Preventive Medicine Reports 4 (2016) 148–154

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: http://ees.elsevier.com/pmedr

Assessment of occupational risks to extremely low frequency magnetic fields: Validation of an empirical non-expert approach

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ARTICLE INFO

Article history:
14 August 2015
24 May 2016
29 May 2016
Available online 31 May 2016

Keywords:
Community-based
Epidemiologic studies
Expert assessment
Extremely low frequency magnetic fields
Job-exposure matrix
Occupational exposure

ABSTRACT

The expert method of exposure assignment involves relying on chemists or hygienists to estimate occupational exposures using information collected on study subjects. Once the estimation method for a particular contaminant has been made available in the literature, it is not known whether a non-expert, briefly trained by an expert remaining available to answer ad hoc questions, can provide reliable exposure estimates. We explored this issue by comparing estimates of exposure to extremely low frequency magnetic fields (ELF-MF) obtained by an expert to those from a non-expert. Using a published exposure matrix, both the expert and non-expert independently calculated a weekly time-weighted average exposure for 208 maternal jobs by considering three main determinants: the work environment, magnetic field sources, and duration of use or exposure to given sources. Agreement between assessors was tested using the Bland-Altman 95% limits of agreement. The overall mean difference in estimates between the expert and non-expert was 0.004 μT (standard deviation 0.104). The 95% limits of agreement were −0.20 μT and +0.21 μT. The work environments and exposure sources were almost always similarly identified but there were differences in estimating exposure duration. This occurred mainly when information collected from study subjects was not sufficiently detailed. Our results suggest that following a short training period and the availability of a clearly described method for estimating exposures, a non-expert can cost-efficiently and reliably assign exposure, at least to ELF-MF.

1. Introduction

Historical exposure reconstruction in community-based epidemiological studies is often done using exposure assignment methods, such as job-exposure matrices (JEMs), and the case-by-case expert method; their use, strengths and weaknesses have been well described (Correa et al., 1994; Kauppinen, 1994; McGuire et al., 1998; Teschke et al., 2002; El-Zein and Infante-Rivard, 2004). In particular, the expert method involves relying on experts such as occupational hygienists or chemists to estimate exposures based on details of work environments and practices provided by study subjects (Gerin et al., 1985; Gérin and Siemiatycki, 1991). The validity and reliability of this method were reported to vary considerably, (Teschke et al., 2002) depending on the expertise of assessors, their familiarity with specific work environments, and the quality of the coding procedure.

Hiring an expert to develop a JEM or to code exposure is labour-intensive and costly, and thus infeasible for most epidemiological studies. Recent approaches were developed in community-based studies that aimed at standardizing the exposure assessment process, increasing its reproducibility and transparency, and decreasing assessment time and associated costs. Their application resulted in comparable exposure estimates to those obtained by experts. These include a web-based application to automate part of the expert exposure assessment, (Fritschi et al., 2009) algorithms developed to assign decision rules for assessing occupational exposure to diesel exhaust, (Pronk et al., 2012; Friesen et al., 2013) statistical learning methods (classification and regression tress and random forests models) to explain and predict expert-based exposure estimates, (Wheeler et al., 2013) and a rule-based approach, made by experts, to assess exposure to diesel exhaust, pesticides and solvents (Peters et al., 2014). The present study reports an empirical low-cost approach when subject-reported lifetime occupational histories are available and the exposure of interest has already been the subject of published expert coding. The present approach of using a trained non-expert to assign exposure based on an existing

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http://dx.doi.org/10.1016/j.pmedr.2016.05.017

job-exposure matrix involves minimal expert time for training a non-expert and reviewing exposure assignments.

Deadman and Infante-Rivard (2002) published a detailed method for estimating occupational exposures to extremely low frequency magnetic fields (ELF-MF) among young women, later applied to a study of childhood leukemia (Infante-Rivard and Deadman, 2003). The method identified exposure sources and durations from individual occupational histories, which were then combined with published magnetic field values to derive individual time-weighted average (TWA) exposures. The exposure values were condensed into a source-exposure matrix and a JEM applicable to women's jobs. With these tools available, it is not known whether non-experts (i.e., educated scientific personnel briefly trained) when presented with relevant self-reported information on exposure determinants can provide valid exposure estimates comparable to those obtained from experts.

The main objective of the current study was to explore whether a published exposure assessment method (Deadman and Infante-Rivard, 2002) can be used by a non-expert, briefly trained by an expert, to derive estimates of maternal occupational exposure to ELF-MF in a given study. We specifically measured agreement between estimates of maternal occupational exposure to ELF-MF obtained by a non-expert and an expert using the same exposure assessment method. Secondary objectives included detailing the exposure assignment decision process, and assessing the reliability of the assessors' judgments.

2. Materials and methods

2.1. Study population and data collected

Fig. 1 presents an overview of the sources of information that were used in the current study. Detailed information on maternal occupational history prior to and during pregnancy was collected in a case-control study of childhood brain cancer in the Province of Québec (Shaw et al., 2006; Li et al., 2009). The approach used to collect this information is similar to one described previously (Infante-Rivard et al., 2005). For each maternal job, information was obtained on the job title and the industry or company, its products, nature of the worksite, mothers' main and subsidiary tasks, equipment and materials used, number of hours worked per week, and any additional information (i.e., activities of coworkers) that could provide clues about possible exposures. For some occupations, additional job-specific questionnaires were used for more detailed probing. Each occupation was assigned to standard Canadian industrial titles at the three-digit level, and job titles at the seven-digit level (Statistics Canada 1980, 1992). As a convenience sample, we selected 75 case and 75 control mothers for the current study covering jobs with a wide range of expected exposure levels, but over-sampling for jobs where exposures were expected to be high. The 150 women had held a total of 208 jobs, of which 106 were office occupations (mainly secretaries, receptionists, office clerks, data entry or accounting clerks), 16 were bank tellers, 11 were sewing machine operators, 11 were nurses, and 10 were cashiers.

2.2. Assignment of ELF-MF exposures

The main guidance material used by both assessors in their estimation process is the one described in full detail in the Deadman and Infante-Rivard publication (Deadman and Infante-Rivard, 2002). The exposure assessment process involved the use of self-reported work history information which was transcribed into an electronic database by the non-expert. Blind to case-control status, the estimation process was independently done by an expert (JED, PhD, experienced hygienist with a specialty in ELF-MF) and a trained non-expert (MZ, newly graduated PhD student in occupational health who is neither a chemist nor an ELF-MF specialist). The work history was reviewed by each assessor to identify the activities of the industry, and tasks performed by the worker. Subsequently, information on potential determinants of exposure was identified and extracted; specifically the work environment, magnetic field sources of ELF-MF (up to three sources primarily from electrical equipment), and duration of use or exposure to the source. For each job held by a subject, a weekly TWA exposure estimate, expressed in micro-tesla (μT), was calculated by multiplying the ELF-MF intensity of each identified source by the weekly duration of use for that source. Any remaining work duration was multiplied by the background field level, which had been assigned to the specific work environment. The products of source and duration as well as of environment and duration were summed and divided by the total weekly hours spent at work. When magnetic field levels for newly identified potential sources were not in the published matrix, the non-expert consulted the expert. This type of consultation could occur naturally in a setting where an expert is not necessarily part of the study, and thus is not considered a violation of the independence criterion of the assessors' exposure assessment. Both assessors took detailed notes of their decision-making process, documenting reasons and/or justifications to support each of their decisions, and the time it took to estimate the exposure of each job as a proxy indicator of the monetary cost of hiring experts.

2.3. Training of the non-expert

Prior to assessing exposure to ELF-MF for the present study, the non-expert was trained by the expert in two stages to use the published method and matrix. To accomplish that, data from the childhood leukemia study, which had been used to develop the published matrix, (Deadman and Infante-Rivard, 2002) were used. In the first stage (equivalent of a working day), the expert explained the different sources and work environments considered, giving examples of jobs entailing high and low exposures. The second stage (also equivalent of a working day) was a self-learning phase, where the non-expert was provided with a sample of 15 leukemia cases and 15 controls to assess and compare estimates of ELF-MF with those initially obtained by the expert. A total of 34 job descriptions were reviewed by the trained non-expert, blind to case-control status. Of these jobs, 18 were sewing machine operators while the 16 other jobs were varied. Points of disagreement were discussed when the non-expert was not able to

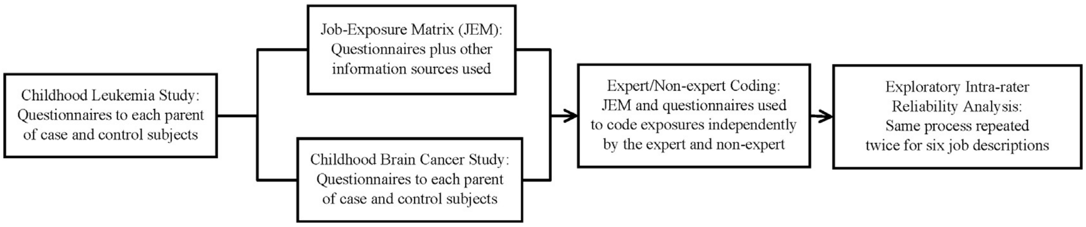

Fig. 1. Overview of information sources. A job-exposure matrix (Deadman and Infante-Rivard, 2002) had been developed using information from a case-control study of childhood leukemia (Infante-Rivard and Deadman, 2003) and published data on the intensities of ELF-MF associated with occupational environments. This JEM was largely based on questionnaires to each parent in the leukemia case-control study. The same questionnaire was used in another case-control study of childhood brain cancer (Shaw et al., 2006; Li et al., 2009). Based on reported information in these childhood brain cancer questionnaires and the job-exposure matrix, the expert and trained non-expert independently assessed exposure to ELF-MF in the current study.

provide an estimate due to difficulties in identifying the correct sources and/or work environments.

2.4. Evaluating reliability/repeatability of the assessors' judgments

Intra-rater reliability was measured by inserting five repeat dummy questionnaires among the questionnaires to evaluate, corresponding to six job descriptions. These questionnaires were hand written by the same person, who reported the same information in a different manner.

2.5. Statistical analysis

The Bland-Altman 95% limits of agreement method was used to determine the extent of agreement of exposure assessment between both assessors (Bland and Altman, 1986; Bland and Altman, 1999; Bland and Altman, 2003). Two plots were drawn to see if the data met two required assumptions; the mean and standard deviation (SD) of the differences between assessors' estimates (expressed in μT) must be constant throughout the range of estimates, and these differences

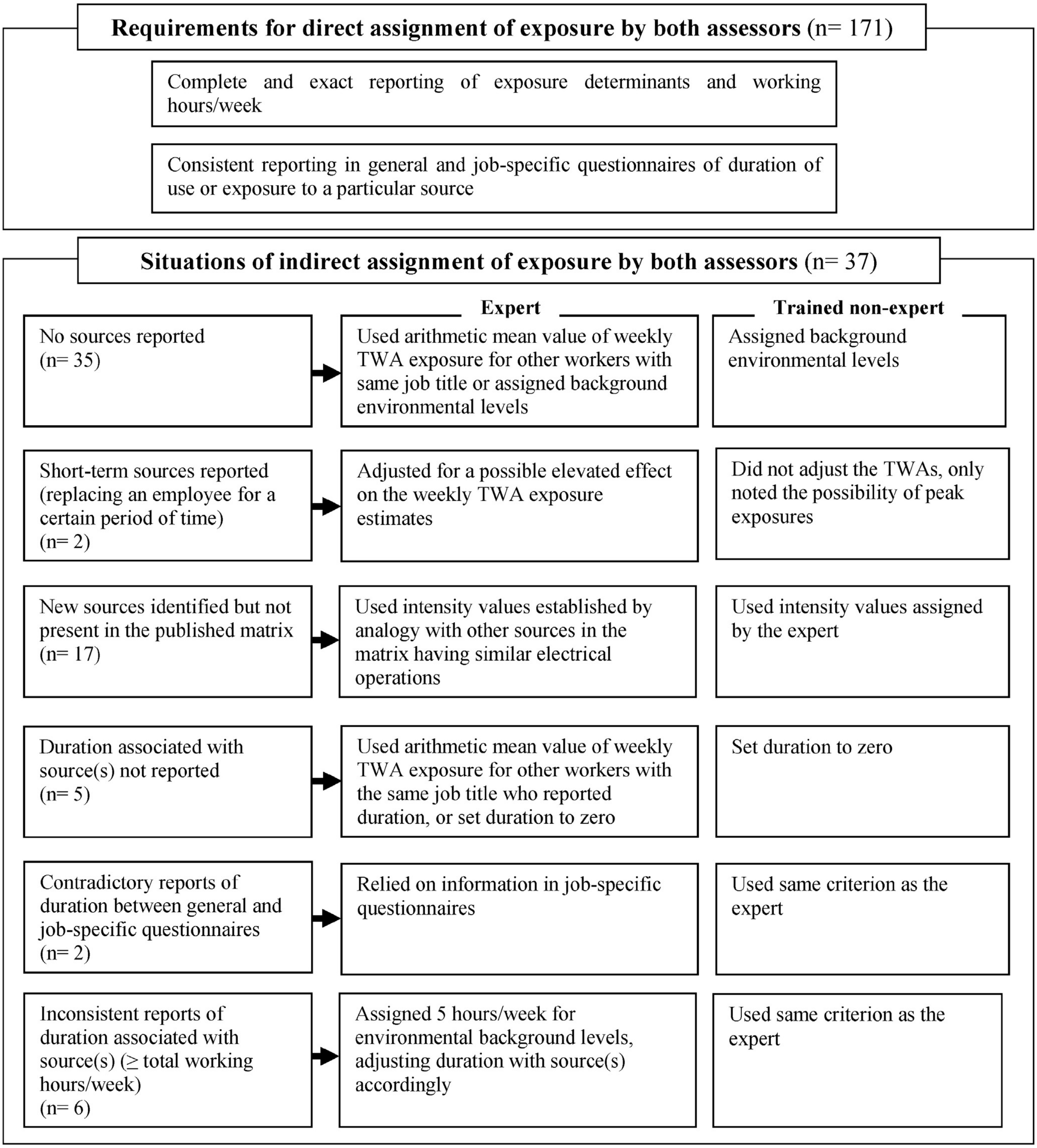

Fig. 2. Description of the exposure decisions and criteria used by the assessors in estimating exposure to ELF-MF ($n = 208$ jobs). The figure describes the assessors' exposure assignment process in estimating exposure to ELF-MF in terms of requirements or situations for direct (availability and consistency of information reported for 171 job descriptions) or indirect (lack of information on exposure source or duration reported for 37 job descriptions) assignment of exposure.

Table 1
New ELF-MF sources identified in the present study.

New sources	Analogy with source in the matrix[a]
Electric calculator	Cash register
Electric grinder	Electric drill
Laser printer	Photocopier
Teletype machine	Video display terminal
Typewriter 'Olivetti'	Video display terminal
Diathermy equipment	Radiofrequency heater/sealer
Electric oven	Oven, residential
Electric wave soldering machine[b]	Soldering iron
Rock crushing machine	No intensity data available
Electric furnace	No intensity data available
Book demagnetiser	No intensity data available
Metal reduction cell	No intensity data available
Electric range (commercial)	No intensity data available
Fax machine	No intensity data available
Electric eraser	No intensity data available
Electric sharpener	No intensity data available
Plate glazing calendar	No intensity data available

[a] Analogy made by the expert, when applicable, with sources having similar electrical operations.

[b] Intensity level set to 1 μT, instead of 0.4 μT for a soldering iron, due to the larger size of the machine.

must come from an approximately normal distribution. Measurement of inter-rater concordance was also performed by means of the concordance correlation coefficient used with continuous data, (Lin, 1989) which is equivalent to the kappa statistic. The coefficient varies between 0 and 1 with values greater than 0.81 representing very high agreement, while other cutpoints are interpreted as follows: between 0.61 and 0.80 (substantial agreement), between 0.41 and 0.60 (moderate agreement), between 0.21 and 0.40 (fair agreement) and values less than 0.21 represent poor agreement. We also used the concordance correlation coefficient to measure intra-rater test/retest reliability. Data analyses were performed using Stata Statistical software, Release 8 (College Station, TX: StataCorp LP.).

3. Results

3.1. Exposure assignment

Fig. 2 summarizes the exposure assignment decisions made by the assessors in estimating exposure to ELF-MF. Direct assignment of exposure by both assessors was achieved for 171 job descriptions (82.2%). Also indicated are six types of situations where exposure estimates could not be assigned directly. The main factor preventing direct assignment was the lack of reported duration of use or of exposure to a particular source. This occurred for 37 job descriptions. Direct assignment of exposure by either assessor was also not possible when a new source, not present in the published matrix, was identified. For these (17 of 28 reported sources), ELF-MF intensity values were established by the expert by analogy with other sources in the matrix involving similar electrical operations (Table 1). The study documentation revealed that job-specific questionnaires were not administered for 59 job descriptions, but that the duration of use or exposure to a given source was reported in the general questionnaire for 27 of these. Documentation also revealed that the interviewer had mistakenly administered a job-specific questionnaire for a 'textile manufacturer' rather than that for a 'sewing machine operator' for an additional 3 job descriptions.

Whereas it took the expert about 12 h (range = 2–15 min per job; mean = 3.4 min) to assess the exposure of all subjects, it took the non-expert close to 9 h (range = 1–9 min per job; mean = 2.1 min). A similar amount of time (i.e., 12 vs. 9 h) for the expert and non-expert, respectively, was spent later to check and revise estimates.

3.2. Evaluating agreement

Table 2 shows only small differences between the assessors' weekly TWA estimates of exposure, except for the exposure of sewing machine operators where the non-expert's estimation was underestimated in comparison to that of the expert. A scatter diagram of the difference between the non-expert and the expert against the average of the assessors' estimates for all occupational groups (Fig. 3a) was used to check the assumptions of the limits of agreement approach; it showed that the mean and SD appeared uniform throughout the range of the estimates. The differences had a mean of 0.004 μT and a SD of 0.104. The histogram of differences for the weekly TWA estimates (Fig. 3b) shows that the differences appeared to approximate a normal distribution. Fig. 3a also displays the line of equality, which is the line on which all points would lie if the assessors' exposure estimates were identical. The 95% limits of agreement were −0.20 μT (mean difference − 1.96 SD) and +0.21 μT (mean difference + 1.96 SD). That is, for 95% of the estimates, an estimate by the non-expert would be between 0.2 μT less and 0.2 μT greater than an estimate by the expert. The 95% confidence interval (CI) was −0.22 to −0.18 for the lower 95% limits of agreement, and 0.18 to 0.23 for the upper limit. Very high agreement was found between the assessors' estimates with the concordance correlation coefficient estimated at 0.85 (95% CI: 0.82–0.89). Excluding jobs where 'new sources' were identified and thus based on 153 observations, the correlation coefficient was 0.82 (95% CI: 0.77–0.87).

As seen in Fig. 3a, 96.6% of the points were within the 95% limits, while 3.4% of the points were outside. Table 3 provides a summary description of the exposure assessment process for these seven points. In general, both assessors correctly identified the work environment and sources, but since they followed different criteria in assigning duration, when not explicitly collected by the interviewers, their exposure estimates differed. This was especially true for sewing machine operators. Excluding these seven points from the analysis, the 95% limits of agreement were −0.09 μT and 0.11 μT and the concordance correlation coefficient increased to 0.95 (95% CI: 0.94–0.96).

3.3. Intra-rater reliability

The expert and the non-expert showed almost perfect repeatability (Table 4) as measured by the concordance correlation coefficient; for the former the estimate was 0.99 (95% CI: 0.98–1.01), while that for the latter was 1.00 (95% CI: 1.00–1.00).

Table 2
Description of the assessors' estimates of exposure to ELF-MF (μT) by job groups.

Job groups	Non-expert estimates		Expert estimates		Difference[a]	
	Min, max	Mean ± SD	Min, max	Mean ± SD	Min, max	Mean ± SD
Office occupations, $n = 106$	0.08, 0.62	0.23 ± 0.08	0.08, 0.62	0.23 ± 0.08	−0.34, 0.15	−0.001 ± 0.07
Bank tellers, $n = 16$	0.17, 0.34	0.25 ± 0.04	0.11, 0.34	0.25 ± 0.06	−0.11, 0.13	0.002 ± 0.05
Sewing machine operators, $n = 11$	0.20, 1.04	0.65 ± 0.35	0.55, 0.91	0.82 ± 0.10	−0.59, 0.14	−0.17 ± 0.31
Nurses, $n = 11$	0.03, 0.20	0.15 ± 0.05	0.03, 0.20	0.15 ± 0.05	–	–
Cashiers, $n = 10$	0.20, 0.50	0.27 ± 0.11	0.20, 0.32	0.25 ± 0.06	−0.12, 0.18	−0.02 ± 0.08
Others, $n = 54$	0.09, 1.53	0.26 ± 0.22	0.08, 1.53	0.24 ± 0.21	−0.14, 0.49	0.16 ± 0.08

Min, minimum; Max, maximum; SD, standard deviation.

[a] Difference between trained non-expert and expert estimates.

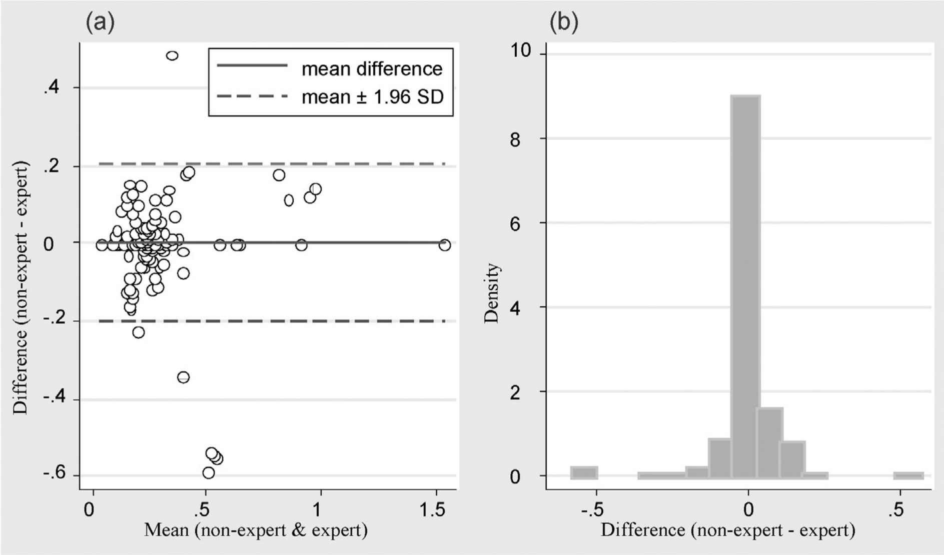

Fig. 3. Weekly time weighted average estimates of exposure to extremely low frequency magnetic fields, a) differences (non-expert minus expert) vs. average values (non-expert & expert) with 95% limits of agreement, (b) histogram of differences (non-expert minus expert). Plots a and b test two required assumptions; the mean and standard deviation of the differences between assessors' estimates (expressed in μT) must be constant throughout the range of estimates, and these differences must come from an approximately normal distribution. Fig. 3a displays the line of equality, which is the line on which all points would lie if the expert and non-expert exposure estimates were identical, and the 95% limits of agreement.

4. Discussion

Overall, the study demonstrated that a non-expert, briefly trained by an expert available for occasional questions and who uses an explicitly detailed method as available in a publication, can estimate an individual's specific exposure in a way comparable to that from an expert. The study also underscores the importance of obtaining detailed information from study subjects, because divergent results between assessors were mainly due to a lack of precision in the collected data. In addition, the estimation of maternal occupational exposures to ELF-MF was found to be highly reproducible, although based on small numbers.

To our knowledge, this is the first study to answer a simple yet intriguing question asked as to who qualifies to be an expert, (Burstyn and Kromhout, 2003) and to confirm Wild's viewpoint who stated that '…an expert is anybody (or any group) who is capable of synthesizing what can be known about the exposure determinants and ancillary information from the workers themselves to obtain semi-quantitative estimates' (Wild, 2003). Both assessors showed high agreement in identifying two of the three main determinants of exposure: well-characterized work environment and sources. The main source of discrepancy in exposure assessment was shown to be generally the same for both assessors; incompleteness of occupational histories. In addition, the lack of a consistent framework for assigning and calculating exposure duration for each individual task, when not reported as such in the questionnaire, resulted in different estimates.

Although the expert method is extensively used and often cited as the most accurate method for retrospective occupational exposure assessment, (McGuire et al., 1998; Teschke et al., 2002) the process and decision logic it entails are generally not well documented or explicitly published. In the present study, using detailed annotation about the coding process, the assessors were able to identify the limitations and discrepancies in their decision-making process. The study identified the sources of inconsistent exposure decisions, and what appears to be the most important information to assign an exposure. Not surprisingly, we found that the success of the estimation process depends heavily on the quality of information on exposure determinants recorded by

Table 3
Description of the assessors' exposure assessment process for the points lying outside of the 95% limits of agreement.

Difference (μT)[a]	Job title	Work environment	Sources and duration (hours/week)	
			Non-expert assessment	Expert assessment
0.59–0.1 = 0.49	Assembler, printed circuit	Factory, assembly	Soldering iron (30)	Electric wave soldering machine (0) Soldering iron (0)
0.08–0.30 = −0.22	Accountant	Office	No sources identified[b]	No sources identified[c]
0.25–0.79 = −0.54[d]	Sewing machine operator	Factory, textile	Sewing machine (not reported) Pressing machine (7.5)[b]	Sewing machine (not reported)[c]
0.25–0.79 = −0.54[d]	Sewing machine operator	Factory, textile	Sewing machine (not reported)[b]	Sewing machine (not reported)[c]
0.25–0.79 = −0.54[d]	Sewing machine operator	Factory, textile	Sewing machine (not reported)[b]	Sewing machine (not reported)[c]
0.20–0.79 = −0.59	Sewing machine operator	Residential	Sewing machine (not reported)[b]	Sewing machine (not reported)[c]
0.22–0.56 = −0.34	Training specialist, computers	Office/road	Computer (10), driving a car (3)	Computer (10), driving a car (18)

[a] Difference between the non-expert and expert estimates.
[b] Background level was used.
[c] Arithmetic mean weekly TWA exposure for workers with the same job title was used.
[d] A slight adjustment was made in order to avoid overlapping of these points in Fig 3a.

Table 4
Description of the repeatability of the assessors' exposure assessment process.

a) Non-expert

Questionnaire	TWA	Job title	Working hours/week	Work environment	Sources and duration (hours/week)
Original 1	0.22	Office clerk	35	Office	Photocopier (20)
Repeat 1	0.22	Office clerk	35	Office	Photocopier (20)
Original 2	0.28	Office clerk	35	Office	Typewriter (25), photocopier (0.42), calculator (5)
Repeat 2	0.25	Office clerk	40	Office	Typewriter (25), photocopier (0.42), calculator (5)
Original 3	0.08[a]	Receptionist	40	Office	No sources identified
Repeat 3	0.08[a]	Office clerk	40	Office	
Original 4	0.91	Sewing machine operator	40	Factory, textile	Sewing machine (35)
Repeat 4	0.91	Sewing machine operator	40	Factory, textile	Sewing machine (35)
Original 5	0.22	Teller	28	Bank	Computer (23)
Repeat 5	0.24	Teller	28	Bank	Computer (24) and photocopier (1.25)
Original 6	0.20	Nurse, general duty	37.5	Hospital, emergency/obstetrics	Computer (1)
Repeat 6	0.20	Nurse, general duty	37.5	Hospital, emergency/obstetrics	Computer (1)

b) Expert

Questionnaire	TWA	Job title	Working hours/week	Work environment	Sources and duration (hours/week)
Original	0.22	Office clerk	35	Office	Photocopier (20)
Repeat	0.22	Office clerk	35	Office	Photocopier (20)
Original	0.28	Office clerk	35	Office	Typewriter (25), photocopier (1), calculator (5)
Repeat	0.23	Office clerk	40	Office	Computer (25), photocopier (1), calculator (5)
Original	0.21[a]	Receptionist	40	Office	No sources identified
Repeat	0.25[a]	Office clerk	40	Office	
Original	0.91	Sewing machine operator	40	Factory, textile	Sewing machine (35)
Repeat	0.91	Sewing machine operator	40	Factory, textile	Sewing machine (35)
Original	0.20	Teller	28	Bank	Computer (20)
Repeat	0.23	Teller	28	Bank	Computer (23), photocopier (1)
Original	0.20	Nurse, general duty	37.5	Hospital, emergency/obstetrics	Computer (1)
Repeat	0.20	Nurse, general duty	37.5	Hospital, emergency/obstetrics	Computer (0)

[a] Background level was assigned.

[a] Arithmetic mean value of weekly TWA exposure for other workers with the same job title was assigned.

Table 5
Specific recommendations for exposure decisions.

Develop a systematic and consistent exposure decision-making process

- Account for unreported duration, using or being exposed to a given source, by assigning it the average duration associated with the same source and reported by other workers with the same job title, rather than using the arithmetic mean value of the weekly TWA exposure for other workers with the same job title who reported duration, as this might include or exclude certain sources.
- Take into account the specific work environment (i.e., differentiating between average duration reported by sewing machine operators working in a factory vs. those working in a residential environment).
- Assign a minimum fixed duration for exposure to background levels.
- Decide on the weight of reduced or elevated effect of exposures associated with subsidiary tasks.

Report modifications made in the matrix

- Table 1 provide a list of new sources identified.
- The magnetic field level of an accounting machine should be revised from 0.5 μT to 0.33 μT (in analogy with an electric calculator and cash register).

Provide a definition of the work environments in the matrix. Selected examples of work environments assigned to job titles or descriptions include:

- ‘Kitchen, commercial’ assigned to cooks and cafeteria workers.
- ‘Restaurant’ assigned to waitresses.
- ‘Store’ assigned to pharmacy workers (retail), cashiers, sales persons, and gas station workers.
- ‘Residential’ assigned to baby sitters, charwoman, and sewing machine operators working at private homes.
- ‘Hospital, chronic’ assigned to nurses, nurse aids, and other workers at visitor centers.
- ‘Office, road’ assigned to jobs that entail working in an office and using a car during work time to visit clients at their home or workplace (i.e., sale representatives).
- ‘Office/factory (mixed)’ assigned to jobs that entail working in an office but close to factory workers (i.e., occupational nurse, industrial engineer).

interviewers. Thus, any attempt to standardize the expert method (Clavel et al., 1993; Stewart et al., 1996) should first begin with refining questionnaires, as well as with improving interviewers' ability to probe, record comprehensive and consistent answers, and recognize the required level of detail needed at the data collection stage. We provide in Table 5 several recommendations relating to uncertainties and difficulties dealt with in this retrospective exposure assessment study of ELF-MF.

One interesting finding of our study was that the exposure assignment was relatively quick. The time needed to assign initial exposure estimates, and to document difficulties or missing information, was largely similar between the expert and the non-expert (24 h in total vs. 18 h, respectively). That it took the expert more time than the trained non-expert to assess exposure was unexpected. One possible explanation could be that the expert, in addition to the questionnaire data and source-exposure matrix, was aware of and consulted other information sources on occupational ELF-MF exposure during the assignment process. Another explanation, shown in Fig. 1, could be the extra effort put by the expert in certain circumstances such as when reassessing or adjusting for TWAs. It is also likely that since the non-expert had already reviewed the questionnaire information, while transcribing the work history information into a database, this might have reduced the time required to later identify exposure determinants. Although not formally noted, the process of transcribing the handwritten questionnaires' information into a database was more time-consuming than the exposure assignment process itself, which would justify the computerization and standardization of questionnaire format.

The high level of intra-rater reliability should be interpreted with caution due to the small size (6 job descriptions). Moreover, there was only a short time interval between the two ratings. However, the possibility that the assessors would recall particular jobs was unlikely as it was found that all pertinent information in this sub-sample was completely and explicitly available, which resulted in automatically-generated weekly TWA exposure estimates. Therefore, reliability is fundamentally dependent on the availability of comprehensive questionnaire information.

Our study was limited in that its conclusions apply to a situation restricted to exposure assessments made by one expert and one trained non-expert, and involving a specific set of occupational exposure conditions among women. In addition, the expert was required for a minimal amount of time to train the non-expert and identify new sources of EMF, and was available for consultation. However, comparing results obtained from an expert to those from a non-expert without the benefit of consultation may not be a realistic situation in the field of occupational exposure assessment. Overall, the relatively low cost of the approach, its feasibility, and quality of results are promising and deserve further consideration.

5. Conclusion

The results of this “proof of concept” study are encouraging; they indicate that estimates of maternal occupational exposure to ELF-MF derived by a non-expert, briefly trained, can be used interchangeably with those derived by an expert attesting to its feasibility and usefulness. Our simple method could be even more widely applied if the expert-based work was more transparent and more explicitly reported in publications. Given the limited number of available experts with extensive knowledge about historical occupational settings, the non-expert method could become increasingly useful.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The study was funded by the Réseau de Recherche en Santé Environnementale, Fonds de recherche du Québec-Santé.

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