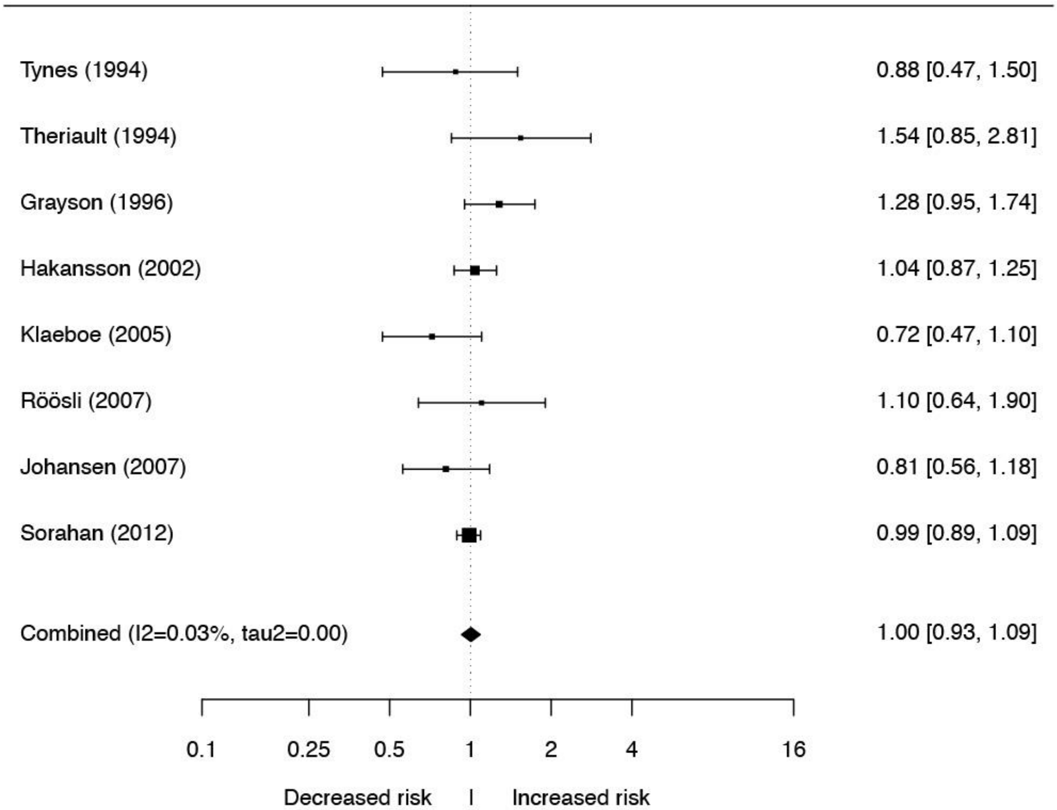


Figure 56 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of diagnosis alone

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). A risk estimate is only possible for the first subcategory and is not statistically significantly increased (figure 57).

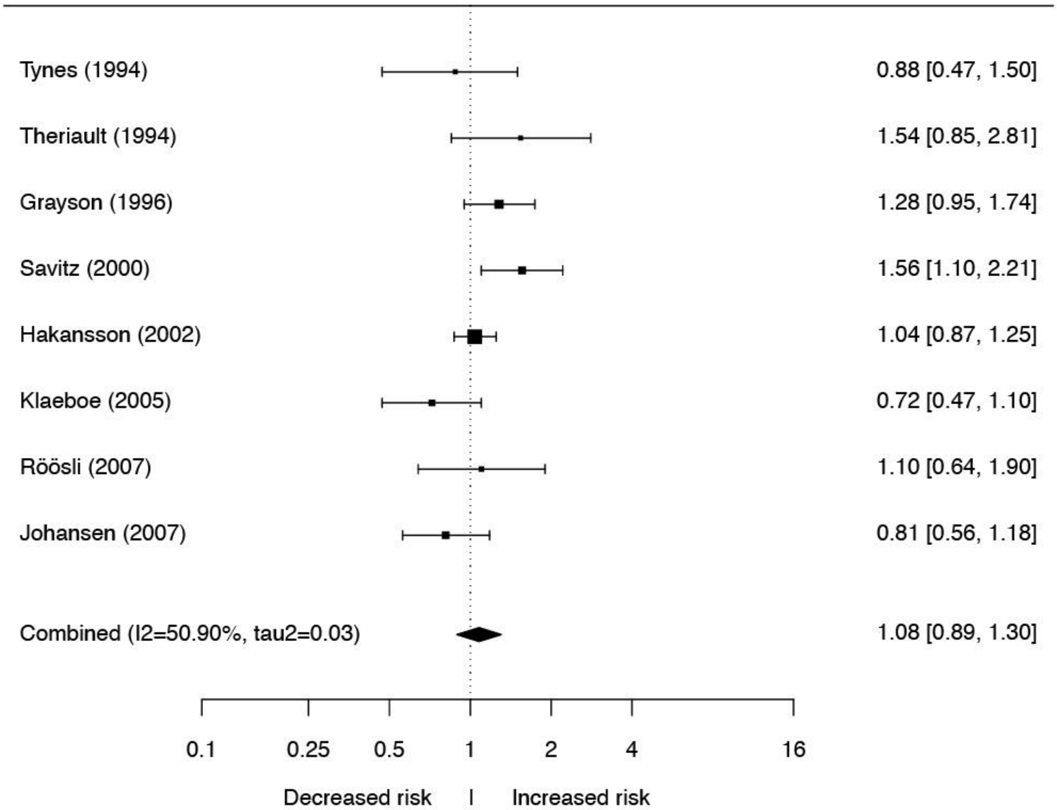


Figure 57 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone.

The subanalysis according to complete versus incomplete occupational history shows a statistically significantly increased risk estimate for complete occupational history (figure 58).

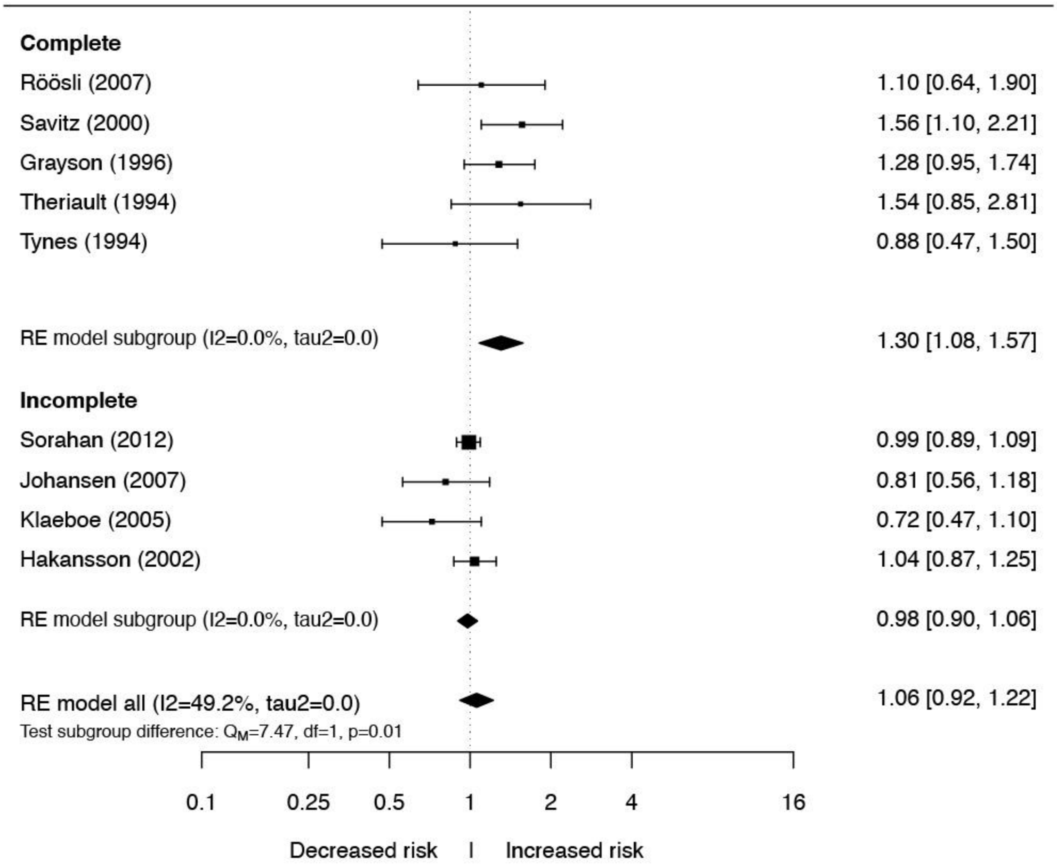


Figure 58 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of complete versus incomplete occupational history

The subanalysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 59).

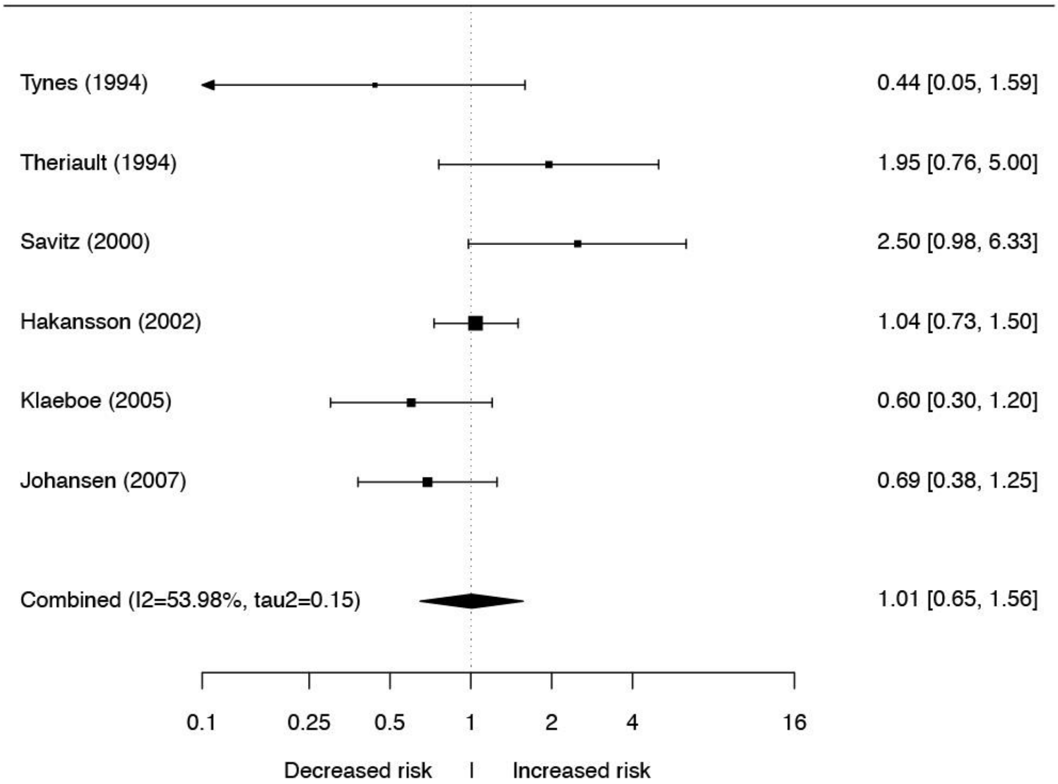


Figure 59 Meta-analysis of data on brain cancer and occupational exposure to magnetic fields - industrial populations; risk estimate for subanalysis of highest versus background exposure

The subanalysis of longest exposure versus background exposure cannot be carried out due to the low number of studies.

Table 47 summarises the results of the meta-analyses.

Table 47 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of brain cancer

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis of general population	Exposure above background levels	**1.13**	**1.04-1.23**	23	67.0%
Subanalysis 1: recording of disease	Diagnosis	**1.11**	**1.02-1.21**	21	65.4%
	Mortality	--	--	2	--
Subanalysis 2: exposure assessment	Calculated / measured	1.06	0.98-1.14	16	52.7%
	Occupation	**1.32**	**1.13-1.53**	7	32.2%
Subanalysis 3: occupational history	Incomplete	**1.21**	**1.08-1.36**	12	58.7%
	Complete	1.03	0.93-1.13	11	46.0%
Subanalysis 4	Highest exposure	1.03	0.94-1.13	9	0.0%
Subanalysis 5	Longest exposure	1.38	0.88-2.16	5	60.9%
Main analysis of industrial populations	Exposure above background levels	1.06	0.92-1.22	9	49.2%
Subanalysis 1: recording of disease	Diagnosis	1.00	0.93-1.09	8	0.0%
	Mortality	**--**	**--**	1	--
Subanalysis 2: exposure assessment	Calculated / measured	1.08	0.89-1.30	8	50.9%
	Occupation	**--**	**--**	1	--
Subanalysis 3: occupational history	Incomplete	0.98	0.90-1.05	4	0.0%
	Complete	**1.30**	**1.08-1.57**	5	0.0%
Subanalysis 4	Highest exposure	1.01	0.65-1.56	6	54.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.6 Testicular cancer

7.6.1 Testicular cancer and residential distance to high-voltage power lines

There is no data on testicular cancer in relation to residential distance to high-voltage power lines.

7.6.2 Testicular cancer and residential exposure to magnetic fields

One study was found that investigates the relationship between cumulative exposure to magnetic fields from high-voltage power lines in the residential environment, expressed in microtesla-year, and the occurrence of testicular cancer.[3] For the category of ever exposed to ELF magnetic fields, the Committee calculated an SIR (standardized incidence ratio) of 1.00 (0.78-1.29). For the highest exposure, the SIR was 0.00 (0.00-5.51).

One study was also found that investigates the relationship between electric blanket use and the occurrence of testicular cancer.[153] A risk estimate of 1.00 (0.70-1.40) was found for the category of ever used, and a risk estimate of 1.20 (0.70-1.90) was found for the highest exposure.

7.6.3 Testicular cancer and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 60).

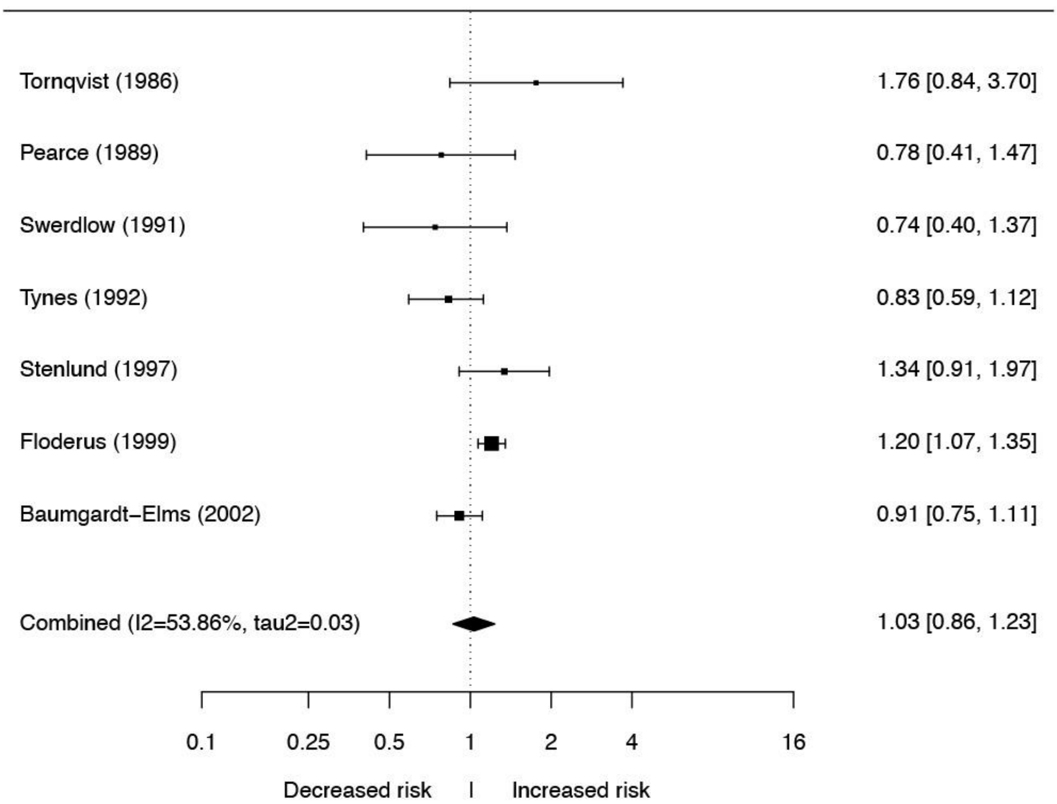


Figure 60 Meta-analysis of data on testicular cancer and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is not possible because all studies use diagnosis.

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). The risk estimates for both subcategories are not statistically significantly increased (figure 61).

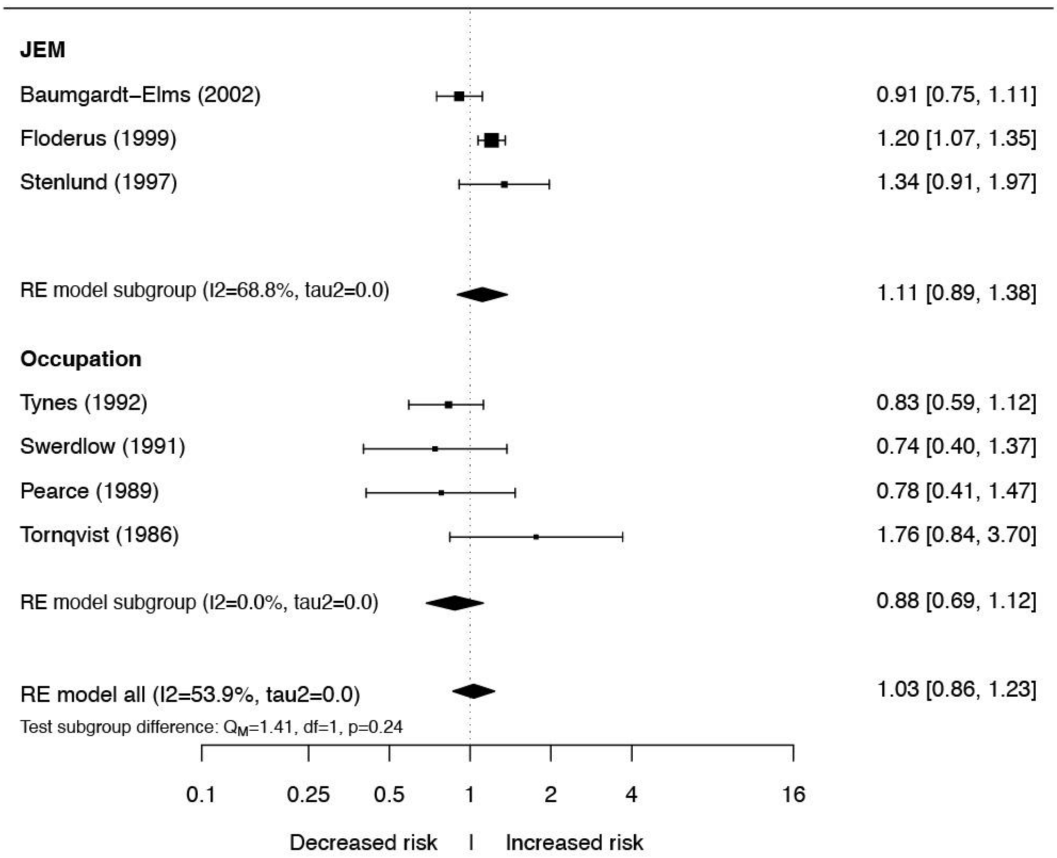


Figure 61 Meta-analysis of data on testicular cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) versus job title (Occupation)

The subanalysis according to completeness of occupational history is only possible for studies with an incomplete occupational history. These show no statistically significantly increased risk (figure 62).

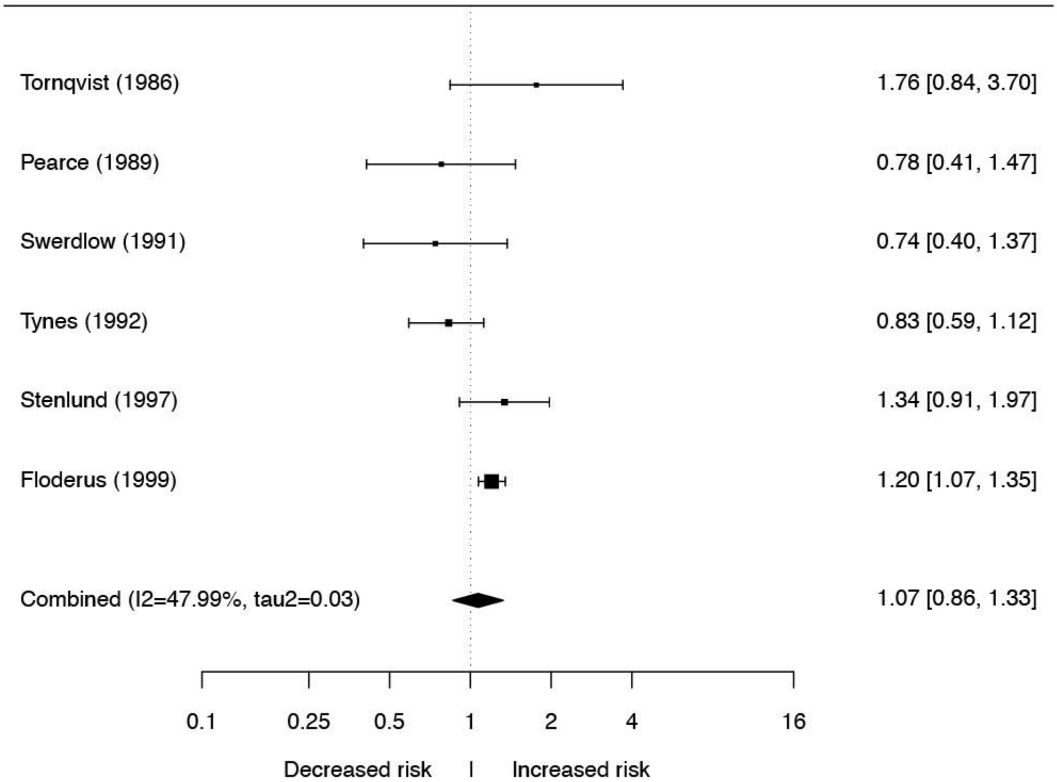


Figure 62 Meta-analysis of data on testicular cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of incomplete occupational history alone

The analysis of highest or longest exposure versus background exposure is not possible due to a low number of studies.

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 63).

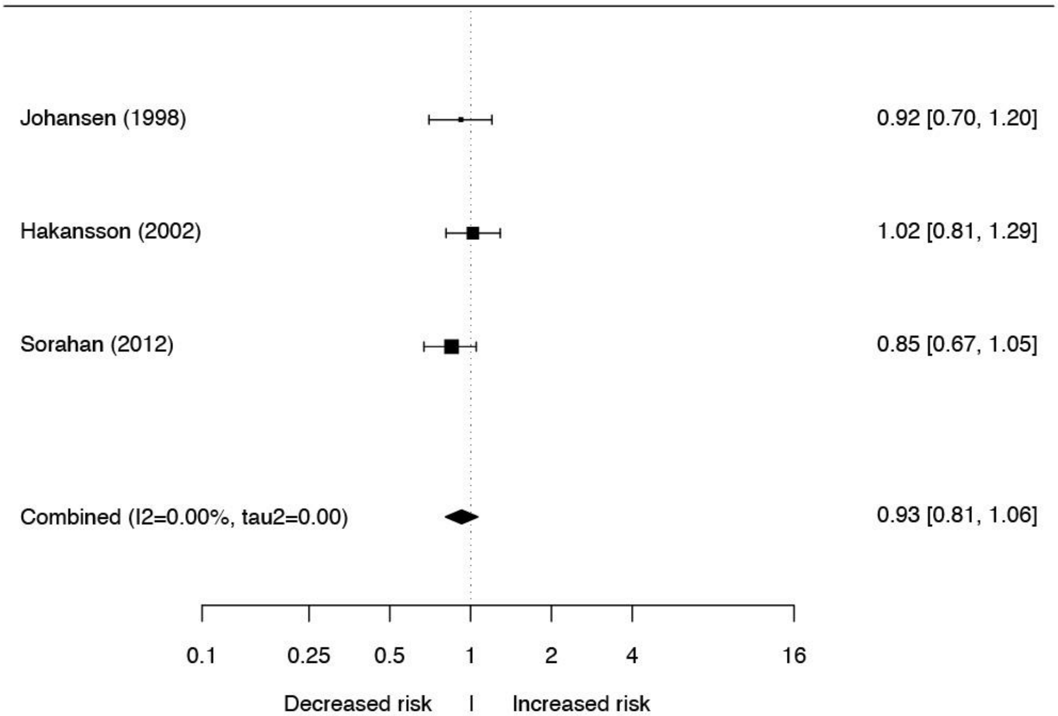


Figure 63 Meta-analysis of data on testicular cancer and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

Subanalyses were not possible due to the low number of studies.

Table 48 summarises the results of the meta-analyses.

Table 48 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of testicular cancer

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis of general population	Exposure above background levels	1.03	0.86-1.23	7	53.9%
Subanalysis 1: exposure assessment	Calculated/measured	1.11	0.89-1.38	3	68.8%
	Occupation	0.88	0.69-1.12	4	0.0%
Subanalysis 2: occupational history	Incomplete	1.07	0.86-1.33	6	48.9%
	Complete	--	--	1	--
Main analysis of industrial populations	Exposure above background levels	0.93	0.81-1.06	3	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.7 Pancreatic cancer

7.7.1 Pancreatic cancer and residential distance to high-voltage power lines

One study was found that investigates the relationship between distance to high-voltage power lines and mortality from pancreatic cancer.[13] For all addresses at a distance of less than 100 metres from a high-voltage power line in the five years prior to diagnosis, an SMR (standardised mortality ratio) of 124 (25-361) was found.

7.7.2 Pancreatic cancer and residential exposure to magnetic fields

One study was found that investigates the relationship between cumulative exposure to magnetic fields from high-voltage power lines in the residential environment, expressed in microtesla-year, and the occurrence of pancreatic cancer.[3] For the category of ever exposed to ELF magnetic fields, the Committee calculated an SIR (standardised incidence ratio) of 1.04 (0.94-1.16). For the highest exposure, the SIR was 0.83 (0.36-1.64).

7.7.3 Pancreatic cancer and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 64).

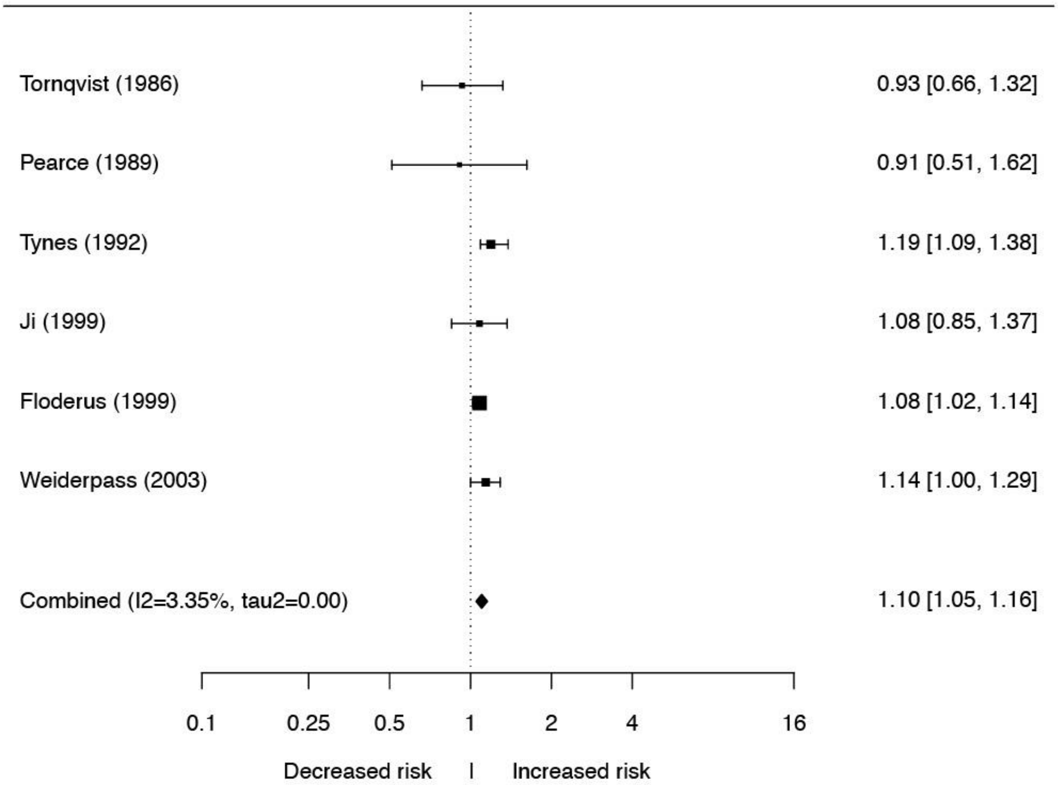


Figure 64 Meta-analysis of data on pancreatic cancer and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is not possible because all studies use diagnosis.

In the subanalysis according to accuracy of the exposure assessment, a distinction was made between studies where this was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) and studies that used job title alone (Occupation). In both subcategories, the risk estimates are statistically significantly increased (figure 65).

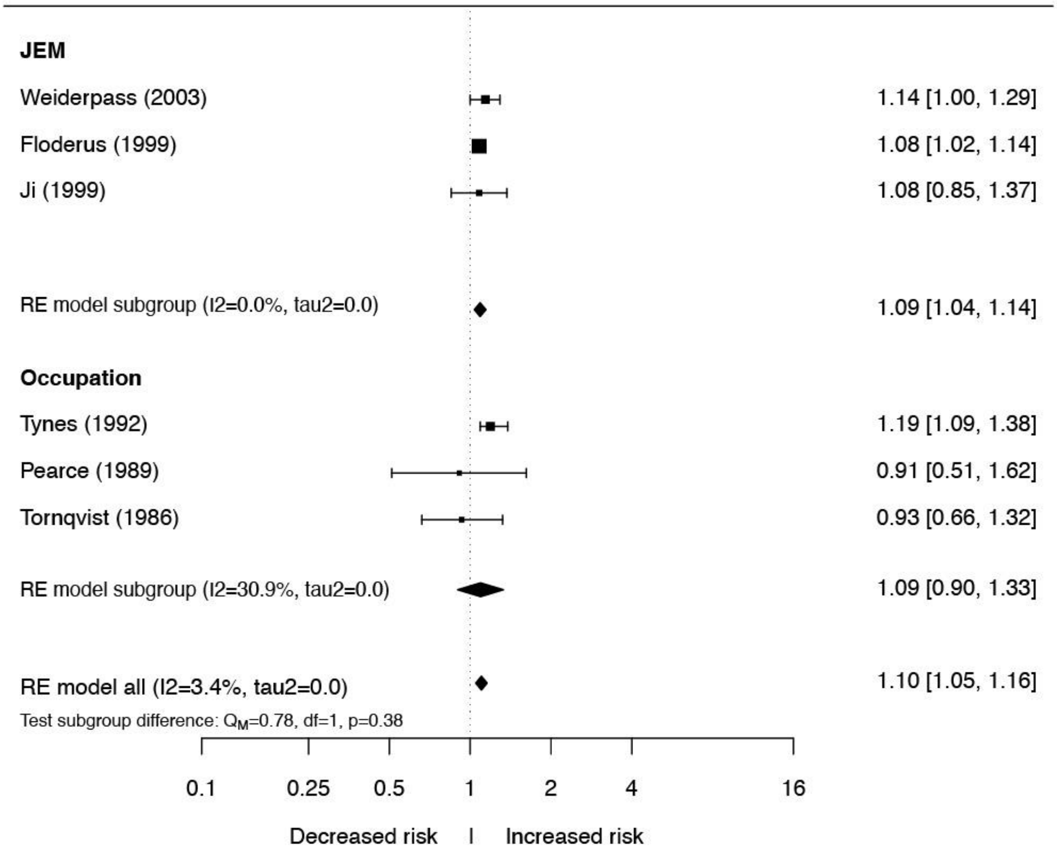


Figure 65 Meta-analysis of data on pancreatic cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) versus job title (Occupation)

The subanalysis according to completeness of occupational history is not possible because all studies have an incomplete occupational history.

The subanalysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 66).

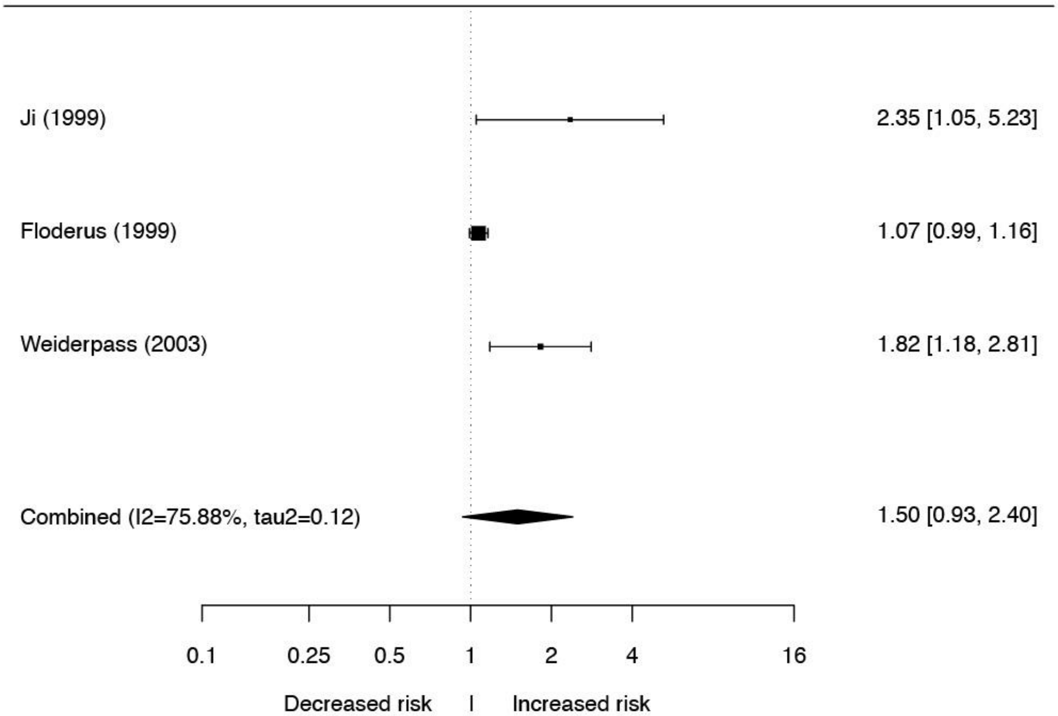


Figure 66 Meta-analysis of data on pancreatic cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of highest exposure versus background exposure

The analysis of longest exposure versus background exposure is not possible due to a low number of studies.

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 67).

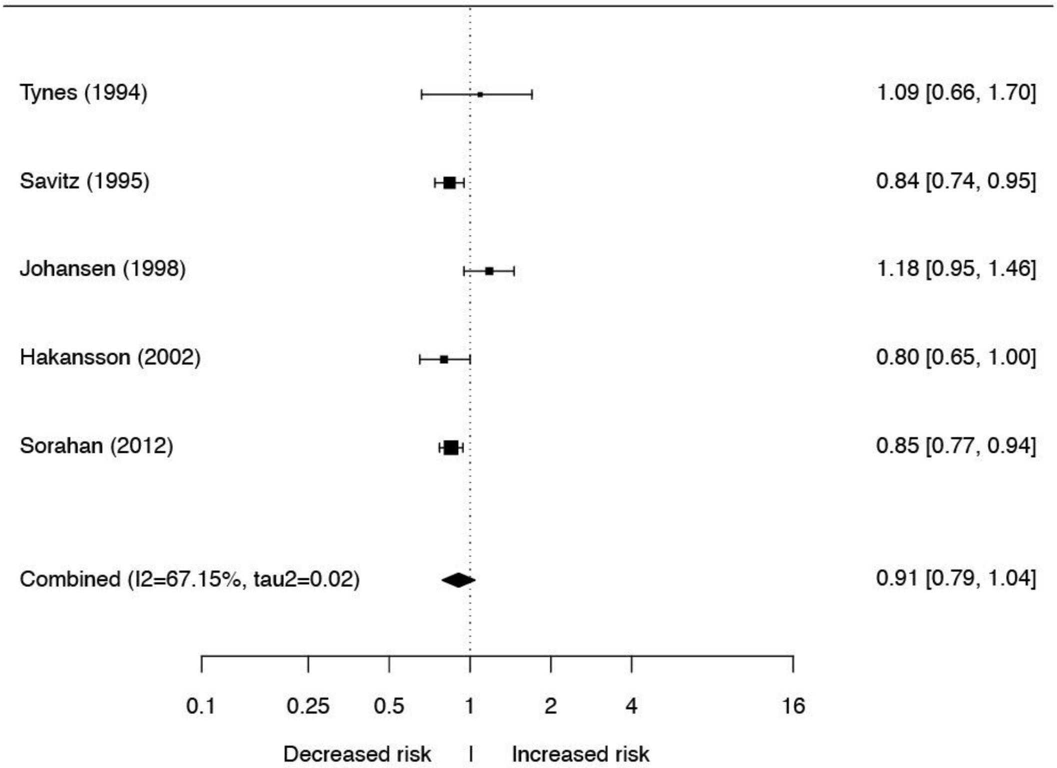


Figure 67 Meta-analysis of data on pancreatic cancer and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is not possible because all studies use diagnosis.

The subanalysis according to accuracy of the exposure assessment is only possible for studies in which exposure was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM). These show no statistically significantly increased risk (figure 68).

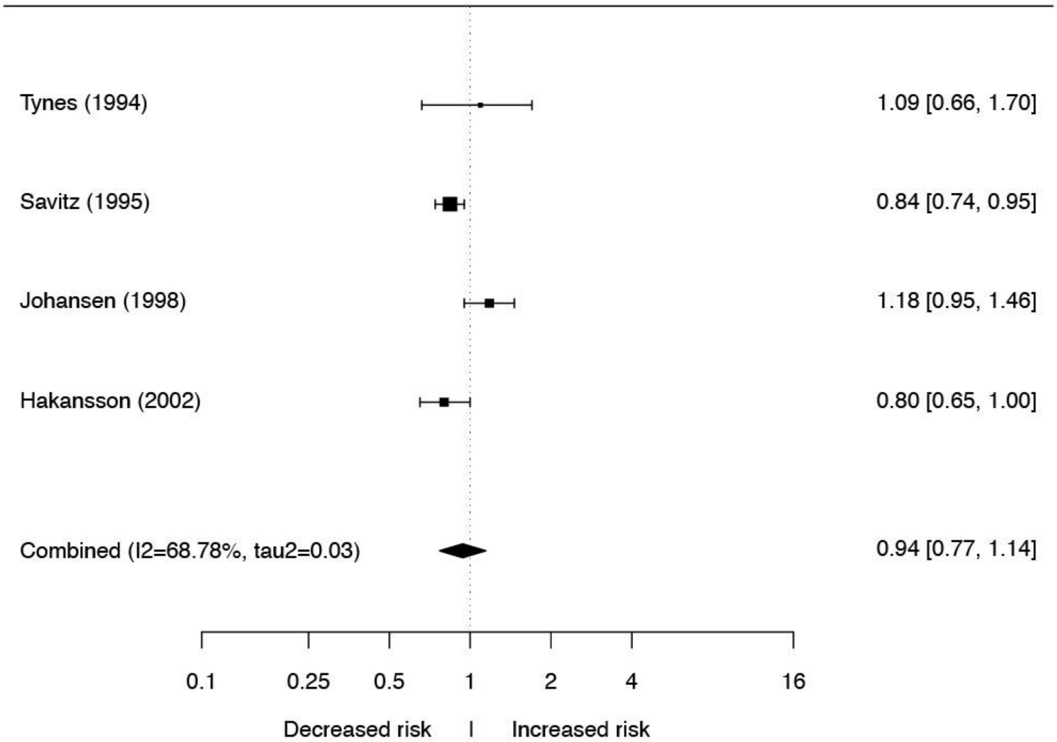


Figure 68 Meta-analysis of data on pancreatic cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone

The subanalysis according to completeness of occupational history is only possible for studies with a complete occupational history. The risk estimate is not statistically significantly increased (figure 69).

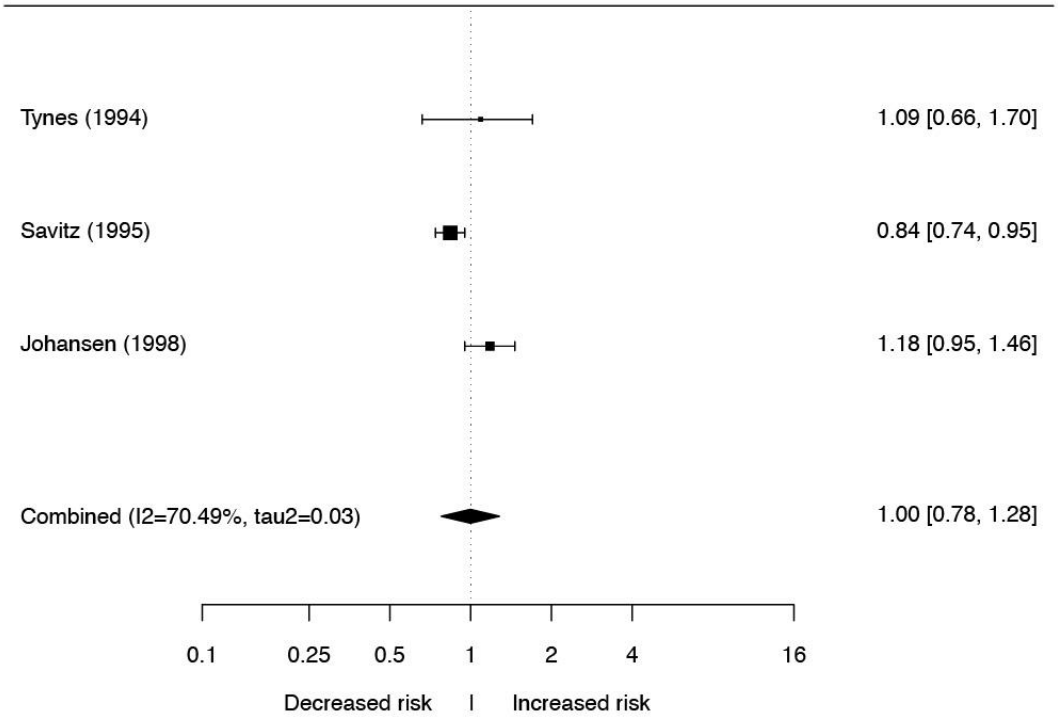


Figure 69 Meta-analysis of data on pancreatic cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of complete occupational history alone

The analyses of highest or longest exposure versus background exposure cannot be carried out due to the low number of studies.

Table 49 summarises the results of the meta-analyses.

Table 49 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of pancreatic cancer

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis of general population	Exposure above background levels	**1.10**	**1.05-1.16**	6	6.6%
Subanalysis 1: exposure assessment	Calculated / measured	**1.09**	**1.04-1.15**	3	0.0%
	Occupation	**1.09**	**0.90-1.33**	3	30.9%
Subanalysis 2	Highest exposure	1.50	0.93-2.40	3	75.9%
Main analysis of industrial populations	Exposure above background levels	0.91	0.79-1.04	5	67.2%
Subanalysis 1: exposure assessment	Calculated / measured	0.94	0.77-1.14	4	68.8%
	Occupation	--	--	1	--
Subanalysis 2: occupational history	Incomplete	--	--	2	--
	Complete	1.00	0.78-1.28	3	70.5%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.8 Lung cancer

7.8.1 Lung cancer and residential distance to high-voltage power lines

One study was found that investigates the relationship between distance to high-voltage power lines and the occurrence of lung cancer.[13] For all addresses at a distance of less than 100 metres from a high-voltage power line in the five years prior to diagnosis, an SMR (standardised mortality ratio) of 114 (65-185) was found.

7.8.2 Lung cancer and residential exposure to magnetic fields

One study was found that investigates the relationship between cumulative exposure to magnetic fields from high-voltage power lines in the residential environment, expressed in microtesla-year, and the occurrence of lung cancer.[3] For the category of ever exposed to ELF magnetic fields, the Committee calculated an SIR (standardised incidence ratio) of 0.92 (0.85-1.00). For the highest exposure, the SIR was 0.91 (0.62-1.29).

7.8.3 Lung cancer and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 70).

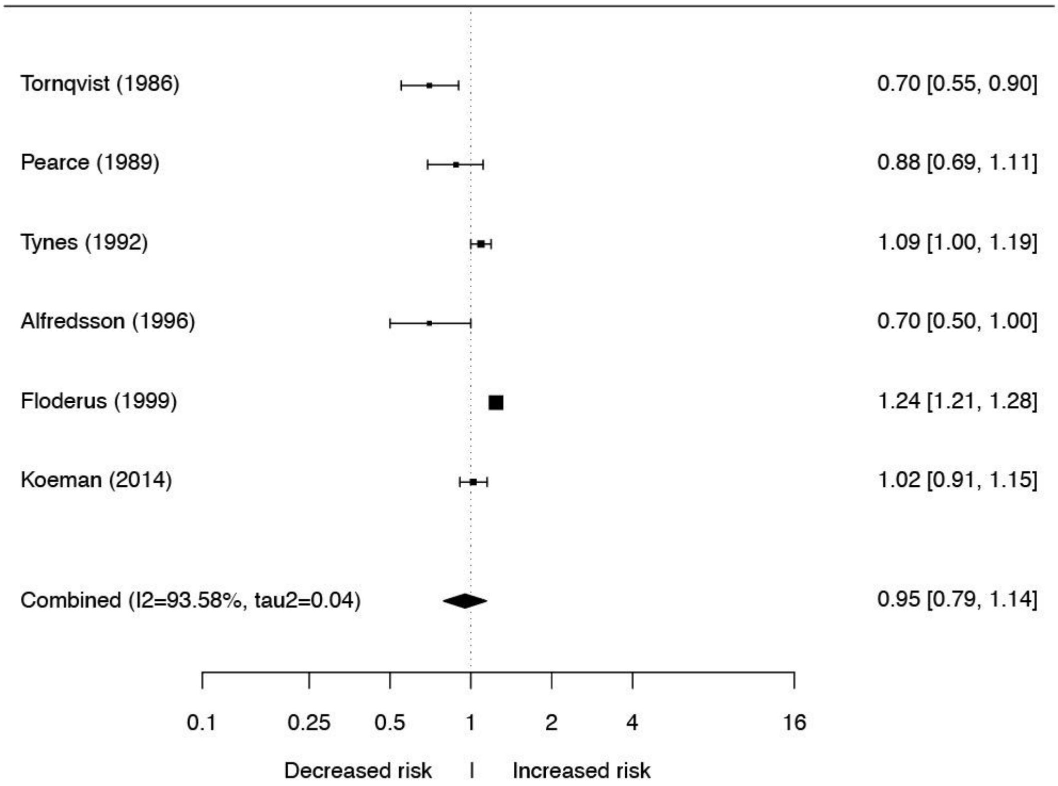


Figure 70 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is not possible because all studies use diagnosis.

The subanalysis according to accuracy of the exposure assessment is only possible for studies that used job title alone (Occupation). The risk estimate is not statistically significantly increased (figure 71).

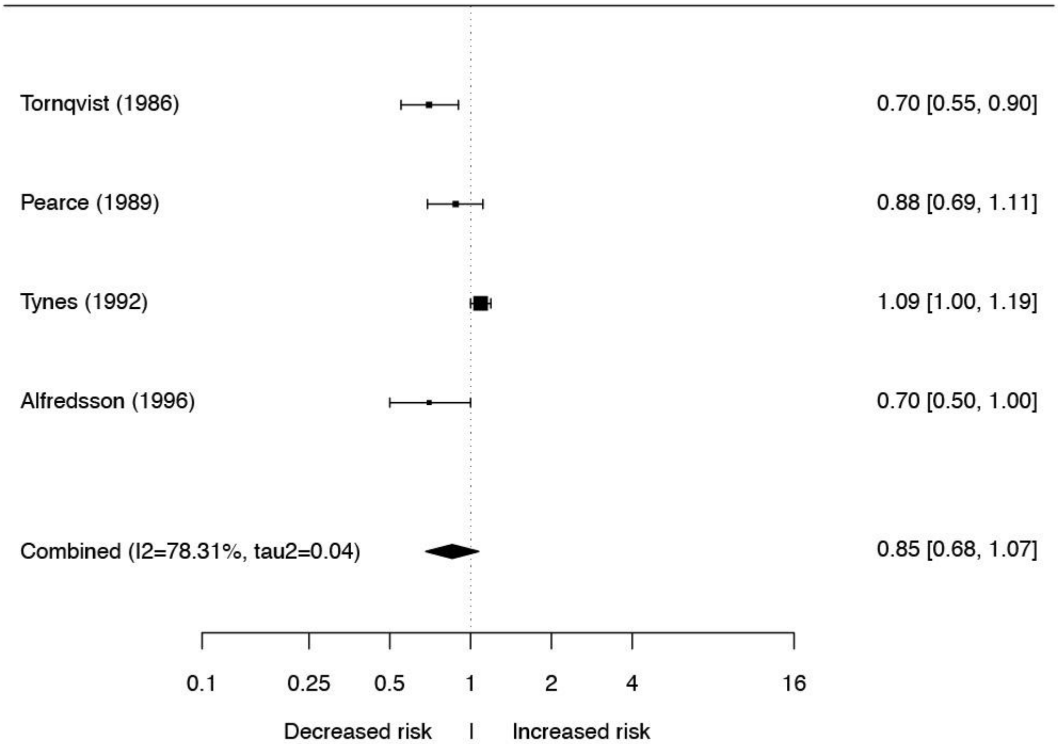


Figure 71 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of exposure as classified by job title alone (Occupation)

The subanalysis according to completeness of occupational history is only possible for studies with an incomplete occupational history. This shows no statistically significantly increased risk (figure 72).

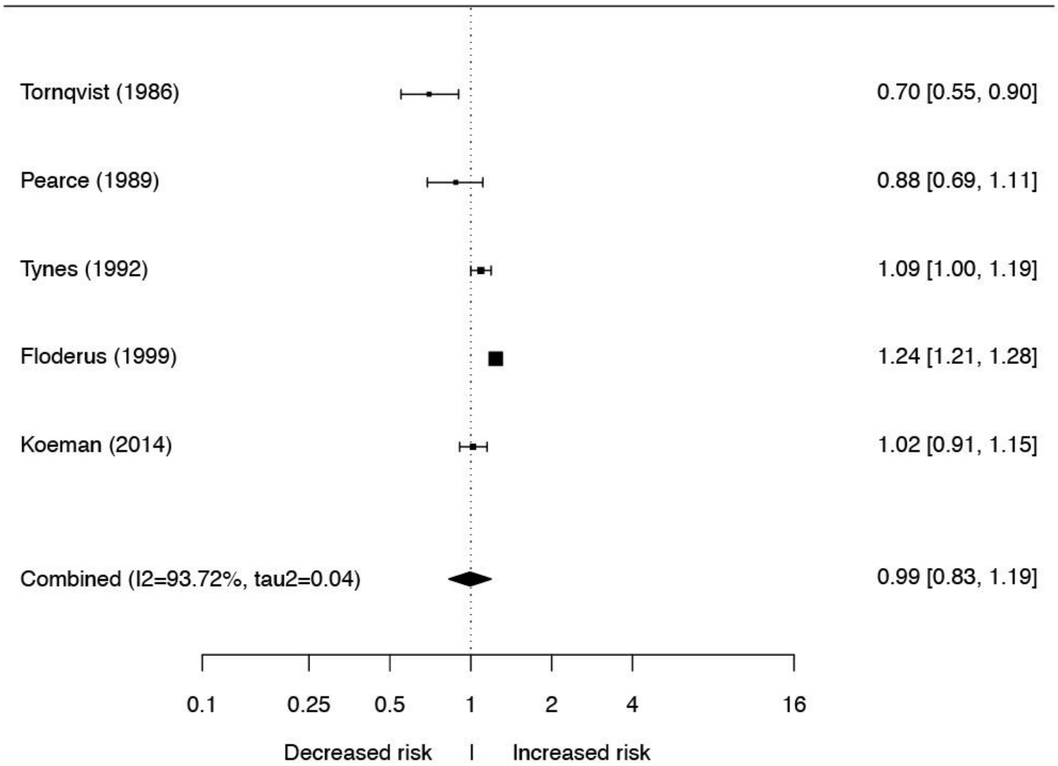


Figure 72 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of incomplete occupational history alone

There is insufficient data for an analysis of highest or longest exposure versus background exposure.

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 73).

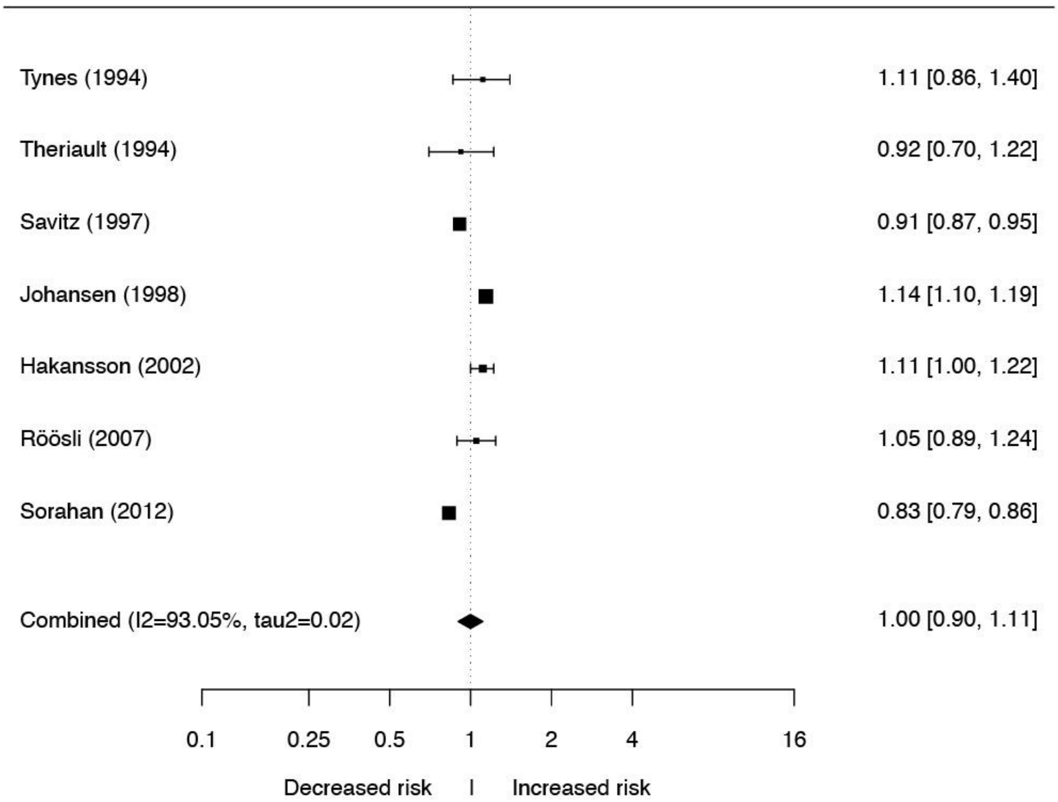


Figure 73 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnosis versus information from the death certificate) is only possible for diagnosis. This shows no statistically significantly increased risk (figure 74).

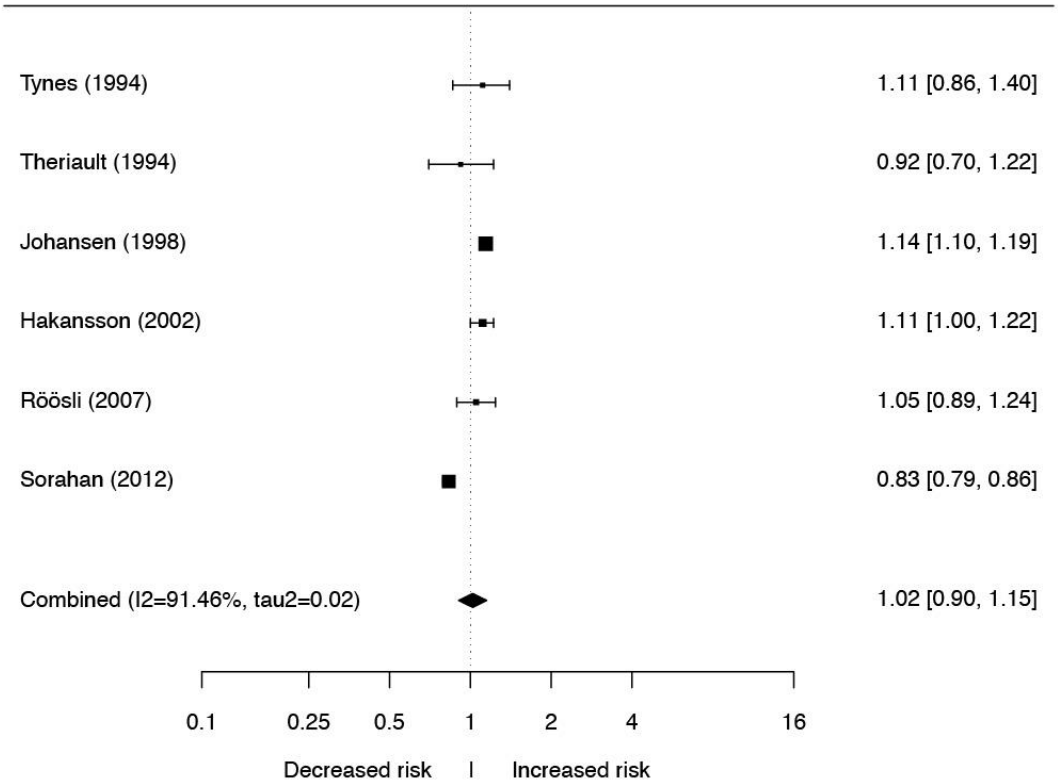


Figure 74 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of diagnosis alone

The subanalysis according to accuracy of the exposure assessment is only possible for studies in which exposure was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM). The risk estimate is not statistically significantly increased (figure 75).

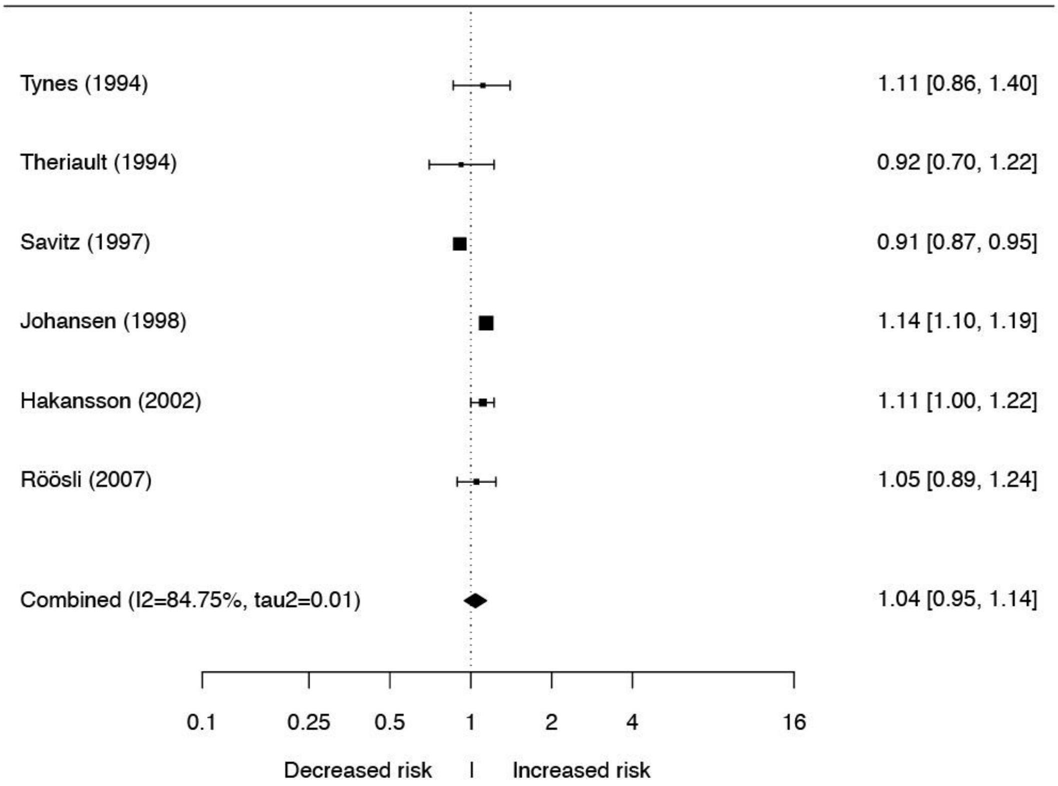


Figure 75 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone

The subanalysis according to completeness of occupational history is only possible for studies with a complete occupational history. The risk estimate is not statistically significantly increased (figure 76).

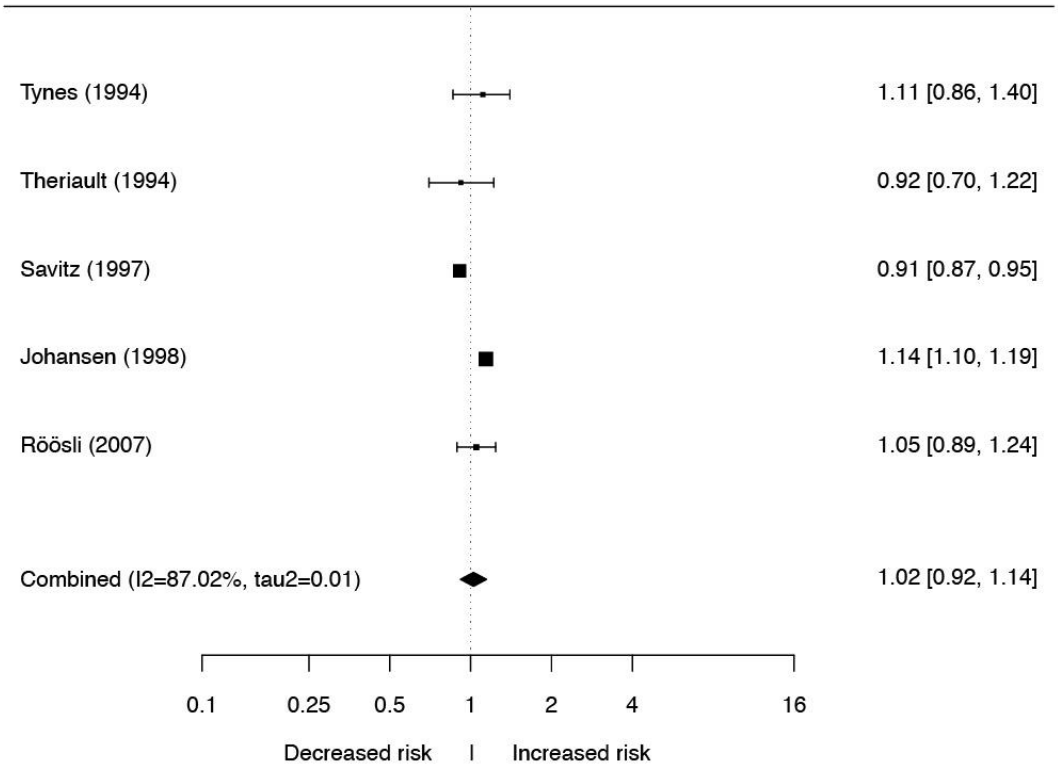


Figure 76 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of complete occupational history only

The analysis of highest exposure versus background exposure shows a statistically significantly increased risk (figure 77).

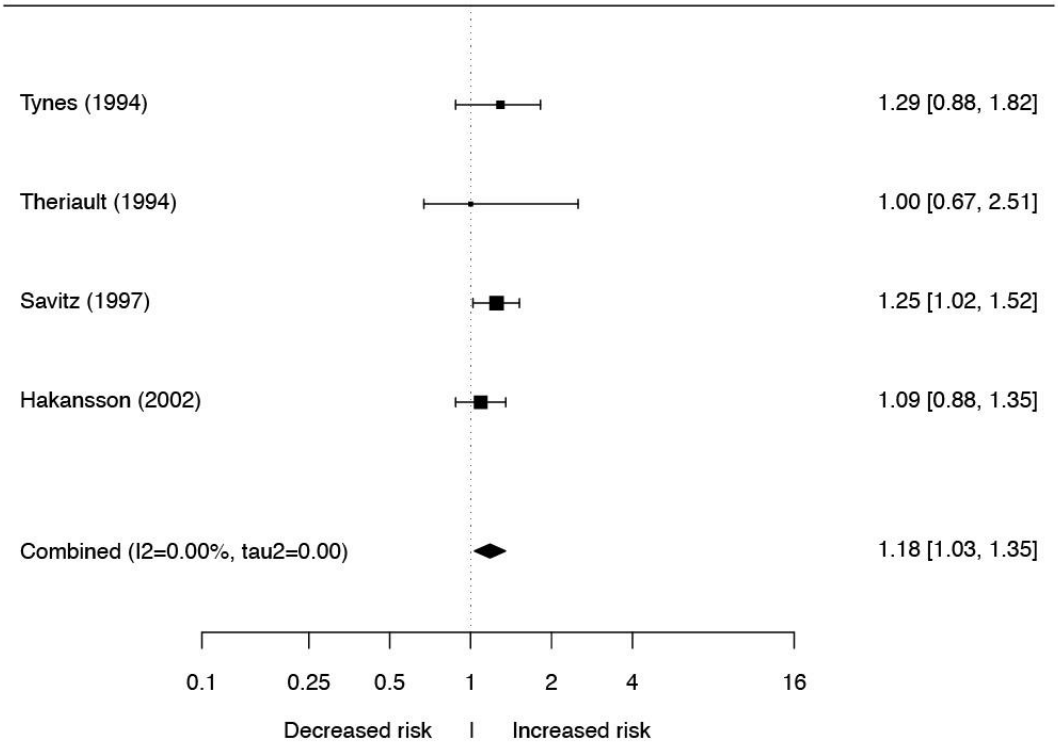


Figure 77 Meta-analysis of data on lung cancer and occupational exposure to magnetic fields - industrial populations; risk estimate for subanalysis of highest exposure versus background exposure

The analysis of longest exposure versus background exposure cannot be carried out due to the low number of studies.

Table 50 summarises the results of the meta-analyses.

Table 50 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of lung cancer

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis of general population	Exposure above background levels	0.95	0.79-1.14	6	93.6%
Subanalysis 1: exposure assessment	Calculated/measured	--	--	2	--
	Occupation	0.85	0.68-1.07	4	78.3%
Subanalysis 2: occupational history	Incomplete	0.99	0.83-1.19	5	93.7%
	Complete	--	--	1	--
Main analysis of industrial populations	Exposure above background levels	1.00	0.90-1.11	7	92.7%
Subanalysis 1: recording of disease	Diagnosis	1.02	0.90-1.15	6	90.9%
	Mortality	--	--	1	--
Subanalysis 2: exposure assessment	Calculated/measured	1.04	0.94-1.14	6	83.8%
	Occupation	--	--	1	--
Subanalysis 3: occupational history	Incomplete	--	--	2	--
	Complete	1.02	0.92-1.14	5	87.0%
Subanalysis 4	Highest exposure	**1.18**	**1.03-1.35**	4	0.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.9 Prostate cancer

7.9.1 Prostate cancer and residential distance to high-voltage power lines

There is no data on prostate cancer in relation to distance from home to high-voltage power lines.

7.9.2 Prostate cancer and residential exposure to magnetic fields

One study was found that investigates the relationship between cumulative exposure to magnetic fields from high-voltage power lines in the residential environment, expressed in microtesla-year, and the occurrence of prostate cancer.[3] For the category of ever exposed to ELF magnetic fields, the Committee calculated an SIR (standardized incidence ratio) of 0.99 (0.91-1.07). For the highest exposure, the SIR was 1.22 (0.70-1.85).

One study was also found that investigates the relationship between electric blanket use and the occurrence of prostate cancer.[165] A risk estimate of 1.38 (0.97-1.95) was found for the category of ever used, and the risk estimate for the highest exposure was 1.70 (0.70-3.90).

7.9.3 Prostate cancer and occupational exposure to magnetic fields

General population

For the studies in subjects from the general population, the main analysis of exposure above background levels versus background exposure shows a statistically significantly increased risk (figure 78).

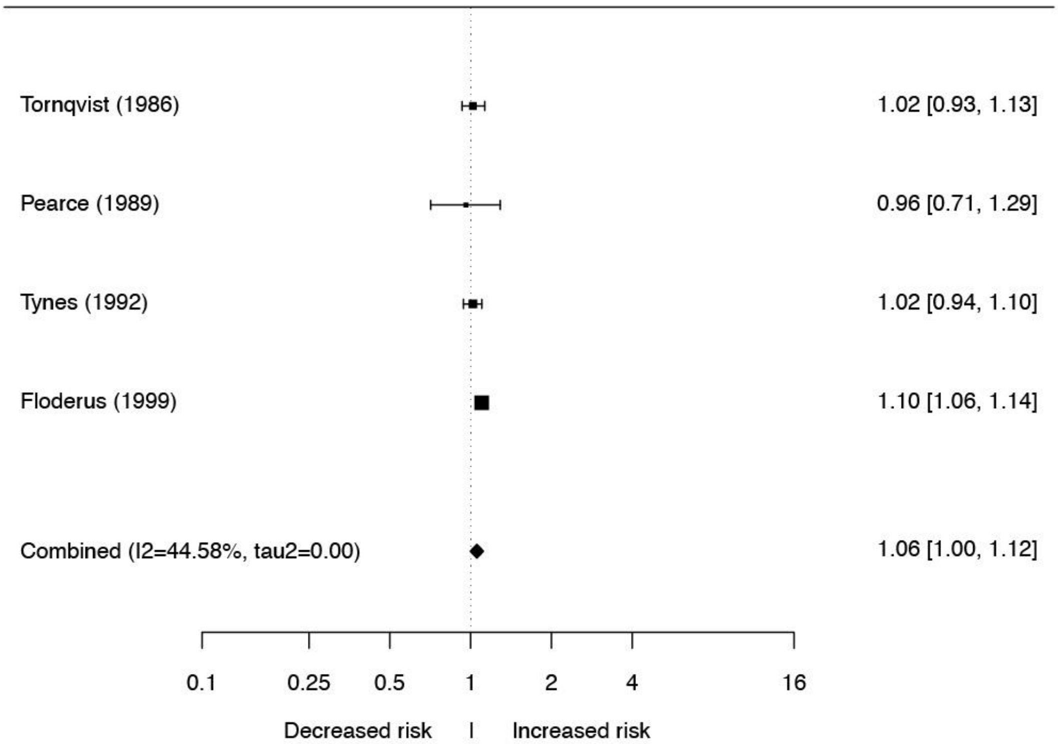


Figure 78 Meta-analysis of data on prostate cancer and occupational exposure to magnetic fields - general population; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is not possible because all studies use diagnosis.

The subanalysis according to accuracy of the exposure assessment is only possible for studies that used job title alone (Occupation). The risk estimate for this subcategory is statistically significantly increased (figure 79).

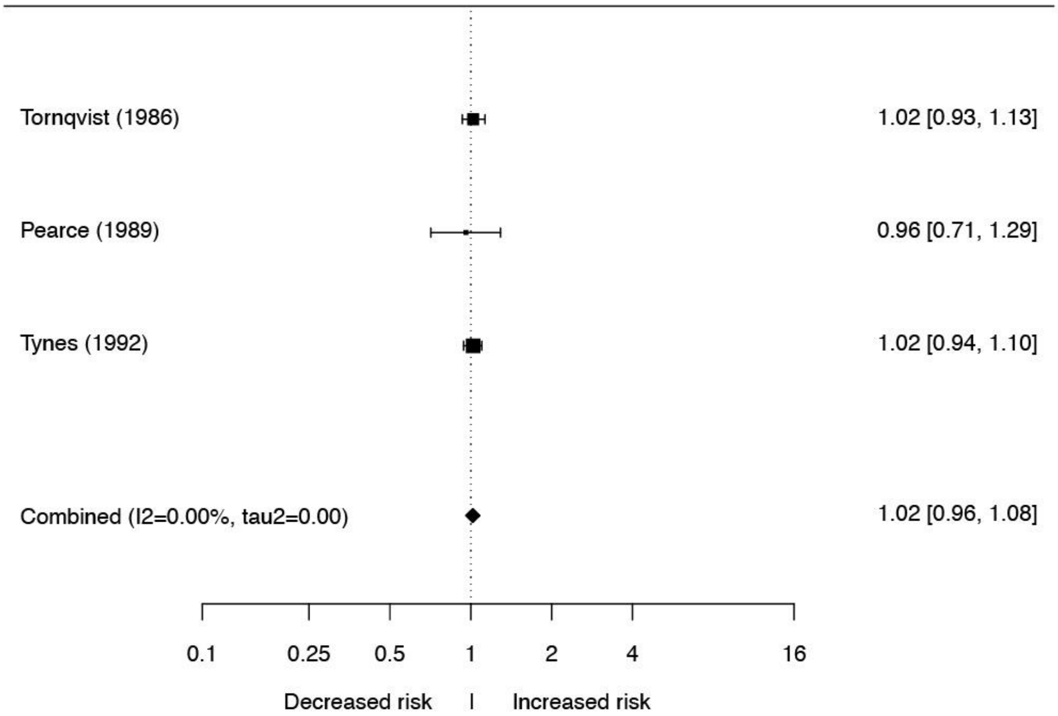


Figure 79 Meta-analysis of data on prostate cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of job title alone (Occupation)

The subanalysis according to completeness of occupational history is not possible because all studies have an incomplete occupational history.

The analysis of highest or longest exposure versus background exposure is not possible due to a low number of studies.

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 80).

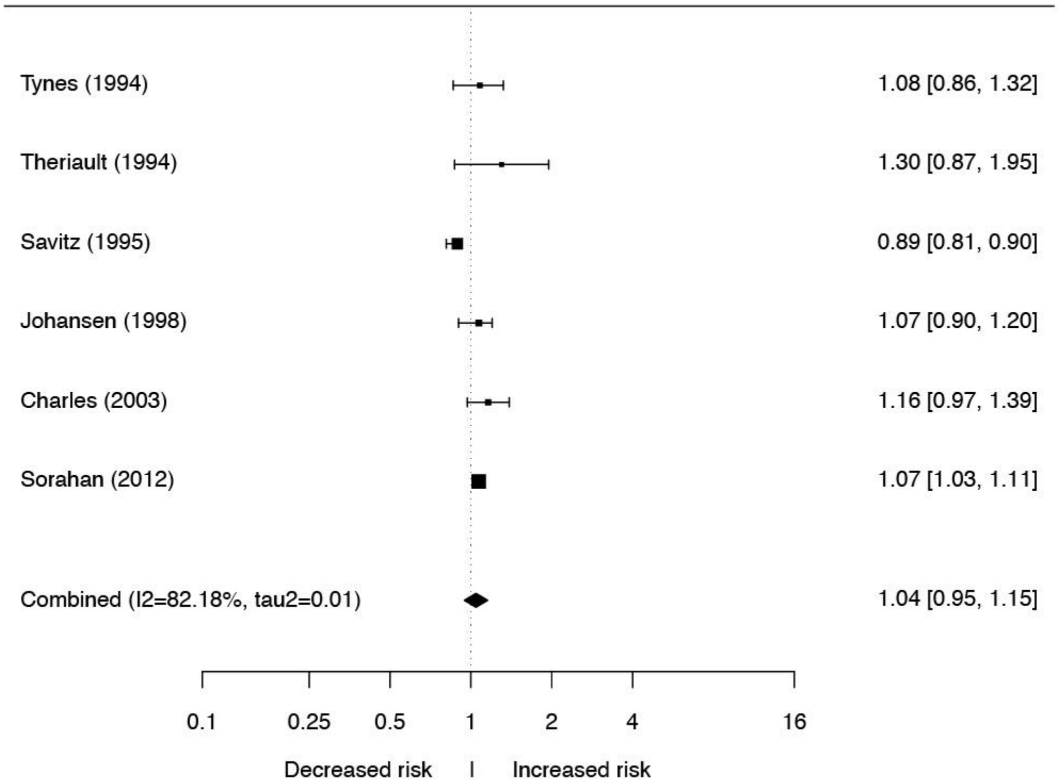


Figure 80 Meta-analysis of data on prostate cancer and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnosis versus information from the death certificate) is only possible for diagnosis. This shows a statistically significantly increased risk (figure 81).

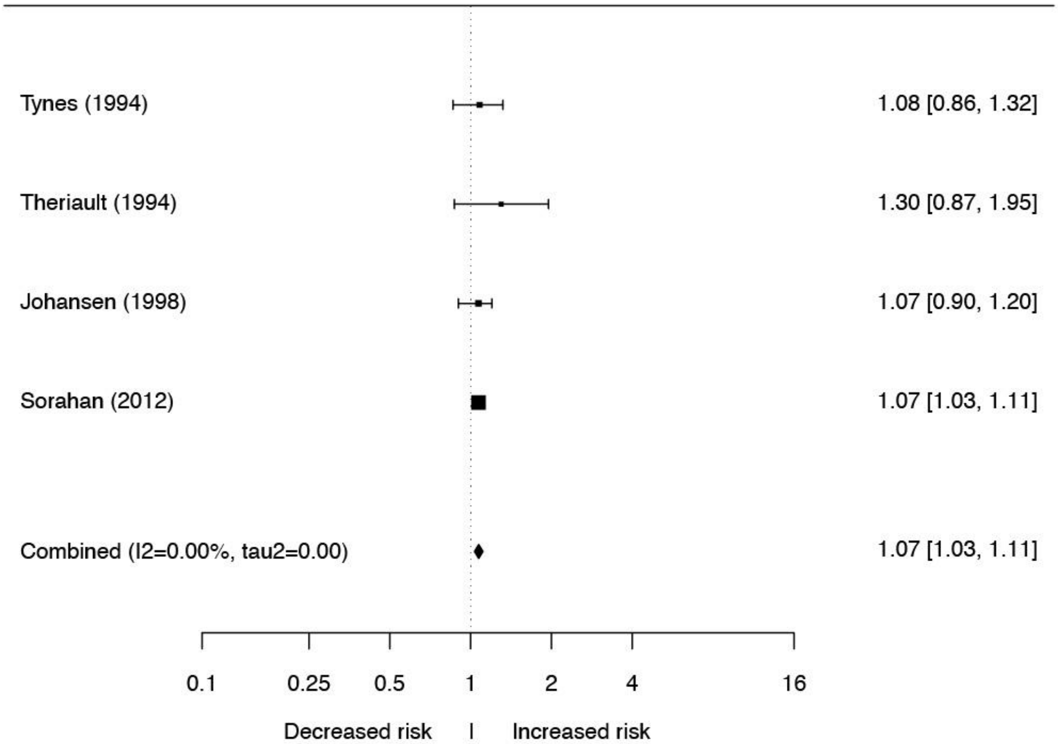


Figure 81 Meta-analysis of data on prostate cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of diagnosis alone

The subanalysis according to accuracy of the exposure assessment is only possible for studies in which exposure was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM). This shows no statistically significantly increased risk (figure 82).

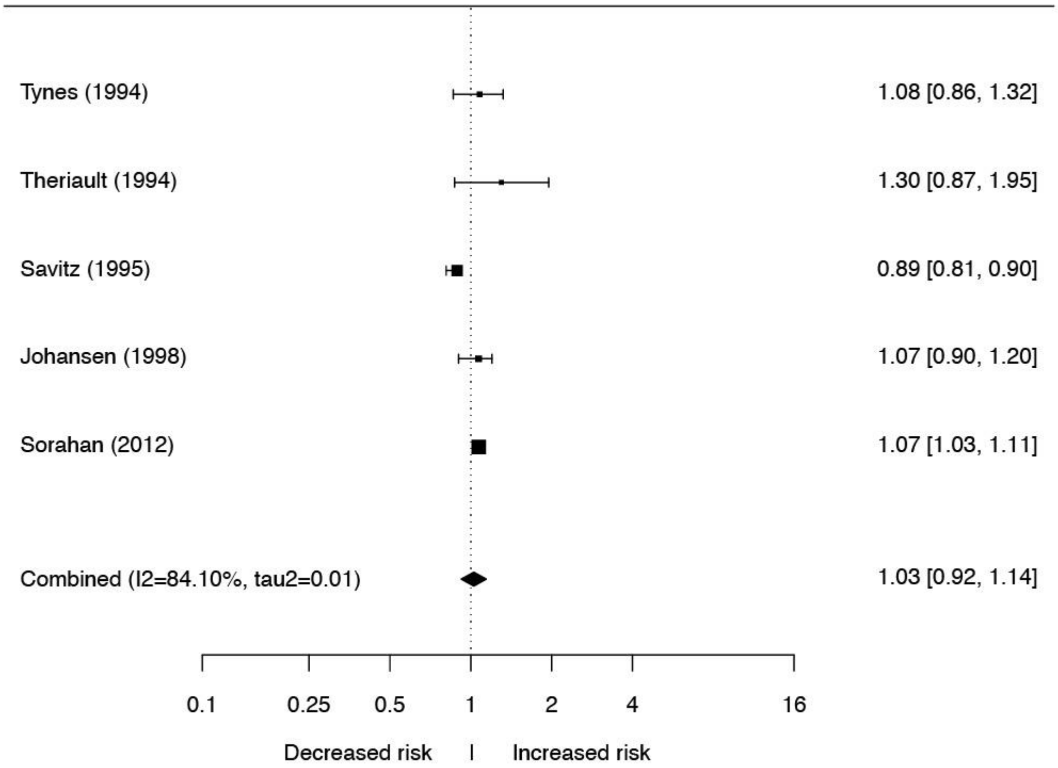


Figure 82 Meta-analysis of data on prostate cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone

The subanalysis according to completeness of occupational history is only possible for studies with a complete occupational history. The risk estimate is not statistically significantly increased (figure 83).

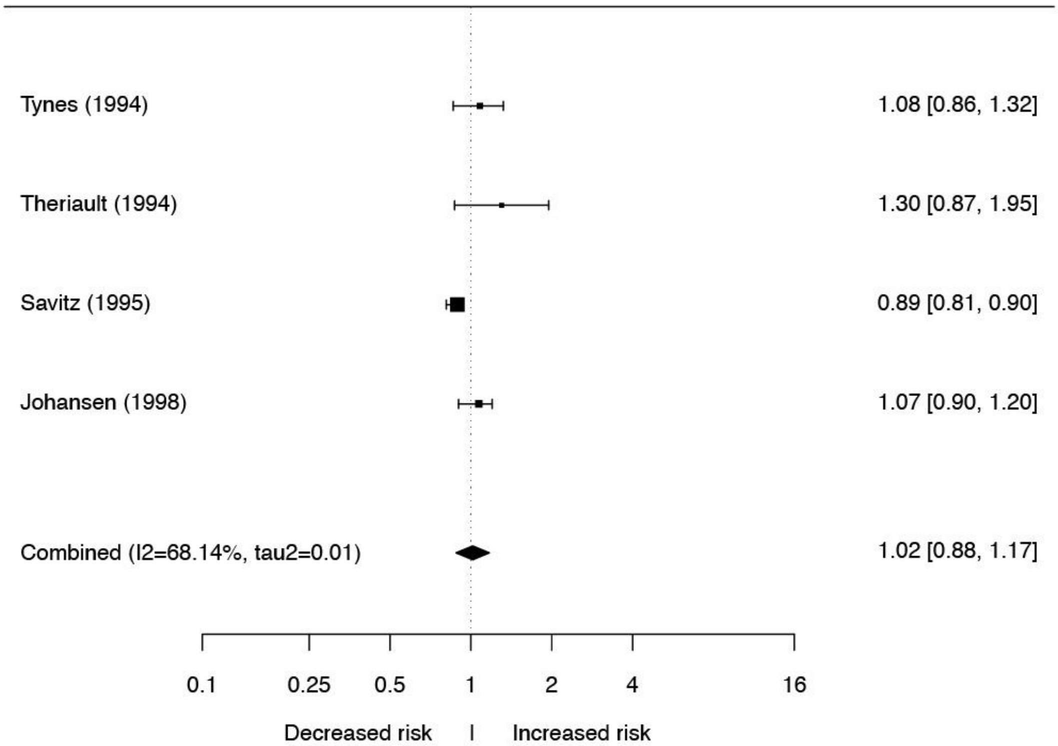


Figure 83 Meta-analysis of data on prostate cancer and occupational exposure to magnetic fields - industrial populations; subanalysis of complete occupational history only

The analysis of highest exposure versus background exposure shows no statistically significantly increased risk (figure 84).

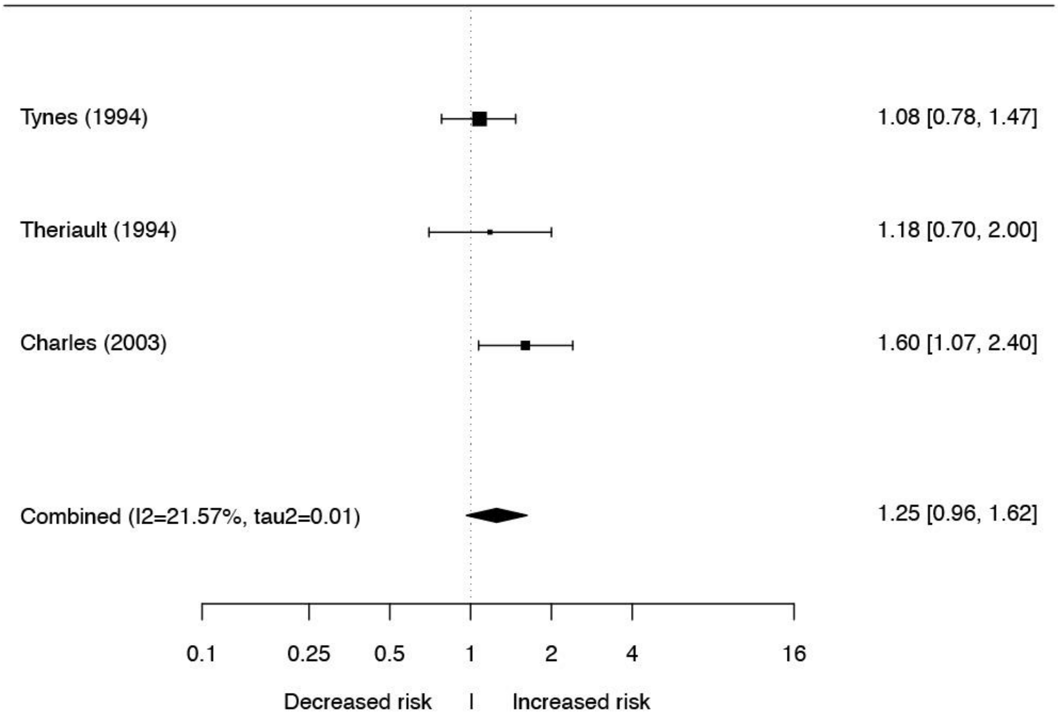


Figure 84 Meta-analysis of data on prostate cancer and occupational exposure to magnetic fields - general population; risk estimate for subanalysis of highest exposure versus background exposure

The analysis of longest exposure versus background exposure cannot be carried out due to the low number of studies.

Table 51 summarises the results of the meta-analyses.

Table 51 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of prostate cancer

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis of general population	Exposure above background levels	1.06	1.00-1.12	4	44.6%
Subanalysis 1: exposure assessment	Calculated / measured	--	--	1	--
	Occupation	1.02	0.96-1.08	3	0.0%
Main analysis of industrial populations	Exposure above background levels	1.04	0.95-1.15	6	82.2%
Subanalysis 1: recording of disease	Diagnosis	**1.07**	**1.03-1.11**	4	0.0%
	Mortality	--	--	2	--
Subanalysis 2: exposure assessment	Calculated / measured	1.04	0.92-1.19	5	69.4%
	Occupation	--	--	1	--
Subanalysis 3: occupational history	Incomplete	--	--	2	--
	Complete	1.02	0.88-1.17	4	68.1%
Subanalysis 4	Highest exposure	1.25	0.96-1.62	3	21.6%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.10 Skin melanomas

7.10.1 Skin melanomas and residential distance to high-voltage power lines

One study was found that investigates the relationship between distance to high-voltage power lines and the occurrence of skin melanomas. The risk estimate for residing at a distance of 0-50 metres from a high-voltage power line is 0.82 (0.61-1.11).[8]

7.10.2 Skin melanomas and residential exposure to magnetic fields

For studies on residential exposure and skin melanomas, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 85).

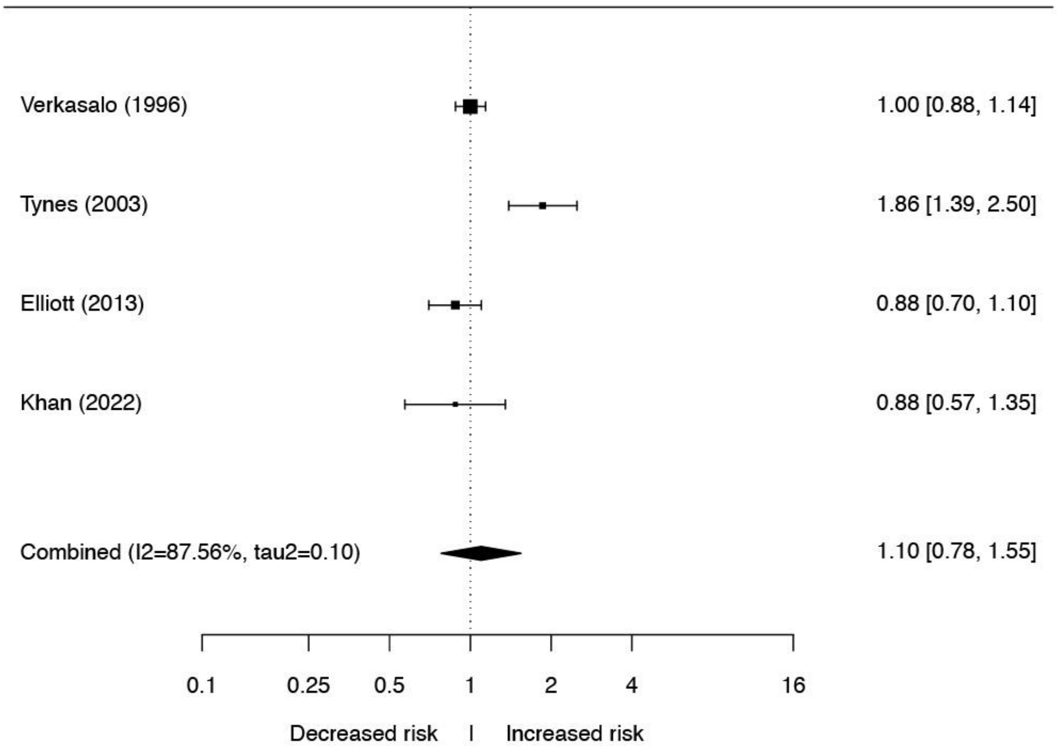


Figure 85 Meta-analysis of data on skin melanomas and residential exposure to magnetic fields; risk estimate for main analysis of exposure above background levels versus background exposure

The subanalysis according to highest exposure also shows no statistically significantly increased risk (figure 86).

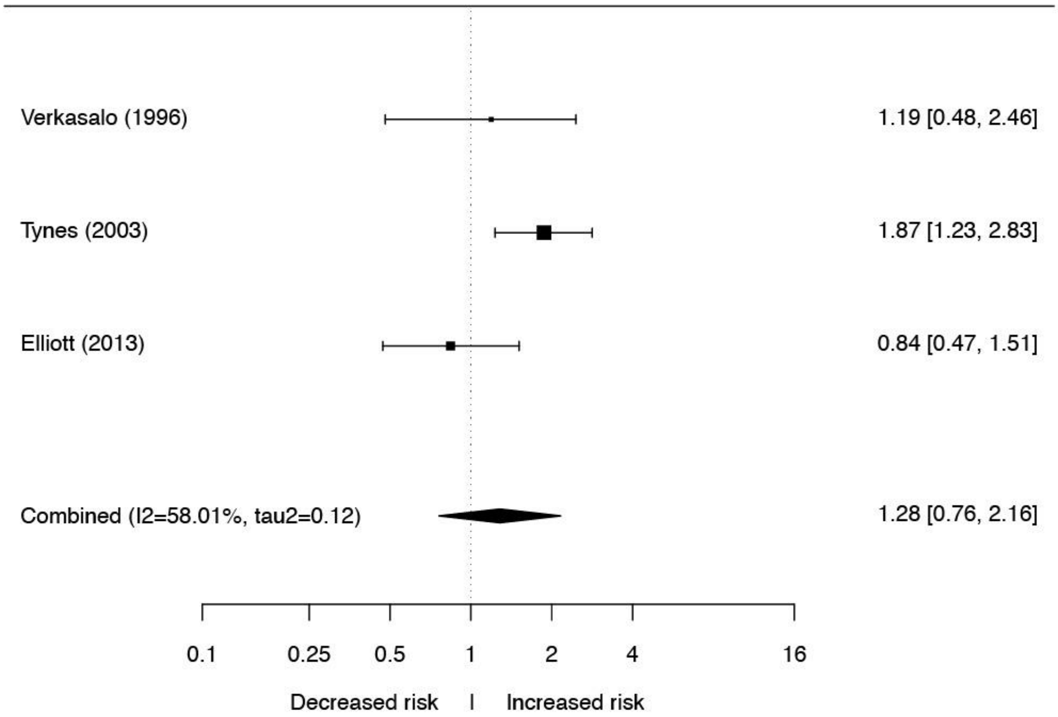


Figure 86 Meta-analysis of data on skin melanomas and residential exposure to magnetic fields; risk estimate for subanalysis of highest exposure versus background exposure

Other subanalyses were not possible due to the low number of studies in the subcategories.

Table 52 summarises the results of the meta-analyses.

Table 52 Analysis of data on the relationship between residential exposure to magnetic fields and risk of skin melanomas

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis	Exposure above background levels	1.10	0.78-1.55	4	87.6%
	Highest exposure	1.28	0.76-2.16	3	58.0%

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

7.10.3 Skin melanomas and occupational exposure to magnetic fields

General population

Two studies were found in subjects from the general population that contain data on exposure above background levels versus background exposure. In the first study, the risk estimate is statistically significantly increased: OR=1.39 (1.32-1.47).[40] In the second study that was not the case: OR=1.11 (0.87-1.41).[168]

Industrial populations

For the studies in subjects from specific industries, the main analysis of exposure above background levels versus background exposure shows no statistically significantly increased risk (figure 87)

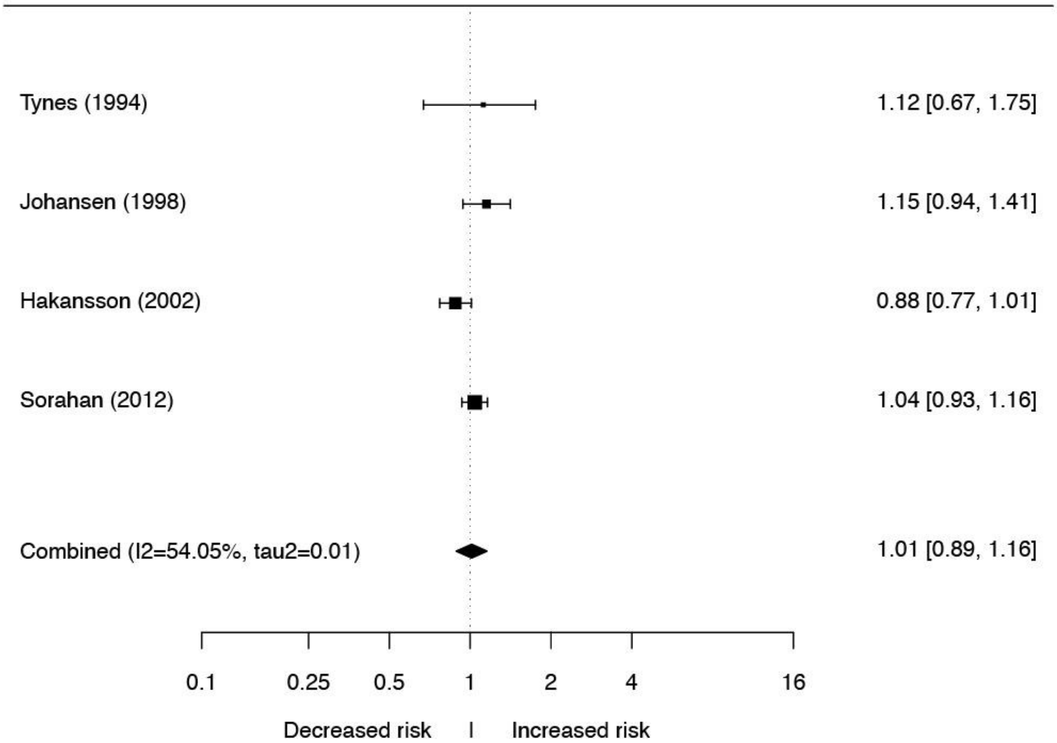


Figure 87 Meta-analysis of data on skin melanomas and occupational exposure to magnetic fields - industrial populations; main analysis of exposure above background levels versus background exposure

The subanalysis according to disease detection method (diagnose versus information from the death certificate) is not possible because all studies use diagnosis.

The subanalysis according to accuracy of the exposure assessment is only possible for studies in which exposure was determined using a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM). These show no statistically significantly increased risk (figure 88).

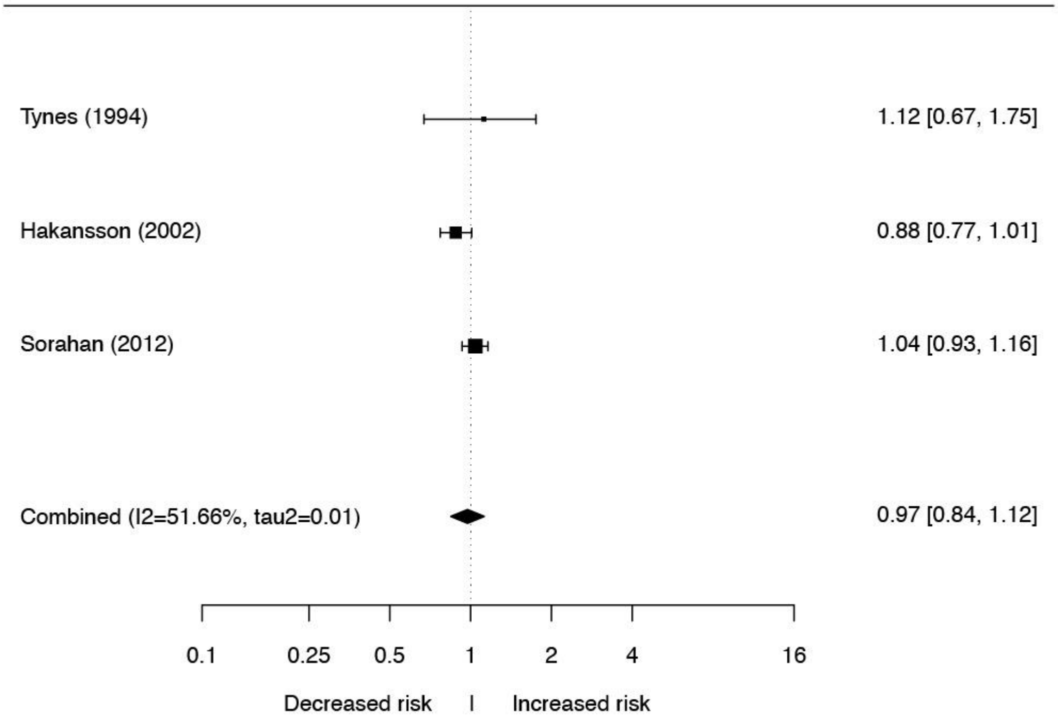


Figure 88 Meta-analysis of data on skin melanomas and occupational exposure to magnetic fields - industrial populations; subanalysis of exposure as classified by a job-exposure matrix or actual measurements or assessment by an occupational hygienist (JEM) alone

Other subanalyses could not be carried out due to a low number of studies in the subcategories.
Table 53 summarises the results of the meta-analyses.

Table 53 Analysis of data on the relationship between occupational exposure to magnetic fields and risk of skin melanomas

Analysis	Exposure	Risk estimate*	95% CI*	Number of studies	Heterogeneity
Main analysis of industrial populations	Exposure above background levels	<u>1.01</u>	<u>0.89-1.16</u>	4	54.0%
Subanalysis 1: exposure assessment	Calculated/measured	0.97	0.84-1.14	3	51.7%
	Occupation	--	--	1	--

* See chapter 5 for explanatory notes on the risk estimate and confidence interval. Statistically significant values are shown in bold. Data included in the advisory report is underlined.

References

1 Owens EO, Patel MM, Kirrane E, Long TC, Brown J, Cote I, et al. *Framework for assessing causality of air pollution-related health effects for reviews of the National Ambient Air Quality Standards*. Regul Toxicol Pharmacol 2017; 88: 332-337.

2 Youngson JHAM, Clayden AD, Myers A, Cartwright RA. *A case control study of adult hematological malignancies in relation to overhead powerlines*. Br J Cancer 1991; 63(6): 977-985.

3 Verkasalo PK, Pukkala E, Kaprio J, Heikkila KV, Koskenvuo M. *Magnetic-fields of high voltage power lines and risk of cancer in Finnish adults - nationwide cohort study*. Br Med J 1996; 313(7064): 1047-1051.

4 Feychting M, Forssén U, Floderus B. *Occupational and residential magnetic field exposure and leukemia and central nervous system tumors*. Epidemiology 1997; 8(4): 384-389.

5 Li CY, Thériault G, Lin RS. *Residential exposure to 60-Hertz magnetic fields and adult cancers in Taiwan*. Epidemiology 1997; 8(1): 25-30.

6 Tynes T, Haldorsen T. *Residential and occupational exposure to 50 Hz magnetic fields and hematological cancers in Norway*. Cancer Causes Control 2003; 14(8): 715-720.

7 Marcilio I, Gouveia N, Pereira Filho ML, Kheifets L. *Adult mortality from leukemia, brain cancer, amyotrophic lateral sclerosis and magnetic fields from power lines: a case-control study in Brazil*. Rev Bras Epidemiol 2011; 14(4): 580-588.

8 Elliott P, Shaddick G, Douglass M, de Hoogh K, Briggs DJ, Toledano MB. *Adult cancers near high-voltage overhead power lines*. Epidemiology 2013; 24(2): 184-190.

9 Khan MW, Juutilainen J, Auvinen A, Naarala J, Pukkala E, Roivainen P. *A cohort study on adult hematological malignancies and brain tumors in relation to magnetic fields from indoor transformer stations*. Int J Hyg Environ Health 2021; 233: 113712.

10 McDowall ME. *Mortality of persons resident in the vicinity of electricity transmission facilities*. Br J Cancer 1986; 53: 271-279.

11 Severson RK, Stevens RG, Kaune WT, Thomas DB, Heuser L, Davis S, et al. *Acute nonlymphocytic leukemia and residential exposure to power frequency magnetic fields*. Am-J-Epidemiol 1988; 128(1): 10-20.

12 Coleman MP, Bell CM, Taylor HL, Primic-Zakelj M. *Leukaemia and residence near electricity transmission equipment: a case-control study*. Br J Cancer 1989; 60(5): 793-798.

13 Schreiber GH, Swaen GMH, Meijers JMM, Slangen JJM, Sturmans F. *Cancer mortality and residence near electricity transmission equipment - A retrospective cohort study*. Int J Epidemiol 1993; 22(1): 9-15.

14 Feychting M, Ahlbom A. *Magnetic fields, leukemia, and central nervous system tumors in Swedish adults residing near high-voltage power lines*. Epidemiology 1994; 5(5): 501-509.

15 Lovely RH, Buschbom RL, Slavich AL, Anderson LE, Hansen NH, Wilson BW. *Adult leukemia risk and personal appliance use - A preliminary-study*. Am-J-Epidemiol 1994; 140(6): 510-517.

16 Verkasalo PK. *Magnetic fields and leukemia--risk for adults living close to power lines*. Scand J Work Environ Health 1996; 22 Suppl 2: 1-56.

17 Gurvich EB, Novokhatskaia EA, Rubtsova NB. *[Mortality of people residing near electric power supply line with voltage of 500 kV]*. Med Tr Prom Ekol 1996; (9): 23-27.

18 Fazzo L, Grignoli M, Iavarone I, Polichetti A, De Santis M, Fano V, et al. *[Preliminary study of cause-specific mortality of a population exposed to 50 Hz magnetic fields, in a district of Rome municipality]*. Epidemiol Prev 2005; 29(5-6): 243-252.

19 Lowenthal RM, Tuck DM, Bray IC. *Residential exposure to electric power transmission lines and risk of lymphoproliferative and myeloproliferative disorders: a case-control study*. Intern Med J 2007; 37(9): 614-619.

20 Fazzo L, Tancioni V, Polichetti A, Iavarone I, Vanacore N, Papini P, et al. *Morbidity experience in populations residentially exposed to 50 hz magnetic fields: methodology and preliminary findings of a cohort study*. Int J Occup Environ Health 2009; 15(2): 133-142.

21 Kaufman DW, Anderson TE, Issaragrisil S. *Risk factors for leukemia in Thailand*. Ann Hematol 2009; 88(11): 1079-1088.

22 Preston-Martin S, Peters JM, Yu MC, Garabrant DH, Bowman JD. *Myelogenous leukemia and electric blanket use*. Bioelectromagnetics 1988; 9(3): 207-213.

23 Oppenheimer M, Preston-Martin S. *Adult onset acute myelogenous leukemia and electromagnetic fields in Los Angeles County: bed-heating and occupational exposures*. Bioelectromagnetics 2002; 23(6): 411-415.

24 Pearce N, Reif J, Fraser J. *Case-control studies of cancer in New Zealand electrical workers*. Int J Epidemiol 1989; 18(1): 55-59.

25 Juutilainen J, Laara E, Pukkala E. *Incidence of leukaemia and brain tumours in Finnish workers exposed to ELF magnetic fields*. Int Arch Occup Environ Health 1990; 62(4): 289-293.

26 Loomis DP, Savitz DA. *Mortality from brain cancer and leukaemia among electrical workers*. Br J Ind Med 1990; 47(9): 633-638.

27 Pachocki KA, Gajewski AK. *Exposure to electromagnetic fields and risk of leukemia*. Rocz Panstw Zakl Hig 1991; 42(3): 217-221.

28 Törnqvist S, Knave B, Ahlbom A, Persson T. *Incidence of leukemia and brain tumors in some electrical occupations*. Br J Ind Med 1991; 48(9): 597-603.

29 Tynes T, Andersen A, Langmark F. *Incidence of cancer in Norwegian workers potentially exposed to electromagnetic fields*. Am J Epidemiol 1992; 136(1): 81-88.

30 Richardson S, Zittoun R, Bastuji-Garin S, Lasserre V, Guihenneuc C, Cadiou M, et al. *Occupational risk factors for acute leukaemia: a case-control study*. Int J Epidemiol 1992; 21(6): 1063-1073.

31 Sahl JD, Kelsh MA, Greenland S. *Cohort and nested case-control studies of hematopoietic cancers and brain cancer among electric utility workers*. Epidemiology 1993; 4(2): 104-114.

32 Guénel P, Raskmark P, Andersen JB, Lynge E. *Incidence of cancer in persons with occupational exposure to electromagnetic fields in Denmark*. Br J Ind Med 1993; 50(8): 758-764.

33 Matanoski GM, Elliott EA, Breysse PN, Lynberg MC. *Leukemia in telephone linemen*. Am-J-Epidemiol 1993; 137(6): 609-619.

34 Floderus B, Persson T, Stenlund C, Wennberg A, Ost A, Knave B. *Occupational exposure to electromagnetic fields in relation to leukemia and brain tumors: a case-control study in Sweden*. Cancer Causes Control 1993; 4(5): 465-476.

35 Tynes T, Jynge H, Vistnes AI. *Leukemia and brain tumors in Norwegian railway workers, a nested case-control study*. Am J Epidemiol 1994; 139(7): 645-653.

36 Tynes T, Reitan JB, Andersen A. *Incidence of cancer among workers in Norwegian hydroelectric power companies*. Scand J Work Environ Health 1994; 20(5): 339-344.

37 Thériault G, Goldberg M, Miller AB, Armstrong B, Guenel P, Deadman J, et al. *Cancer risks associated with occupational exposure to magnetic-fields among electric utility workers in Ontario and Quebec, Canada, and France - 1970-1989*. Am J Epidemiol 1994; 139(6): 550-572.

38 London SJ, Bowman JD, Sobel E, Thomas DC, Garabrant DH, Pearce N, et al. *Exposure to magnetic fields among electrical workers in relation to leukemia risk in Los Angeles County*. Am J Ind Med 1994; 26(1): 47-60.

39 Alfredsson L, Hammar N, Karlehagen S. *Cancer incidence among male railway engine-drivers and conductors in Sweden, 1976-90*. Cancer Causes Control 1996; 7(3): 377-381.

40 Floderus B, Stenlund C, Persson T. *Occupational magnetic field exposure and site-specific cancer incidence: a Swedish cohort study*. Cancer Causes Control 1999; 10(5): 323-332.

41 Savitz DA, Cai J, van Wijngaarden E, Loomis D, Mihlan G, Dufort V, et al. *Case-cohort analysis of brain cancer and leukemia in electric utility workers using a refined magnetic field job-exposure matrix*. Am J Ind Med 2000; 38(4): 417-425.

42 Harrington JM, Nichols L, Sorahan T, van Tongeren M. *Leukaemia mortality in relation to magnetic field exposure: findings from a study of United Kingdom electricity generation and transmission workers, 1973-97*. Occup Environ Med 2001; 58(5): 307-314.

43 Bethwaite P, Cook A, Kennedy J, Pearce N. *Acute leukemia in electrical workers: A New Zealand case-control study*. Cancer-Causes-Control 2001; 12: 683-689.

44 Blair A, Zheng T, Linos A, Stewart PA, Zhang YW, Cantor KP. *Occupation and leukemia: a population-based case-control study in Iowa and Minnesota*. Am J Ind Med 2001; 40(1): 3-14.

45 Håkansson N, Floderus B, Gustavsson P, Johansen C, Olsen JH. *Cancer incidence and magnetic field exposure in industries using resistance welding in Sweden*. Occup Environ Med 2002; 59(7): 481-486.

46 Willett EV, McKinney PA, Fear NT, Cartwright RA, Roman E. *Occupational exposure to electromagnetic fields and acute leukaemia: analysis of a case-control study*. Occup Environ Med 2003; 60(8): 577-583.

47 Adegoke OJ, Blair A, Shu XO, Sanderson M, Jin F, Dosemeci M, et al. *Occupational history and exposure and the risk of adult leukemia in Shanghai*. Ann Epidemiol 2003; 13(7): 485-494.

48 Johansen C, Raaschou-Nielsen O, Olsen JH, Schüz J. *Risk for leukaemia and brain and breast cancer among Danish utility workers: a second follow-up*. Occup Environ Med 2007; 64(11): 782-784.

49 Röösli M, Lortscher M, Egger M, Pfluger D, Schreier N, Lortscher E, et al. *Leukaemia, brain tumours and exposure to extremely low frequency magnetic fields: cohort study of Swiss railway employees*. Occup Environ Med 2007; 64(8): 553-559.

50 Koeman T, van den Brandt PA, Slottje P, Schouten LJ, Goldbohm RA, Kromhout H, et al. *Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort*. Cancer Causes Control 2014; 25(2): 203-214.

51 Huss A, Spoerri A, Egger M, Kromhout H, Vermeulen R, Swiss National Cohort. *Occupational extremely low frequency magnetic fields (ELF-MF) exposure and hematolymphopoietic cancers - Swiss National Cohort analysis and updated meta-analysis*. Environ Res 2018; 164: 467-474.

52 Milham S. *Mortality in workers exposed to electromagnetic fields*. Environ Health Perspect 1985; 62(Oct): 297-300.

53 Törnqvist S, Norell S, Ahlbom A, Knave B. *Cancer in the electric power industry*. Br J Ind Med 1986; 43(3): 212-213.

54 Linet MS, Malker HS, McLaughlin JK, Weiner JA, Stone BJ, Blot WJ, et al. *Leukemias and occupation in Sweden: a registry-based analysis*. Am J Ind Med 1988; 14(3): 319-330.

55 Garland FC, Shaw E, Gorham ED, Garland CF, White MR, Sinsheimer PJ. *Incidence of leukemia in occupations with potential electromagnetic field exposure in united states navy personnel*. Am J Epidemiol 1990; 132(2): 293-303.

56 Bastuji-Garin S, Richardson S, Zittoun R. *Acute leukaemia in workers exposed to electromagnetic fields*. Eur-J-Cancer 1990; 26: 1119-1120.

57 Balli-Antunes M, Pfluger DH, Minder CE. *The mortality from malignancies of haematopoietic and lymphatic systems (MHLS) among railway engine drivers. Is exposure to low frequency electromagnetic fields associated with an increase of mortality from MHLS?* Environmetrics 1990; 1(1): 121-130.

58 Robinson C, Lalich NR, Burnett CA, Sestito JP, Frazier TM, Fine LJ. *Electromagnetic field exposure and leukemia mortality in the United States*. J-Occup-Med 1991; 33: 160-162.

59 Floderus B, Törnqvist S, Stenlund C. *Incidence of selected cancers in Swedish railway workers, 1961-79*. Cancer Causes Control 1994; 5(2): 189-194.

60 Dosemeci M, Blair A. *Occupational cancer mortality among women employed in the telephone industry*. J Occup Med 1994; 36(11): 1204-1209.

61 Savitz DA, Loomis DP. *Magnetic field exposure in relation to leukemia and brain cancer mortality among electric utility workers*. Am J Epidemiol 1995; 141(2): 123-134.

62 Fear NT, Roman E, Carpenter LM, Newton R, Bull D. *Cancer in electrical workers - An analysis of cancer registrations in England, 1981-87*. Br J Cancer 1996; 73(7): 935-939.

63 Miller AB, To T, Agnew DA, Wall C, Green LM. *Leukemia following occupational exposure to 60-hz electric and magnetic-fields among ontario electric utility workers*. Am-J-Epidemiol 1996; 144(2): 150-160.

64 Baris D, Armstrong BG, Deadman J, Thériault G. *A mortality study of electrical utility workers in Québec*. Occup Environ Med 1996; 53(1): 25-31.

65 Guénel P, Nicolau J, Imbernon E, Chevalier A, Goldberg M. *Exposure to 50-Hz electric field and incidence of leukemia, brain tumors, and other cancers among French electric utility workers*. Am J Epidemiol 1996; 144(12): 1107-1121.

66 Kelsh MA, Sahl JD. *Mortality among a cohort of electric utility workers, 1960-1991*. Am J Ind Med 1997; 31(5): 534-544.

67 Johansen C, Olsen JH. *Risk of cancer among Danish utility workers--a nationwide cohort study*. Am J Epidemiol 1998; 147(6): 548-555.

68 Pulsoni A, Stazi A, Cotichini R, Allione B, Cerri R, Di Bona E, et al. *Acute promyelocytic leukaemia: epidemiology and risk factors. A report of the GIMEMA Italian archive of adult acute leukaemia. GIMEMA Cooperative Group*. Eur J Haematol 1998; 61(5): 327-332.

69 Pira E, Turbiglio M, Maroni M, Carrer P, La Vecchia C, Negri E, et al. *Mortality among workers in the geothermal power plants at Larderello, Italy*. Am J Ind Med 1999; 35(5): 536-539.

70 Johansen C, Olsen JH. *[Risk of cancer among Danish electricity workers. A cohort study]*. Ugeskr Laeger 1999; 161(14): 2079-2085.

71 Kheifets LI, Gilbert ES, Sussman SS, Guenel P, Sahl JD, Savitz DA, et al. *Comparative analyses of the studies of magnetic fields and cancer in electric utility workers: studies from France, Canada, and the United States*. Occup Environ Med 1999; 56(8): 567-574.

72 Robinson CF, Petersen M, Palu S. *Mortality patterns among electrical workers employed in the U.S. construction industry, 1982-1987*. Am J Ind Med 1999; 36(6): 630-637.

73 Ronneberg A, Haldorsen T, Romundstad P, Andersen A. *Occupational exposure and cancer incidence among workers from an aluminum smelter in western Norway*. Scand J Work Environ Health 1999; 2(3): 207-214.

74 Villeneuve PJ, Agnew DA, Miller AB, Corey PN, Purdham JT. *Leukemia in electric utility workers: the evaluation of alternative indices of exposure to 60 Hz electric and magnetic fields*. Am J Ind Med 2000; 37(6): 607-617.

75 Minder CE, Pfluger DH. *Leukemia, brain tumors, and exposure to extremely low frequency electromagnetic fields in Swiss railway workers*. Am J Epidemiol 2001; 153: 825-835.

76 van Wijngaarden E, Savitz DA, Kleckner RC, Kavet R, Loomis D. *Mortality patterns by occupation in a cohort of electric utility workers*. Am J Ind Med 2001; 40(6): 667-673.

77 Bjork J, Albin M, Welinder H, Tinnerberg H, Mauritzson N, Kauppinen T, et al. *Are occupational, hobby, or lifestyle exposures associated with Philadelphia chromosome positive chronic myeloid leukaemia?* Occup Environ Med 2001; 58(11): 722-727.

78 Guénel P, Imbernon E, Chevalier A, Crinquand-Calastreng A, Goldberg M. *Leukemia in relation to occupational exposures to benzene and other agents: a case-control study nested in a cohort of gas and electric utility workers*. Am J Ind Med 2002; 42(2): 87-97.

79 Groves FD, Page WF, Gridley G, Lisimaque L, Stewart PA, Tarone RE, et al. *Cancer in Korean war navy technicians: mortality survey after 40 years*. Am J Epidemiol 2002; 155(9): 810-818.

80 Nichols L, Sorahan T. *Mortality of UK electricity generation and transmission workers, 1973-2002*. Occup Med (Lond) 2005; 55(7): 541-548.

81 Sorahan T. *Cancer incidence in UK electricity generation and transmission workers, 1973-2008*. Occup Med (Lond) 2012; 62(7): 496-505.

82 Sorahan T. *Magnetic fields and leukaemia risks in UK electricity supply workers*. Occup Med (Lond) 2014; 64(3): 150-156.

83 Talibov M, Guxens M, Pukkala E, Huss A, Kromhout H, Slottje P, et al. *Occupational exposure to extremely low-frequency magnetic fields and electrical shocks and acute myeloid leukemia in four Nordic countries*. Cancer Causes Control 2015; 26(8): 1079-1085.

84 Flodin U, Fredriksson M, Persson B, Hardell L, Axelson O. *Background radiation, electrical work, and some other exposures associated with acute myeloid leukemia in a case-referent study*. Arch Environ Health 1986; 41(2): 77-84.

85 Feychting M, Forssén U, Rutqvist LE, Ahlbom A. *Magnetic fields and breast cancer in Swedish adults residing near high-voltage power lines*. Epidemiology 1998; 9: 392-397.

86 Coogan PF, Aschengrau A. *Exposure to power frequency magnetic fields and risk of breast cancer in the upper Cape Cod cancer incidence study*. Arch Environ Health 1998; 53: 359-367.

87 Davis S, Mirick DK, Stevens RG. *Residential magnetic fields and the risk of breast cancer*. Am J Epidemiol 2002; 155(5): 446-454.

88 Schoenfeld ER, O'Leary ES, Henderson K, Grimson R, Kabat GC, Ahnn S, et al. *Electromagnetic fields and breast cancer on Long Island: a case-control study*. Am J Epidemiol 2003; 158(1): 47-58.

89 London SJ, Pogoda JM, Hwang KL, Langholz B, Monroe KR, Kolonel LN, et al. *Residential magnetic field exposure and breast cancer risk: a nested case-control study from a multiethnic cohort in Los Angeles County, California*. Am J Epidemiol 2003; 158(10): 969-980.

90 Kliukiene J, Tynes T, Andersen A. *Residential and occupational exposures to 50-Hz magnetic fields and breast cancer in women: a population-based study*. Am J Epidemiol 2004; 159(9): 852-861.

91 Vena JE, Graham S, Hellmann R, Swanson M, Brasure J. *Use of electric blankets and risk of postmenopausal breast cancer*. Am J Epidemiol 1991; 134(2): 180-185.

92 Vena JE, Freudenheim JL, Marshall JR, Laughlin R, Swanson M, Graham S. *Risk of premenopausal breast cancer and use of electric blankets*. Am J Epidemiol 1994; 140(11): 974-979.

93 Gammon MD, Schoenberg JB, Britton JA, Kelsey JL, Stanford JL, Malone KE, et al. *Electric blanket use and breast cancer risk among younger women*. Am J Epidemiol 1998; 148(6): 556-563.

94 Laden F, Neas LM, Tolbert PE, Holmes MD, Hankinson SE, Spiegelman D, et al. *Electric blanket use and breast cancer in the Nurses' Health Study*. Am J Epidemiol 2000; 152(1): 41-49.

95 Zheng T, Holford TR, Mayne ST, Owens PH, Zhang B, Boyle P, et al. *Exposure to electromagnetic fields from use of electric blankets and other in-home appliances and breast cancer risk*. Am J Epidemiol 2000; 151: 1103-1111.

96 McElroy JA, Newcomb PA, Remington PL, Egan KM, Titus-Ernstoff L, Trentham-Dietz A, et al. *Electric blanket or mattress cover use and breast cancer incidence in women 50-79 years of age*. Epidemiology 2001; 12(6): 613-617.

97 Zhu K, Hunter S, Payne-Wilks K, Roland CL, Forbes DS. *Use of electric bedding devices and risk of breast cancer in African-American women*. Am J Epidemiol 2003; 158(8): 798-806.

98 Kabat GC, O'Leary ES, Schoenfeld ER, Greene JM, Grimson R, Henderson K, et al. *Electric blanket use and breast cancer on Long Island*. Epidemiology 2003; 14(5): 514-520.

99 Davis S, Mirick DK. *Residential magnetic fields, medication use, and the risk of breast cancer*. Epidemiology 2007; 18(2): 266-269.

100 Loomis DP, Savitz DP, Ananth CV. *Breast cancer mortality among female electrical workers in the United States*. J Natl Cancer Inst 1994; 86(12): 921-925.

101 Coogan PF, Clapp RW, Newcomb PA, Wenzl TB, Bogdan G, Mittendorf R, et al. *Occupational exposure to 60-hertz magnetic fields and risk of breast cancer in women*. Epidemiology 1996; 7(5): 459-464.

102 Petralia SA, Chow WH, McLaughlin J, Jin F, Gao YT, Dosemeci M. *Occupational risk factors for breast cancer among women in Shanghai*. Am J Ind Med 1998; 34(5): 477-483.

103 Kliukiene J, Tynes T, Martinsen J, I, Blaasaas KG, Andersen A. *Incidence of breast cancer in a Norwegian cohort of women with potential workplace exposure to 50 Hz magnetic fields*. Am J Ind Med 1999; 36(1): 147-154.

104 van Wijngaarden E, Nylander-French LA, Millikan RC, Savitz DA, Loomis D. *Population-based case-control study of occupational exposure to electromagnetic fields and breast cancer*. Ann Epidemiol 2001; 11: 297-303.

105 Labrèche F, Goldberg MS, Valois MF, Nadon L, Richardson L, Lakhani R, et al. *Occupational exposures to extremely low frequency magnetic fields and postmenopausal breast cancer*. Am J Ind Med 2003; 44(6): 643-652.

106 Forssén UM, Rutqvist LE, Ahlbom A, Feychting M. *Occupational magnetic fields and female breast cancer: a case-control study using Swedish population registers and new exposure data*. Am J Epidemiol 2005; 161(3): 250-259.

107 Peplonska B, Stewart P, Szeszenia-Dabrowska N, Rusiecki J, Garcia-Closas M, Lissowska J, et al. *Occupation and breast cancer risk in Polish women: a population-based case-control study*. Am J Ind Med 2007; 50(2): 97-111.

108 McElroy JA, Egan KM, Titus-Ernstoff L, Anderson HA, Trentham-Dietz A, Hampton JM, et al. *Occupational exposure to electromagnetic field and breast cancer risk in a large, population-based, case-control study in the United States*. J Occup Environ Med 2007; 49(3): 266-274.

109 Li W, Ray RM, Thomas DB, Yost M, Davis S, Breslow N, et al. *Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China*. Am J Epidemiol 2013; 178(7): 1038-1045.

110 Forssén UM, Feychting M, Rutqvist LE, Floderus B, Ahlbom A. *Occupational and residential magnetic field exposure and breast cancer in females*. Epidemiology 2000; 11(1): 24-29.

111 Rafnsson V, Tulinius H, Jonasson JG, Hrafnkelsson J. *Risk of breast cancer in female flight attendants: a population-based study (Iceland)*. Cancer Causes Control 2001; 12(2): 95-101.

112 Kliukiene J, Tynes T, Andersen A. *Follow-up of radio and telegraph operators with exposure to electromagnetic fields and risk of breast cancer*. Eur J Cancer Prev 2003; 12(4): 301-307.

113 Beniashvili D, Avinoach I, Baazov D, Zusman I. *Household electromagnetic fields and breast cancer in elderly women*. In Vivo 2005; 19(3): 563-566.

114 Ray RM, Gao DL, Li W, Wernli KJ, Astrakianakis G, Seixas NS, et al. *Occupational exposures and breast cancer among women textile workers in Shanghai*. Epidemiology 2007; 18(3): 383-392.

115 Milham S, Morgan LL. *A new electromagnetic exposure metric: high frequency voltage transients associated with increased cancer incidence in teachers in a California school*. Am J Ind Med 2008; 51(8): 579-586.

116 Demers PA, Thomas DB, Rosenblatt KA, Jimenez LM, McTiernan A, Stalsberg H, et al. *Occupational exposure to electromagnetic fields and breast cancer in men*. Am J Epidemiol 1991; 134(4): 340-347.

117 Rosenbaum PF, Vena JE, Zielezny MA, Michalek AM. *Occupational exposures associated with male breast cancer*. Am J Epidemiol 1994; 139(1): 30-36.

118 Stenlund C, Floderus B. *Occupational exposure to magnetic fields in relation to male breast cancer and testicular cancer: a Swedish case-control study*. Cancer Causes Control 1997; 8(2): 184-191.

119 Cocco P, Figgs L, Dosemeci M, Hayes R, Linet MS, Hsing AW. *Case-control study of occupational exposures and male breast cancer*. Occup Environ Med 1998; 55(9): 599-604.

120 Pollán M, Gustavsson P, Floderus B. *Breast cancer, occupation, and exposure to electromagnetic fields among Swedish men*. Am J Industr Med 2001; 39(3): 276-285.

121 Grundy A, Harris SA, Demers PA, Johnson KC, Agnew DA, Canadian Cancer Registries Epidemiology Research Group, et al. *Occupational exposure to magnetic fields and breast cancer among Canadian men*. Cancer Med 2016; 5(3): 586-596.

122 Koc M, Polat P. *Epidemiology and aetiological factors of male breast cancer: a ten years retrospective study in eastern Turkey*. Eur J Cancer Prev 2001; 10(6): 531-534.

123 Milham S. *A cluster of male breast cancer in office workers*. Am J Ind Med 2004; 46(1): 86-87.

124 Wrensch M, Yost M, Miike R, Lee G, Touchstone J. *Adult glioma in relation to residential power frequency electromagnetic field exposures in the San Francisco Bay area*. Epidemiology 1999; 10(5): 523-527.

125 Klaeboe L, Blaasaas KG, Haldorsen T, Tynes T. *Residential and occupational exposure to 50-Hz magnetic fields and brain tumours in Norway: A population-based study*. Int J Cancer 2005:

126 Mutnick A, Muscat JE. *Primary brain cancer in adults and the use of common household appliances: a case-control study*. Rev Environ Health 1997; 12(1): 59-62.

127 Aldrich TE, Andrews KW, Liboff AR. *Brain cancer risk and electromagnetic fields (EMFs): assessing the geomagnetic component*. Arch Environ Health 2001; 56(4): 314-319.

128 Li CY, Lin RS, Sung FC. *Elevated residential exposure to power frequency magnetic field associated with greater average age at diagnosis for patients with brain tumors*. Bioelectromagnetics 2003; 24(3): 218-221.

129 Kleinerman RA, Linet MS, Hatch EE, Tarone RE, Black PM, Selker RG, et al. *Self-reported electrical appliance use and risk of adult brain tumors*. Am J Epidemiol 2005; 161(2): 136-146.

130 Lin RS, Dischinger PC, Conde J, Farrell KP. *Occupational exposure to electromagnetic fields and the occurrence of brain tumors. An analysis of possible associations*. J Occup Med 1985; 27(6): 413-419.

131 Speers MA, Dobbins JG, Miller VS. *Occupational exposures and brain cancer mortality: a preliminary study of east Texas residents*. Am J Ind Med 1988; 13(6): 629-638.

132 Schlehofer B, Kunze S, Sachsenheimer W, Blettner M, Niehoff D, Wahrendorf J. *Occupational risk factors for brain tumors: results from a population-based case-control study in Germany*. Cancer Causes Control 1990; 1(3): 209-215.

133 Mack W, Preston MS, Peters JM. *Astrocytoma risk related to job exposure to electric and magnetic fields*. Bioelectromagnetics 1991; 12(1): 57-66.

134 Grayson JK. *Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study*. Am J Epidemiol 1996; 143(5): 480-486.

135 Rodvall Y, Ahlbom A, Stenlund C, Preston-Martin S, Lindh T, Spannare B. *Occupational exposure to magnetic fields and brain tumours in central Sweden*. Eur J Epidemiol 1998; 14: 563-569.

136 Villeneuve PJ, Agnew DA, Johnson KC, Mao Y, Canadian Cancer Registries Epidemiology Research Group. *Brain cancer and occupational exposure to magnetic fields among men: results from a Canadian population-based case-control study*. Int J Epidemiol 2002; 31(1): 210-217.

137 Navas-Acién A, Pollán M, Gustavsson P, Floderus B, Plato N, Dosemeci M. *Interactive effect of chemical substances and occupational electromagnetic field exposure on the risk of gliomas and meningiomas in Swedish men*. Cancer Epidemiol Biomarkers Prev 2002; 11(12): 1678-1683.

138 Karipidis KK, Benke G, Sim MR, Kauppinen T, Giles G. *Occupational exposure to ionizing and non-ionizing radiation and risk of glioma*. Occup Med (Lond) 2007; 57(7): 518-524.

139 Coble JB, Dosemeci M, Stewart PA, Blair A, Bowman J, Fine HA, et al. *Occupational exposure to magnetic fields and the risk of brain tumors*. Neuro Oncol 2009; 11(3): 242-249.

140 Baldi I, Coureau G, Jaffre A, Gruber A, Ducamp S, Provost D, et al. *Occupational and residential exposure to electromagnetic fields and risk of brain tumors in adults: a case-control study in Gironde, France*. Int J Cancer 2011; 129(6): 1477-1484.

141 Turner MC, Benke G, Bowman JD, Figuerola J, Fleming S, Hours M, et al. *Occupational exposure to extremely low-frequency magnetic fields and brain tumor risks in the INTEROCC study*. Cancer Epidemiol Biomarkers Prev 2014; 23(9): 1863-1872.

142 Thomas TL, Stolley PD, Stemhagen A, Fontham ET, Bleecker ML, Stewart PA, et al. *Brain tumor mortality risk among men with electrical and electronics jobs: a case-control study*. J Natl Cancer Inst 1987; 79(2): 233-238.

143 Preston-Martin S, Mack W, Henderson BE. *Risk factors for gliomas and meningiomas in males in Los Angeles County*. Cancer Res 1989; 49(21): 6137-6143.

144 Beall C, Delzell E, Cole P, Brill I. *Brain tumors among electronics industry workers*. Epidemiology 1996; 7(2): 125-130.

145 Harrington JM, McBride DI, Sorahan T, Paddle GM, van Tongeren M. *Occupational exposure to magnetic fields in relation to mortality from brain cancer among electricity generation and transmission workers*. Occup Environ Med 1997; 54(1): 7-13.

146 Cocco P, Dosemeci M, Heineman EF. *Occupational risk factors for cancer of the central nervous system: a case-control study on death certificates from 24 U.S. states*. Am J Ind Med 1998; 33(3): 247-255.

147 Cocco P, Heineman EF, Dosemeci M. *Occupational risk factors for cancer of the central nervous system (CNS) among US women*. Am J Ind Med 1999; 36(1): 70-74.

148 Santana VS, Silva M, Loomis D. *Brain neoplasms among naval military men*. Int J Occup Environ Health 1999; 5(2): 88-94.

149 Sorahan T, Nichols L, van Tongeren M, Harrington JM. *Occupational exposure to magnetic fields relative to mortality from brain tumours: updated and revised findings from a study of United Kingdom electricity generation and transmission workers, 1973-97*. Occup Environ Med 2001; 58(10): 626-630.

150 Forssén UM, Lonn S, Ahlbom A, Savitz DA, Feychting M. *Occupational magnetic field exposure and the risk of acoustic neuroma*. Am J Ind Med 2006; 49(2): 112-118.

151 Karipidis KK, Benke G, Sim MR, Yost M, Giles G. *Occupational exposure to low frequency magnetic fields and the risk of low grade and high grade glioma*. Cancer Causes Control 2007; 18(3): 305-313.

152 Marsh GM, Youk AO, Buchanich JM, Xu H, Downing S, Kennedy KJ, et al. *Long-term health experience of jet engine manufacturing workers: VI: incidence of malignant central nervous system neoplasms in relation to estimated workplace exposures*. J Occup Environ Med 2013; 55(6): 654-675.

153 Verreault R, Weiss NS, Hollenbach KA, Strader CH, Daling JR. *Use of electric blankets and risk of testicular cancer*. Am-J-Epidemiol 1990; 131(5): 759-762.

154 Swerdlow AJ, Douglas AJ, Huttly SR, Smith PG. *Cancer of the testis, socioeconomic status, and occupation*. Br J Ind Med 1991; 48(10): 670-674.

155 Baumgardt-Elms C, Schumann M, Ahrens W, Bromen K, Stang A, Jahn I, et al. *Residential exposure to overhead high-voltage lines and the risk of testicular cancer: results of a population-based case-control study in Hamburg (Germany)*. Int Arch Occup Environ Health 2005; 78(1): 20-26.

156 Pearce N, Sheppard RA, Howard JK, Fraser J, Lilley BM. *Time trends and occupational differences in cancer of the testis in New Zealand*. Cancer 1987; 59(9): 1677-1682.

157 Van den Eeden SK, Weiss NS, Strader CH, Daling JR. *Occupation and the occurrence of testicular cancer*. Am J Ind Med 1991; 19(3): 327-337.

158 Knoke JD, Gray GC, Garland FC. *Testicular cancer and Persian Gulf War service*. Epidemiology 1998; 9(6): 648-653.

159 Hardell L, Nasman A, Ohlson CG, Fredrikson M. *Case-control study on risk factors for testicular cancer*. Int J Oncol 1998; 13(6): 1299-1303.

160 Pollán M, Gustavsson P, Cano MI. *Incidence of testicular cancer and occupation among Swedish men gainfully employed in 1970*. Ann Epidemiol 2001; 11(8): 554-562.

161 Ji BT, Silverman DT, Dosemeci M, Dai Q, Gao YT, Blair A. *Occupation and pancreatic cancer risk in Shanghai, China*. Am J Ind Med 1999; 35(1): 76-81.

162 Weiderpass E, Vainio H, Kauppinen T, Vasama-Neuvonen K, Partanen T, Pukkala E. *Occupational exposures and gastrointestinal cancers among Finnish women*. J Occup Environ Med 2003; 45(3): 305-315.

163 Savitz DA, Dufort V, Armstrong B, Theriault G. *Lung cancer in relation to employment in the electrical utility industry and exposure to magnetic fields*. Occup Environ Med 1997; 54(6): 396-402.

164 Yenugadhati N, Birkett NJ, Momoli F, Krewski D. *Occupations and lung cancer: a population-based case-control study in British Columbia*. J Toxicol Environ Health A 2009; 72(10): 658-675.

165 Zhu K, Weiss NS, Stanford JL, Daling JR, Stergachis A, McKnight B, et al. *Prostate cancer in relation to the use of electric blanket or heated water bed*. Epidemiology 1999; 10(1): 83-85.

166 Charles LE, Loomis D, Shy CM, Newman B, Millikan R, Nylander-French LA, et al. *Electromagnetic fields, polychlorinated biphenyls, and prostate cancer mortality in electric utility workers*. Am J Epidemiol 2003; 157(8): 683-691.

167 Khan MW, Juutilainen J, Naarala J, Roivainen P. *Residential extremely low frequency magnetic fields and skin cancer*. Occup Environ Med 2022; 79(1): 49-54.

168 Tynes T, Klaeboe L, Haldorsen T. *Residential and occupational exposure to 50 Hz magnetic fields and malignant melanoma: a population based study*. Occup Environ Med 2003; 60(5): 343-347.

169 Behrens T, Lynge E, Cree I, Sabroe S, Lutz JM, Afonso N, et al. *Occupational exposure to electromagnetic fields and sex-differential risk of uveal melanoma*. Occup Environ Med 2010; 67(11): 751-759.

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