Received: 11 August 2023 | Accepted: 11 April 2024
DOI: 10.1002/bem.22507

RESEARCH ARTICLE

BioEM WILEY

Validation of mobile phone use recall in the multinational MOBI-kids study

Luuk van Wel[1] | Anke Huss[1] | Hans Kromhout[1] | Franco Momoli[2] | Daniel Krewski[2] | Chelsea E. Langer[3,4,5] | Gemma Castaño-Vinyals[3,4,5,6] | Michael Kundi[7] | Milena Maule[8] | Lucia Miligi[9] | Siegal Sadetzki[10] | Alex Albert[3,4,5] | Juan Alguacil[5,11] | Nuria Aragones[5,12] | Francesc Badia[3,4,5] | Revital Bruchim[10] | Geertje Goedhart[1] | Patricia de Llobet[3,4,5] | Kosuke Kiyohara[13] | Noriko Kojimahara[13] | Brigitte Lacour[14,15] | Maria Morales-Suarez-Varela[5,16] | Katja Radon[17] | Thomas Remen[15] | Tobias Weinmann[17] | Martine Vrijheid[3,4,5] | Elisabeth Cardis[3,4,5] | Roel Vermeulen[1] | MOBI-Kids consortium

[1]Institute for Risk Assessment Sciences (IRAS), Utrecht University, Utrecht, The Netherlands

[2]School of Epidemiology and Public Health, University of Ottawa, Ottawa, Ontario, Canada

[3]ISGlobal, Barcelona, Spain

[4]Universitat Pompeu Fabra (UPF), Barcelona, Spain

[5]CIBER in Epidemiology and Public Health (CIBERESP), Madrid, Spain

[6]IMIM (Hospital del Mar Medical Research Institute), Barcelona, Spain

[7]Center for Public Health, Institute of Environmental Health, Medical University Vienna, Vienna, Austria

[8]Cancer Epidemiology Unit, Department of Medical Sciences, University of Turin, Turin, Italy

[9]Unit of Occupational and Environmental Epidemiology, Prevention and Research Institute (ISPRO), Florence, Italy

[10]Cancer and Radiation Epidemiology Unit, Gertner Institute, Chaim Sheba Medical Center, Ramat Gan, Israel

[11]Centro de Investigación en Salud y Medio Ambiente (CYSMA), Universidad de Huelva, Huelva, Spain

[12]Epidemiology Section, Public Health Division, Department of Health of Madrid, Madrid, Spain

[13]Tokyo Women's Medical University, Tokyo, Japan

[14]French National Registry of Childhood Solid Tumors, CHU, Nancy, France

[15]Inserm UMR1153, Center of Research in Epidemiology and StatisticS (CRESS), Epidemiology of Childhood and Adolescent Cancers Team (EPICEA), Paris University, Paris, France

[16]Department of Preventive Medicine, Unit of Public Health and Environmental Care, University of Valencia, Burjassot, Valencia, Spain

[17]Institute and Clinic for Occupational, Social and Environmental Medicine, University Hospital, LMU Munich, Munich, Germany

Correspondence
Roel Vermeulen, Institute for Risk Assessment Sciences (IRAS), Yalelaan 2, 3584CM Utrecht, The Netherlands.
Email: R.C.H.Vermeulen@uu.nl

Abstract
Potential differential and non-differential recall error in mobile phone use (MPU) in the multinational MOBI-Kids case–control study were evaluated. We compared self-reported MPU with network operator billing record data

Funding information
Canadian Institutes of Health Research (CIHR); ZonMw, Grant/Award Numbers: 85500022, 85800001; Pfizer Foundation and League Against Cancer; Japanese Ministry of Internal Affairs and Communications, Grant/Award Numbers: 0155-0007, 0155-0087, 0155-0139, 0155-0171; GGET (General Secretariat for Research and Technology); Canadian Wireless Telecommunications Association (CWTA); Spanish Health Research Fund of the Carlos III National Institute for Health, Grant/Award Number: FIS PI10/02981; New Zealand Health Research Council; Conselleria de Sanitat, Generalitat Valenciana, Grant/Award Number: 025/2010; Cure Kids New Zealand; Austrian Ministry of Science, Grant/Award Number: GZ 651.415/001-WF/V/2/2014; ELKE (Special Account for Research Grants of the National and Kapodistrian University of Athens); Andalusian Consejeria de Salud, Grant/Award Number: PI-0317/2010; CERCA Programme, Generalitat de Catalunya; Ministero della Salute, Grant/Award Number: RF-2009-1546284; French National Cancer Institute (INCa); Board of Research in Nuclear Sciences (BRNS); French National Agency for Sanitary Safety of Food, Environment and Labour (ANSES), Grant/Award Number: FSRF2008-3; Federal Office for Radiation Protection (BfS), Grant/Award Number: 3609S30010; FP7/2007-2013, Grant/Award Numbers: 22687 3- the MOBI-Kids project, 603794-GERoNiMO project; Australian National Health and Medical Research Council, Grant/Award Number: 546130; Korean IT R&D program of MSIP/IITP, Grant/Award Numbers: 2017-0-0096, 2019-0-00102; Spanish Ministry of Science and Innovation (MICCIN), Grant/Award Number: Eurosalud EUS2008-03626

up to 3 months, 1 year, and 2 years before the interview date from 702 subjects aged between 10 and 24 years in eight countries. Spearman rank correlations, Kappa coefficients and geometric mean ratios (GMRs) were used. No material differences in MPU recall estimates between cases and controls were observed. The Spearman rank correlation coefficients between self-reported and recorded MPU in the most recent 3 months were 0.57 and 0.59 for call number and for call duration, respectively. The number of calls was on average underestimated by the participants (GMR = 0.69), while the duration of calls was overestimated (GMR = 1.59). Country, years since start of using a mobile phone, age at time of interview, and sex did not appear to influence recall accuracy for either call number or call duration. A trend in recall error was seen with level of self-reported MPU, with underestimation of use at lower levels and overestimation of use at higher levels for both number and duration of calls. Although both systematic and random errors in self-reported MPU among participants were observed, there was no evidence of differential recall error between cases and controls. Nonetheless, these sources of exposure measurement error warrant consideration in interpretation of the MOBI-Kids case–control study results on the association between children's use of mobile phones and potential brain cancer risk.

KEYWORDS
brain tumor, children, mobile phone use, recall bias, validation study

1 | INTRODUCTION

In 2011, radiofrequency (RF) fields were classified as possibly carcinogenic to humans (IARC classification 2B) by the International Agency for Research on Cancer (International Agency for Research on Cancer IARC, 2013). In 2015, the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) published their final opinion on potential health effects of exposure to electromagnetic fields, concluding that studies do not show an increased risk of brain tumors, while noting the gaps in terms of objective exposure monitoring for longer term exposures (SCENIHR, 2015). The classification was based on findings in adults, who were the main focus of studies involving RF fields and health outcomes at the time. Concern regarding potential health effects of RF fields exposure in children and adolescents pertains to the rapid increase in mobile phone use in younger age groups, who have longer lifetime exposure, potentially increased sensitivity due to a developing neurological system, and higher specific absorption rate (SAR) in the most highly exposed parts of the brain compared to adults due to their thinner skull and ears (Wiart et al., 2011). Both national and international research bodies have recommended RF exposure from mobile phones in children and adolescents as a high priority research area (Kheifets, 2005; World Health Organization, 2010). The MOBI-Kids study was designed to address concerns about a possible association between the carcinogenic effect of mobile phone use among children and young adults and brain cancer risk (Sadetzki et al., 2014). The MOBI-Kids study builds upon the methodology of the INTERPHONE study, a multinational collaboration which investigated

Highlights

- Self-reported and operator-registered phone calls were compared among MobiKids participants.
- On average, number of calls was underestimated, and duration overestimated.
- No differential recall error was found between brain tumor cases and controls in MobiKids.

associations between mobile phone use and multiple types of brain tumors in adults (Cardis et al., 2007).

The main results from the MOBI-Kids study provided no evidence of a relationship between wireless phone use and the risk of brain tumors in young people (Castaño-Vinyals et al., 2022). Reliability and accuracy of risk estimation in studies on mobile phones depends on the quality of the exposure ascertainment, which is most often based on self-reported mobile phone use. It is therefore important to understand and characterize the ability of participants to validly and precisely recall their mobile phone use (MPU). Errors in a participants' MPU recall may be non-differential (i.e., the same for both cases and controls), leading to increased uncertainty and under- or overestimation of risk estimates. There can also be differential recall errors, where cases may recall mobile phone use patterns differently from controls for various reasons, possibly because either they have more trouble remembering details or they may over-report past exposures in an effort to explain their disease. The effect of differential error on risk estimates are often difficult to predict (Vrijheid et al., 2009).

The MOBI-Kids study included two MPU validation efforts. The first was the prospective MOBI-Expo validation study, which compared MPU information gathered using software-modified smartphones to self-reported MPU at several time points, and found that young people can recall MPU moderately well, with recall depending on the amount of phone use (Goedhart et al., 2018). As this study only included healthy subjects, it could not provide information on potential differential recall errors between brain tumor cases and controls. The second validation study, a retrospective effort comparing self-reported MPU of consenting subjects to their phone records obtained from mobile network operators, is described here. The aim of this study was to compare the accuracy of MPU reporting of cases having a primary brain tumor with that of controls who underwent an appendectomy, with recall for three time periods: up to 3 months, 1 year, and 2 years preceding the MPU interview, providing insight into patterns of non-differential or differential recall error. The effects of various demographic variables and of the amount of phone usage on MPU recall are also investigated.

2 | METHODS

The multinational MOBI-Kids study, in which this retrospective validation study is nested, recruited participants from May 2010 to March 2016 within 14 participating countries. All males and females from 10 to 24 years of age within the study regions with a confirmed diagnosis of an eligible first primary brain tumor during the study period were included in the target population (Sadetzki et al., 2014). Both benign and malignant tumors originating in those parts of the brain likely to experience the highest RF-EMF exposure from mobile phones were included, with midline tumors excluded. Cases not speaking the study language within their country/region or having a known genetic syndrome related to brain tumors were excluded (Sadetzki et al., 2014). Cases were identified from appropriate hospital departments. For each case, two hospital-based controls (receiving an appendectomy for suspected appendicitis) were selected, matched on age, sex, date of surgery/interview, and geographic area of residence. Included subjects were interviewed to ascertain their lifetime self-reported MPU and were asked to provide informed consent to obtain MPU information from their mobile phone network operator. Case interviews took place within 12 months of their date of diagnosis; control interviews were scheduled within 12 months of the matched case's interview. The study design was approved by the Institutional Review Boards in each country and all participants provided their informed consent. Further details of the MOBI-Kids study recruitment procedures can be found elsewhere (Sadetzki et al., 2014).

2.1 | Validation study population

Participants from the main MOBI-kids study were included in the validation study population based on their billing record data availability. In detail, a total of 844 subjects (30% of total subjects in MOBI-Kids) consented to obtain their billing record data for validation of self-reported mobile phone utilization. Billing record data was available for 806 subjects, of which 781 also had self-reported MPU data. As an overlap between available operator data and interview data of at least one of 3 months preceding the interview was required, subjects who did not have operator data available in any of the 3 months preceding the interview data were excluded. This resulted in a total of 702 subjects remaining for inclusion in this validation study (24.8% of all MOBI-Kids subjects) (Supporting Information: Figure SF1). In addition to the main analysis with subjects who had data in the 3 months preceding the interview, subsets of subjects with operator data available for the entire year preceding the interview ($N = 357$) and 2 years of operator data available preceding the interview ($N = 104$) were investigated.

2.2 | Self-reported mobile phone use

Subjects were administered a detailed questionnaire by trained interviewers. This included questions regarding the type of mobile phone, the network operator, and their MPU including both voice and data. Subjects were asked about the number and duration of calls for multiple time periods: at the beginning of using a mobile phone, current use (i.e., last 3 months preceding the interview), and changes in between. Subjects (or their legal guardian, as appropriate) were asked whether they agreed to take part in the operator data validation study. Those who agreed signed an informed consent form authorizing the operators to provide their phone use data for the purpose of the study and listed the time periods in which they used different phone numbers and network operators. In addition, interviewers reported how they perceived the responsiveness of subjects during the interview, with a score ranging from "not at all (uninterested, reticent)," "fairly co-operative and responsive," to "very co-operative, responsive and interested."

2.3 | Recorded mobile phone use (operator data)

Study centers contacted mobile phone operators in participating countries, informed them of the study and asked for their collaboration. The data that could be obtained from records of consenting study participants and the length of time covered by records varied by operator and country for legal and logistic reasons. Phone calls in operator records were recorded in both number and duration of calls (in minutes) per month. This information was either separated into incoming calls and outgoing calls or presented as a sum of both incoming and outgoing calls, depending on the network operator involved.

2.4 | Statistical analysis

Two MPU indicators were included in the analyses: the number and the duration (in minutes) of calls per month. The comparison of self-reported and recorded MPU was conducted separately for the number and duration (in minutes) of calls in the 3 months preceding the date of interview. In addition, a subset of subjects who had data available for 1 year, and a subset for 2 years preceding the date of interview were assessed. Incoming and outgoing calls were summed to represent all calls per month of available data.

For 67 subjects (9.6%), at least one month of operator data had partial missing information on either incoming or outgoing calls (e.g., only incoming number of calls was recorded, with missing information on the outgoing number of calls that month). For these months, missing information was imputed (100 times), drawing values from the expected value with corresponding variance, based on a mixed model that modelled the number of calls or duration of calls per month as the dependent variable and modelled type of call (i.e., incoming or outgoing), age and gender (both as interaction term with type of call) as independent variables. The model included random nested intercepts for individuals and country and used a heterogeneous compound symmetry structure for covariance to consider the similarity in measures within the same person over time. Months where information on incoming and outgoing calls was entirely missing for number of and/or duration of calls, were excluded.

For some subjects, information on number and duration of calls for one ($N = 122$; 17.5%) or two ($N = 30$; 4.3%) months of operator data in the 3 months preceding the interview was missing. In these cases, the average of the available month(s) in the 3-month time window was taken as the MPU in the missing month(s). The distributions of the number and duration of calls were skewed and therefore Spearman rank-order correlation coefficients on the natural scale and a kappa-statistic on categorized variables (i.e., quintiles of MPU in control group) were used to assess the agreement between the self-reported and the operator-recorded MPU.

As both the Spearman and kappa-statistic do not provide information on the amount of over- or under-reporting the geometric mean ratio (GMR) of self-reported and recorded MPU values was used for this purpose. The GMR was calculated by taking the exponent of the mean of the logarithms of all self-reported MPU to recorded MPU ratios. A corresponding standard error of the mean was calculated by non-parametric bootstrapping, which in turn was used to calculate a 95% confidence interval for the GMR. The ratio represents the level of underestimation (GMR < 1) or overestimation (GMR > 1) of MPU, while the variance provides information on the random error in recall. Bland-Altman plots showing the ratio of self-reported to recorded MPU (log-transformed) against mean self-reported and recorded MPU (log-transformed) were used to further illustrate the relationship of recalled to recorded MPU, with the limits of agreement providing a graphical representation of the random error.

Two sensitivity analyses were performed by (1) excluding all participants who scored 1 or 2 (not at all interested; fairly co-operative and responsive) on the interview responsiveness score, and (2) excluding all participants with any missing data (either on questionnaire or operator data). All analyses were performed using SAS software version 13.2 (SAS Institute Inc) and R version 3.4.1 (R Foundation for Statistical Computing).

3 | RESULTS

A total of 702 subjects from eight different countries (Canada, France, Germany, Greece, Israel, Italy, Korea, and Spain) had data on both self-reported and recorded MPU in the 3 months preceding the interview date (Table 1). There were 250 (35.6%) cases and 452 (64.4%)

TABLE 1 Self-reported and recorded number and duration of calls, shown by case–control status per country.

Country	*N*	Median (min–max) Self-reported	Recorded
Number of calls (number in 3 months)			
Cases	*250*	*196 (0–4566)*	*260 (0–7128)*
Canada	3	183 (65–502)	482 (57–924)
France	59	130 (13–2055)	258 (18–1617)
Germany	21	91 (0–913)	137 (22–639)
Greece	1	137 (137–137)	276 (276–276)
Israel	28	502 (28–4566)	913 (73–7128)
Italy	99	228 (3–2739)	221 (0–2411)
Korea	4	685 (320–1598)	654 (99—1308)
Spain	35	137 (9–2055)	213 (11–943)
Controls	*452*	*224 (0–6392)*	*308 (0–10,496)*
Canada	2	176 (33–320)	82 (24–141)
France	97	224 (12–6392)	356 (23–6570)
Germany	19	91 (26–2496)	204 (6—809)
Greece	1	75 (75–75)	106 (106–106)
Israel	46	639 (26–3652)	858 (0–10,496)
Italy	211	228 (9–2739)	255 (0–2772)
Korea	8	616 (120–2739)	370 (81–878)
Spain	68	91 (0–3652)	334 (6–1608)
Duration of calls (minutes in 3 months)			
Cases	*250*	*861 (0–37,474)*	*388 (0–12,269)*
Canada	3	360 (196–4109)	1131 (73–5559)
France	59	489 (13–9723)	350 (17–5774)
Germany	21	457 (0–5479)	175 (19–2731)
Greece	1	411 (411–411)	273 (273–273)
Israel	28	1517 (99–16,436)	1396 (3–12,269)
Italy	99	913 (21–16,436)	355 (0–8634)
Korea	4	1027 (548–2283)	682 (79–1002)
Spain	35	326 (13–37,474)	322 (15–7998)
Controls	*452*	*666 (0–32,240)*	*424 (0–28,645)*
Canada	2	502 (91–913)	307 (26–588)
France	97	679 (20–21,862)	428 (18–8141)
Germany	19	1175 (30–10,958)	217 (0–2068)
Greece	1	75 (75–75)	197 (197–197)
Israel	46	1373 (26–32,240)	1128 (0–13,383)
Italy	211	639 (13–18,784)	349 (0–28,645)
Korea	8	845 (135–4109)	792 (162–2634)
Spain	68	228 (0–24,654)	367 (3–3756)

controls, reflecting the matching of two controls to each case in the MOBI-Kids study population. 45.4% of the subjects were female, and the mean age was 17.5 years old (standard deviation 4.0). These numbers are similar to the main MOBI-Kids study population (Supporting Information: Table ST1).

3.1 | Mobile phone use

The absolute number of calls and duration of calls (in minutes) in the 3 months preceding the interview are shown in Table 1. For both self-reported and recorded data, subjects from Israel had considerably higher MPU compared to subjects from other countries. Minimum and maximum mobile phone use varied considerably for both cases and controls in all countries. The distribution of the number and duration of calls in the most recent 3 months given by case–control status in each of the countries are shown in Supporting Information: Figures SF2 and SF3, and percentage difference is shown in Supporting Information: Table ST2.

3.2 | Correlation and agreement of self-reported and recorded MPU

The Spearman rank correlation coefficients comparing self-reported and recorded MPU in the most recent 3 months were 0.57 for call number and 0.59 for call duration. Correlations remained similar when stratified by case–control status. For cases, the correlation coefficients were 0.59 and 0.63 for number and duration of calls, respectively; for controls they were 0.56 and 0.57, respectively. When increasing the time period to 2 years, correlation for call number was 0.42 in cases and 0.66 in controls. Correlation coefficients for duration of calls was 0.63 for cases and 0.66 for controls (Table 2).

TABLE 2 Spearman rank correlation coefficients for self-reported versus recorded MPU.

Time period	Overall *N*	Overall ρ	Cases *N*	Cases ρ	Controls *N*	Controls ρ
Number of calls						
Up to 3 months	702	0.57	250	0.59	452	0.56
Up to 1 year	357	0.64	131	0.67	226	0.62
Up to 2 years	104	0.58	41	0.42	63	0.66
Duration of calls (minutes)						
Up to 3 months	702	0.59	250	0.63	452	0.57
Up to 1 year	357	0.65	131	0.69	226	0.64
Up to 2 years	104	0.64	41	0.63	63	0.66

TABLE 3 Categorical comparison (quintiles of control group) of self-reported and recorded number and duration of calls in the most recent 3 months. Numbers shown are number of subjects.

Recorded number of calls (number/3 months)	Self-reported number of calls (number/3 months)				
	0–80.3	**80.4–182.9**	**193–355.9**	**356–616.9**	**617+**
Cases					
0–80.3	**24**	9	9	1	1
80.4–182.9	22	**6**	16	6	3
193–355.9	14	17	**11**	5	5
356–616.9	2	8	13	**6**	9
617+	1	4	14	17	**27**
Kappa-statistic	*0.37*				
Absolute agreement	*0.30*				
Controls					
0–95.1	**42**	12	4	5	2
95.2–212.9	36	**24**	14	6	5
213–370.9	17	21	**32**	20	9
371–635.9	12	18	28	**29**	19
636+	9	9	15	15	**49**
Kappa-statistic	*0.41*				
Absolute agreement	*0.39*				

Recorded duration of calls (minutes/3 months)	Self-reported duration of calls (minutes/3 months)				
	0–131.9	**132–353.9**	**354–749.9**	**750–1929.9**	**1930+**
Cases					
0–131.9	**26**	16	8	6	5
132–353.9	16	**11**	11	17	5
354–749.9	2	6	**11**	17	14
750–1929.9	1	2	5	**18**	22
1930+	1	1	4	6	**19**
Kappa-statistic	*0.38*				
Absolute agreement	*0.34*				
Controls					
0–131.9	**49**	17	7	13	5
132–353.9	25	**30**	20	25	10
354–749.9	9	12	**27**	34	22
750–1929.9	3	9	16	**17**	37
1930+	3	4	6	10	**42**
Kappa-statistic	*0.39*				
Absolute agreement	*0.37*				

When MPU was categorized using cut-off values based on quintiles from the combined recorded and reported number of calls of the control group, kappa values at 3 months were similar for cases and controls (Table 3). When increasing the time period for the number of calls, the weighted (equal spacing) kappa statistic for controls was similar to the cases at the 1-year time period (0.46 vs. 0.45) but higher at the 2-year time period (0.50 vs. 0.31). Similar results were seen for the duration of calls: at 1 year 0.48 versus 0.44, and at 2 years 0.46 versus 0.36 (not shown).

3.3 | Recall error

There were no differences in GMRs for the duration of calls between cases and controls (Table 5), suggesting an absence of differential recall error between cases and controls. For call number, there was a significant difference in recall between cases and controls in the middle quintile (40th–60th percentile) of self-reported MPU, but not in the other categories of self-reported MPU (Table 4).

The overall GMRs of self-reported versus recorded MPU in the most recent 3 months were 1.59 for call duration and 0.69 for call number, indicating systematic errors in the form of overreporting of call duration of calls and underreporting of the number of calls. Looking at recall over time for subjects with 2 years of data available, there appears to be a lower level of overreporting of duration of calls for both cases (initial GMR 1.62, 1.44 at 1 year) and controls (initial GMR 1.37, 1.08 at 1 year) between recent and 1 year recall. There is however little difference in recall in call duration over time between the 1 and 2 year time points for either cases or controls (1.44 vs. 1.41 and 1.08 vs. 1.07, respectively) (Table 5). Although this same initial decrease can be seen in controls for recall of number of calls, it is less clear for cases (Table 4).

Further analyses stratifying by country, reported years since start of mobile phone use, sex, and age at time of the interview showed differences in GMRs in all groups, but little statistical evidence of heterogeneity (while some statistically significant differences were noted, the magnitude of such differences was small). Comparison of recall of both duration and number of calls by age within cases revealed some evidence of heterogeneity, with the 15–19 years age group having a GMR of 2.25 for call duration compared to 1.11 and 1.62 in the other age groups (Table 5): differences were less pronounced for call number (0.87 for 15–19 years old vs. 0.59 and 0.67 in the other age groups) (Table 4).

When categorizing subjects by self-reported levels of MPU, a trend was seen with underreporting of MPU in the lower categories and overreporting of MPU in the higher categories. This was seen for both call duration and call number in both cases and controls. A graphical illustration of these results is given in Figure 1 (duration of calls) and Figure 2 (number of calls). In addition to systematic error, the limits of agreement shown in these figures indicate a substantial amount of random error. As underreporting in the lowest category indicates that the actual value lies closer to the overall mean (i.e., the MPU would be higher than reported), and overreporting in the highest category indicates a lower actual MPU than reported, the actual contrast between lowest and highest groups may be smaller than these results suggest.

3.4 | Sensitivity analyses

Two sensitivity analyses were performed. No differences in recall of duration and number of calls were found when only looking at subjects who were very co-operative, responsive and interested during the interview ($N = 527$). The overall GMRs for call duration (1.61 vs. 1.59 in the main analysis) and call number (0.71 vs. 0.69 in the main analysis) were similar. Similarly, we observed no material differences in results when restricting to subjects without missing data ($N = 497$), with GMRs of 1.56 (1.59 in main analysis) and 0.67 (0.69 in main analysis) for call duration and call number, respectively.

4 | DISCUSSION

In this validation study, we evaluated differential and non-differential recall error in MPU between cases with a first primary brain tumor and controls. Self-reported MPU obtained from interviews was compared with network operator records in the 3 months, 1 year, and 2 years preceding the interview date. No significant differences were observed in recall estimates between cases and controls based on Spearman rank correlations, kappa-statistics, and geometric mean ratios, and these metrics suggested only a subtle effect of a differential recall error. Non-differential recall errors, both systematic and random, were observed with a systematic underestimation of the number of calls and an overestimation of the call duration. A trend was observed between varying levels of self-reported mobile phone use, with underestimation at lower levels and overestimation at higher levels for both number and duration of calls.

4.1 | Strengths and weaknesses

This is one of the few validation studies thus far comparing differences in recall of MPU between brain tumor cases and controls amongst children and adolescents, using both detailed self-reported data

TABLE 4 Ratio of self-reported versus recorded mobile phone use in number of calls, shown by case–control status.

Number of calls	Cases			Controls			p For difference[b]
	N	GMR[a]	95% CI	*N*	GMR[a]	95% CI	
Overall (at 3 months)	250	0.72	0.63, 0.83	452	0.69	0.61, 0.76	0.48
Subset: 1 year of data							
Up to 3 months	131	0.80	0.66, 0.98	226	0.69	0.6, 0.79	0.20
Up to 1 year	131	0.69	0.58, 0.81	226	0.65	0.57, 0.74	0.52
Subset: 2 years of data							
Up to 3 months	41	0.74	0.55, 1.01	63	0.68	0.53, 0.87	0.66
Up to 1 year	41	0.65	0.49, 0.86	63	0.59	0.47, 0.76	0.64
Up to 2 years	41	0.68	0.5, 0.92	63	0.59	0.46, 0.76	0.50
Subset: 2 years of data							
Months 1–3	41	0.74	0.55, 1	63	0.68	0.46, 0.76	0.83
Months 4–12	41	0.64	0.47, 0.87	63	0.59	0.46, 0.76	0.73
Months 13–24	41	0.73	0.51, 1.03	63	0.58	0.45, 0.76	0.30
By country							
Canada	3	0.62	0.37, 1.04	2	1.76	1.23, 2.5	0.06
France	59	0.53	0.4, 0.69	97	0.56	0.45, 0.69	0.96
Germany	21	0.58	0.35, 0.95	19	0.88	0.53, 1.47	0.24
Greece	1	0.50	0.50, 0.50	1	0.71	0.71, 0.71	–
Israel	28	0.62	0.46, 0.83	46	0.76	0.53, 1.09	0.39
Italy	99	1.02	0.8, 1.3	211	0.83	0.73, 0.95	0.15
Korea	4	2.48	0.57, 10.72	8	1.48	0.48, 4.55	0.59
Spain	35	0.54	0.38, 0.76	68	0.39	0.27, 0.57	0.23
p For heterogeneity	*0.23*			*0.23*			
By reported years since start of mobile phone use							
1–2.9	35	0.42	0.27, 0.67	72	0.58	0.4, 0.83	0.31
3–4.9	43	0.69	0.5, 0.95	90	0.60	0.49, 0.72	0.52
5–6.9	51	1.04	0.77, 1.41	86	0.72	0.56, 0.93	0.07
7–8.9	50	0.77	0.56, 1.08	68	0.81	0.63, 1.06	0.91
9+	65	0.73	0.57, 0.93	119	0.76	0.63, 0.92	0.87
p For heterogeneity	*0.38*			*0.29*			
By sex							
Male	138	0.71	0.58, 0.87	246	0.65	0.56, 0.75	0.38
Female	112	0.73	0.6, 0.91	206	0.73	0.62, 0.86	0.94
p For heterogeneity	*0.62*			*0.18*			
By age							
10–14 years	53	0.59	0.41, 0.85	114	0.64	0.5, 0.82	0.73
15–19 years	98	0.87	0.67, 1.12	180	0.69	0.58, 0.81	0.12
20–24 years	99	0.67	0.56, 0.8	158	0.72	0.6, 0.85	0.68

TABLE 4 (Continued)

Number of calls	Cases *N*	GMR[a]	95% CI	Controls *N*	GMR[a]	95% CI	*p* For difference[b]
p For heterogeneity	*0.04*			*0.32*			
By self-reported level of mobile phone use							
<20th percentile	42	0.22	0.16, 0.3	81	0.26	0.19, 0.34	0.44
20th–40th percentile	48	0.47	0.38, 0.59	86	0.50	0.39, 0.63	0.76
40th–60th percentile	56	0.93	0.69, 1.25	90	0.64	0.54, 0.75	0.02
60th–0th percentile	51	0.94	0.74, 1.19	99	1.01	0.86, 1.19	0.66
>80th percentile	53	1.59	1.23, 2.04	96	1.51	1.22, 1.85	0.75
p For heterogeneity	*0.004*			*0.02*			

[a]Geometric mean of ratio self-reported versus recorded mobile phone use.

[b]Log ratios were compared using a *t* test with unequal variances.

and objective network operator records. A major strength is the inclusion of a large number of adolescents and children from various countries both within and outside Europe. While not all subjects from the main MOBI-Kids study provided informed consent to obtain their network operator data and not all operators provided data, we managed to include a large proportion of subjects (24.8%) from the MOBI-Kids case–control study in this validation study. The proportion of subjects where longer-term data was available (at 1- and 2-year time periods) was smaller, with no subjects from some of the participating countries. The gender distribution in the validation study was the same as in the main MOBI-Kids study and the mean age differed by just 1 year (17.5 vs. 16.6 years in the main study).

Compared to the previous MOBI-Expo validation study using software-modified phones to record MPU for a month (Goedhart et al., 2018), we obtained information on brain tumor cases (and matched controls) as opposed to healthy volunteers. Given MOBI-Expo's approach, subjects were aware of their inclusion in the study and knew they would be asked about their phone use after using the software-modified phones, possibly influencing their MPU and/or responses, while this is not the case in the current retrospective approach. A drawback of using operator data is the fact that these data are often incomplete and not always available for the desired etiological period, particularly if this period is in the past, as is the case in our study. Additionally, it may not always be clear from billing records who the actual user of the phone was when making calls. Therefore, while billing records provide insight into validity and possible calibration of self-reports, they may not represent the gold standard for studies, especially due to the low number of retained study participants, and also because internet-based calling (VoiP) is not included in the records. Additionally, although the period of recall in this study was shorter than the previous MOBI-Expo validation study (3 months vs. 6 months), we assume that it is still an informative time period to measure error, especially in the context of case–control studies on brain tumor risk where the recall of the cases may be worse and worse as they may suffer from physical or/and psychological impairments. In addition, sensitivity analyses covering 1 or 2 years of recall did not provide materially different results.

In all likelihood, mobile phones were also used for example browsing the internet, messenger services or other services, which would also contribute to overall exposure to radiofrequency electromagnetic fields. However, calling has been shown to contribute the lion's share to brain exposure (van Wel et al., 2021) and was therefore selected as the relevant metric to compare with operator data. Also, brain dose received from calling can be calculated as such, but in the absence of information of true output power of the mobile phone during calling, any dose calculation essentially provides the same result as using duration, although expressed in a different metric.

4.2 | Case–control differences

Our data do not provide evidence of differential recall error of MPU between cases and controls. This is in line with findings from the INTERPHONE study, where recall error in MPU amongst adult cases and controls was investigated and where only very small differences between cases and controls were observed. For example, the ratio of number of self-reported calls compared to operator-recorded calls was 0.81 for both cases and controls, and the ratio for duration of calls was 1.40 for cases and 1.39 for controls (Vrijheid et al., 2009). The CEFALO validation study also assessed

TABLE 5 Ratio of self-reported versus recorded mobile phone use in duration of calls (in minutes), shown by case–control status.

Duration of calls	Cases			Controls			p For difference[b]
	N	GMR[a]	95% CI	N	GMR[a]	95% CI	
Overall (at 3 months)	250	1.70	1.43, 2.03	452	1.53	1.34, 1.75	0.26
Subset: 1 year of data							
Up to 3 months	131	1.92	1.51, 2.45	226	1.52	1.28, 1.81	0.10
Up to 1 year	131	1.63	1.33, 2	226	1.37	1.16, 1.6	0.14
Subset: 2 years of data							
Up to 3 months	41	1.90	1.23, 2.96	63	1.41	1.01, 1.98	0.29
Up to 1 year	41	1.47	1.01, 2.13	63	1.08	0.8, 1.47	0.22
Up to 2 years	41	1.44	0.99, 2.09	63	1.07	0.78, 1.46	0.25
Subset: 2 years of data							
Months 1–3	41	1.90	1.22, 2.96	63	1.40	1, 1.97	0.62
Months 4–12	41	1.50	1.02, 2.19	63	1.09	0.8, 1.49	0.32
Months 13–24	41	1.52	0.98, 2.35	63	1.12	0.79, 1.58	0.35
By country							
Canada	3	0.86	0.32, 2.33	2	2.36	1.32, 4.21	0.19
France	59	1.10	0.82, 1.49	97	1.52	1.21, 1.9	0.21
Germany	21	2.60	1.21, 5.55	19	3.35	1.55, 7.2	0.66
Greece	1	1.51	1.51, 1.51	1	0.38	0.38, 0.38	-
Israel	28	1.52	0.9, 2.57	46	1.55	1.06, 2.27	0.96
Italy	99	2.36	1.78, 3.13	211	1.70	1.43, 2.01	0.06
Korea	4	2.62	0.99, 6.89	8	1.08	0.39, 3.01	0.24
Spain	35	1.27	0.81, 1.98	68	0.96	0.6, 1.53	0.40
p For heterogeneity	*0.21*			*0.46*			
By reported years since start of mobile phone use							
1–2.9	35	0.96	0.56, 1.63	72	1.19	0.79, 1.78	0.58
3–4.9	43	2.12	1.37, 3.3	90	1.70	1.29, 2.24	0.40
5–6.9	51	2.01	1.38, 2.93	86	1.94	1.43, 2.64	0.82
7–8.9	50	1.95	1.33, 2.86	68	1.71	1.29, 2.26	0.57
9+	65	1.72	1.27, 2.33	119	1.39	1.09, 1.76	0.21
p For heterogeneity	*0.29*			*0.86*			
By sex							
Male	138	1.73	1.36, 2.19	246	1.40	1.18, 1.67	0.17
Female	112	1.68	1.29, 2.18	206	1.71	1.40, 2.08	0.92
p For heterogeneity	*0.30*			*0.16*			
By age							
10–14 years	53	1.11	0.73, 1.68	114	1.39	1.03, 1.88	0.35
15–19 years	98	2.25	1.66, 3.04	180	1.78	1.45, 2.19	0.13
20–24 years	99	1.62	1.29, 2.04	158	1.39	1.15, 1.68	0.18

TABLE 5 (Continued)

Duration of calls	Cases *N*	GMR[a]	95% CI	Controls *N*	GMR[a]	95% CI	*p* For difference[b]
p For heterogeneity	*0.04*			*0.79*			
By self-reported level of mobile phone use							
<20th percentile	43	0.37	0.27, 0.52	74	0.46	0.33, 0.64	0.37
20th–40th percentile	46	1.39	0.92, 2.11	99	0.95	0.75, 1.21	0.12
40th–60th percentile	38	1.83	1.24, 2.69	85	1.26	1.03, 1.55	0.05
60th–80th percentile	73	2.32	1.83, 2.95	95	2.82	2.18, 3.63	0.32
>80th percentile	50	4.36	3.18, 5.97	99	3.96	3.18, 4.93	0.64
p For heterogeneity	*0.06*			*0.02*			

[a]Geometric mean of ratio self-reported versus recorded mobile phone use.

[b]Log ratios were compared using a t-test with unequal variances.

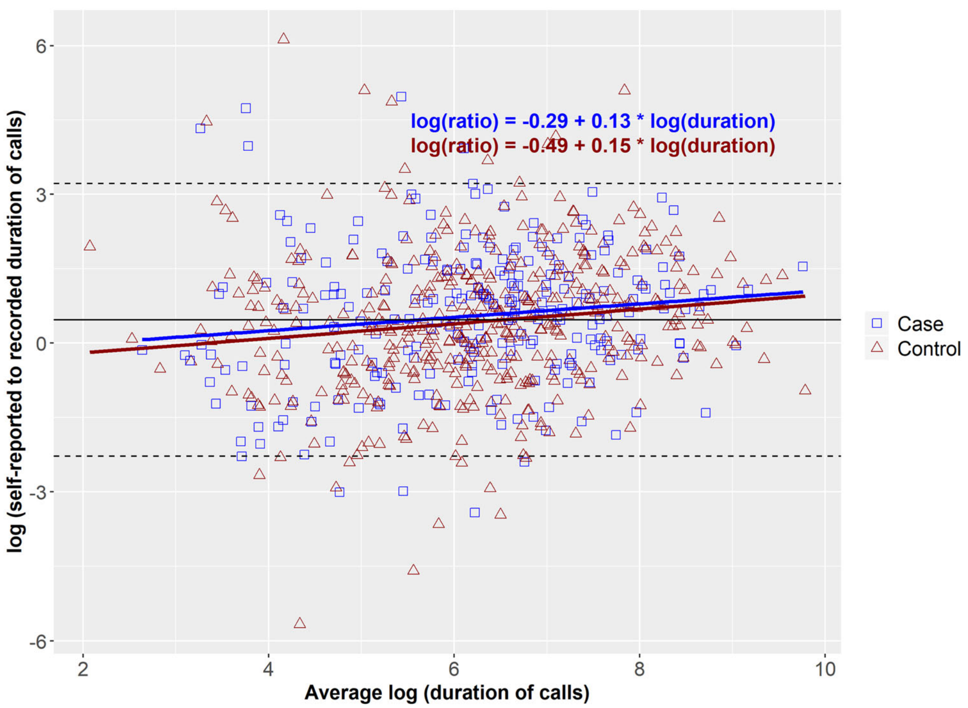

FIGURE 1 Ratio of self-reported to recorded duration of calls against mean phone use (log-transformed data) with dashed lines indicating the 95% limits of agreement and the red (control) and blue (case) lines indicating the corresponding regression line. Average is the average of self-reported and recorded duration of calls. *p* for interaction term, 0.78.

differences between number and duration of calls in 7–19-year-old brain tumor cases and their controls (Tynes et al., 2011). While they found some evidence for more pronounced overestimation in number (9% for cases and 34% for controls) and duration of calls (52% for cases and 163% for controls) in controls compared to cases, this finding was not reproduced here. A potential explanation could be the larger number of subjects we included (135 in the CEFALO study vs. 702 in our study) and the shorter time period between diagnosis and time of interview, which was 844 (for cases) or 886 (for controls) days for the CEFALO subjects, and 365 days for our study.

4.3 | Sensitivity analyses

The effect of responsiveness of subjects during the self-reported MPU interview, and the use of imputed data were investigated in sensitivity analyses. No

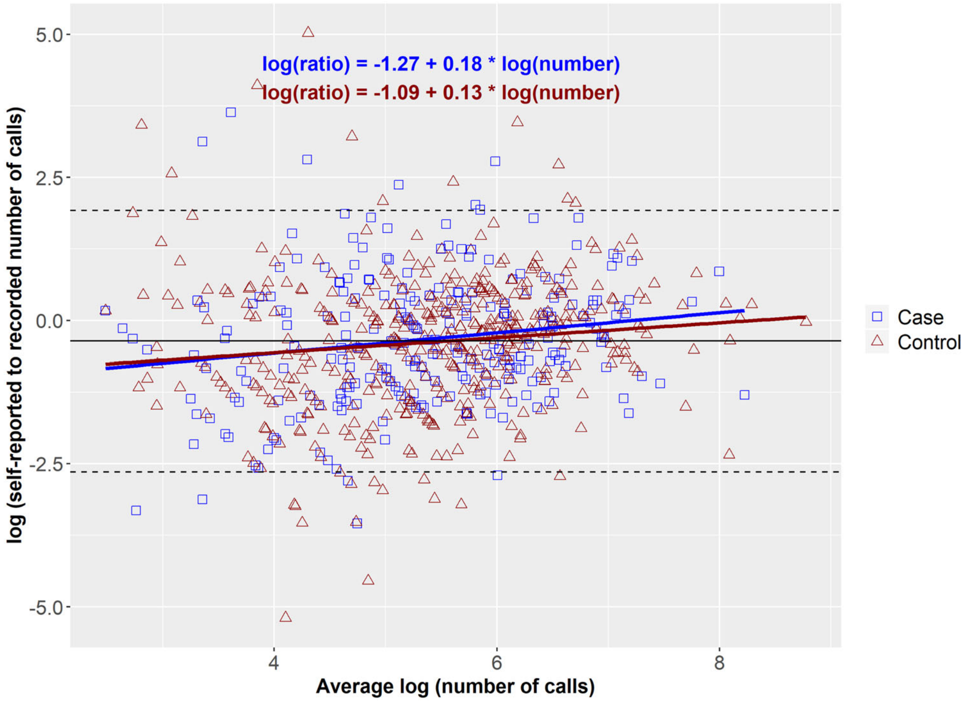

FIGURE 2 Ratio of self-reported to recorded number of calls against mean phone use (log-transformed data) with dashed lines indicating the 95% limits of agreement and the red (control) and blue (case) lines indicating the corresponding regression line. Average log is the average of self-reported and recorded number of calls. p For interaction term, 0.56.

differences in recall statistics were noted, neither non-differential nor differential, suggesting that these factors had little effect on our results. For interview quality, only 15 participants were judged to be poor responders (category "not at all responsive") while the other 160 subjects excluded in the sensitivity analysis were considered "fairly responsive," limiting the ability to draw informative conclusions from this.

4.4 | Over- and underestimation

The overestimation of the duration of calls that we found is in line with previous validation studies among young people, although the degree of overestimation differed (Aydin et al., 2011; Mireku et al., 2018). The comparison is less consistent for number of calls, where overestimation was found in the CEFALO (Tynes et al., 2011) and SCAMP (Mireku et al., 2018) studies. In MOBI-Expo the same direction of systematic error was found as in the current study (number of calls: GMR 0.52 (MOBI-Expo) versus 0.69 (MOBI-Kids, duration of calls: GMR 1.32 (MOBI-Expo) versus 1.59 (MOBI-Kids). The INTERPHONE validation study, performed among adults rather than adolescents and children, showed results in line with our current findings (overall GMR INTERPHONE 0.81 for number and 1.39 for duration of calls) (Vrijheid et al., 2009).

Both the COSMOS (Reedijk et al., 2024) as well as the INTERPHONE validation (Vrijheid et al., 2009) studies found significantly differing ratios between countries. In the present study we did see some differences in GMRs among the eight participating countries, but the differences did not achieve statistical significance. In contrast, the MOBI-Expo validation study by Goedhart et al. (2018) did find significant differences among countries with participants from Greece, Israel, and Korea underestimating the duration of calls while in other countries duration was overestimated. We observed differences in recall among age groups, with the 15–19-year-old group demonstrating the largest degree of overestimation for call duration in both cases and controls, and for call number in cases. These differences in recall of call duration and call number were statistically significant only in cases. The CEFALO validation study used two age groups (10–14 vs. 15–19 years old) and found greater overestimation in the 15–19-year group for both call number and duration (Aydin et al., 2011), while Kiyohara et al. (2016), using the same age groups as our study, found that the youngest age group (Aydin et al., 2011; Kiyohara et al., 2016; Tynes et al., 2011; Vrijheid et al., 2009) had the highest overestimation in call duration. Although patterns in MPU recall are inconsistent between studies it remains important to consider the potential biases that may occur through imperfect MPU recall in studies on the health effects of mobile phones and health. Our results may allow to use operator-recorded data for imputation of self-reported data as a sensitivity analysis of MOBI-Kids. In addition, simulation studies may help to explore the effect of the observed patterns means for bias in risk estimates, in line with Aydin et al. (2011).

5 | CONCLUSIONS

We compared self-reported MPU with operator data at 3 months, 1 year, and 2 years preceding the interview date. No indication of differential recall error between cases and controls was found. Both non-differential systematic and random errors were observed, with number of calls being underreported and duration of calls being over-reported on average in both cases and controls. If there are true underlying risks, then the observed non-differential random errors may bias risk estimates towards their null values and decrease study power.

ACKNOWLEDGMENTS

We would like to thank all mobile phone operator companies contributing data in the various study regions. D. Krewski holds a Natural Sciences and Engineering Research Council of Canada Industrial Research Chair at the University of Ottawa, with CWTA as one of the industrial partners (http://www.nserc-crsng.gc.ca/Chairholders-TitulairesDeChaire/Chairholder-Titulaire_eng.asp?pid=316). ISGlobal is a member of the CERCA Programme, Generalitat de Catalunya. The Japanese study center appreciates the generous support and advice offered. The Canadian study center would like to thank Fatima Kazoun for data collection and recruitment. The French coordination would like to thank Stéphanie Bonnay, Brigitte Chazara, Véronique Dimper, Françoise Du Mazel, Laila Heintz-Benajar with the help of Vanessa Gros, Carine Jeunecourt, Bénédicte Radal, Olivia Rick, Céline Sardano-Garsi, and Xavier Schwall for their support in recruiting and interviewing participants. The French team would also like to thank the mobile operators for their collaboration in the validation study: Orange, Bouygues, SFR. The German study center would like to thank Swaantje Barth, Susanne Brilmayer, and Vanessa Kiessling for their valuable contributions. The Greek study center would like to thank Maria Karalexi, Evangelia Kontogeorgis and Elena Labropoulou for data collection and follow-up of individuals. The Italian study center would like to thank all interviewers for data collection, Marco Gilardetti for data management, and regional coordinators (Enrica Migliore (Piemonte), Mariangela Farinotti (Lombardia), Sara Piro (Toscana), Francesco Marinelli and Stefania Curti (Emilia Romagna). The Spanish coordinating center would like to thank Alex Albert and Albert Dalmau for their invaluable technical support, and Eva Ferreras, Marta Cervantes, Rebeca Sánchez, Angeles Sierra for data collection and recruitment, and Carmen Caban for setting up the complex electronic database. We appreciate the enormous time and effort of the regional coordinators (Marta Cervantes, Eva Ferreras, Irene Gavidia, Rebeca Sánchez, Angeles Sierra, and Angela Zumel). The Dutch study center would like to thank Lutzen Portengen and Max Leenders for their support. All study centers thank the volunteers for their participation in the study. The research leading to these results has received funding from the Netherlands Organisation for Health Research and Development (ZonMw) under grant agreement numbers 85500022 and 85800001. The Korean IT R&D program of MSIP/IITP (B0138-16-1002, Study on the EMF exposure control in smart society, 2017-0-00961 and 2019-0-00102). Japanese participation in MOBI-Kids is supported by the Ministry of Internal Affairs and Communications by Grants No. 0155-0007, 0155-0171, 0155-0087, and 0155-0139. The European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement number 22687 3- the MOBI-Kids project and the European Commission grant 603794-GERoNiMO project. The French National Agency for Sanitary Safety of Food, Environment and Labour (ANSES, contract FSRF2008-3), French National Cancer Institute (INCa), Pfizer Foundation and League against cancer. Italian participation in MOBI-Kids is partially supported by a Ministry of Health grant (RF-2009-1546284). Canadian (Ottawa) participation in MOBI-Kids is supported by a peer reviewed university–industry partnership grant from the Canadian Institutes of Health Research (CIHR), with the Canadian Wireless Telecommunications Association (CWTA) serving as the industrial partner. Australian participation in MOBI-Kids is supported by the Australian National Health and Medical Research Council with a 5-year research grant (grant number: 546130 and Chief Investigators are: M.R. Sim, B. Armstrong, E. Milne and G. Benke). Austrian participation in MOBI-Kids is partly supported by a grant from the Ministry of Science (GZ 651.415/001-WF/V/2/2014). The German branch of MOBI-Kids is partially supported by the Federal Office for Radiation Protection (BfS) under grant number 3609S30010. Greek participation is partially supported by ELKE (Special Account for Research Grants of the National and Kapodistrian University of Athens) and GGET (General Secretariat for Research and Technology). MOBI-Kids India is supported by the Board of Research in Nuclear Sciences (BRNS). MOBI-Kids New Zealand is supported by grants from Cure Kids New Zealand and the New Zealand Health Research Council. Spanish participation is partially supported by the Spanish Health Research Fund of the Carlos III National Institute for Health (FIS PI10/02981), the Spanish Ministry of

Science and Innovation (MICCIN) (Eurosalud EUS2008-03626), the Andalusian Consejeria de Salud (PI-0317/2010), and Conselleria de Sanitat, Generalitat Valenciana under grant number 025/2010. ISGlobal is a member of the CERCA Programme, Generalitat de Catalunya. The funding sources had no role in: the study design; the collection, analysis, and interpretation of data; the writing of the report; and the decision to submit the article for publication. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

CONFLICT OF INTEREST STATEMENT

Canada (Ottawa) received financial support from the Canadian Wireless Telecommunications Association (CWTA) under the federal university-industry research partnerships programs noted below, and provided access subscriber billing records with informed consent of Canadian study participants. The CWTA had no involvement in the design, conduct, analysis, or results interpretation. Michael Kundi serves as an expert witness for brain tumor epidemiology in a court case in Washington DC. The rest of the authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

We have verified consent from subjects participating in the study was received prior to conducting the study. The study has been reviewed and approved by an accredited committee.

ORCID

Anke Huss http://orcid.org/0000-0001-9268-1867
Michael Kundi http://orcid.org/0000-0002-2707-3213
Noriko Kojimahara http://orcid.org/0000-0003-4099-6167

REFERENCES

Aydin, D., et al.: Predictors and overestimation of recalled mobile phone use among children and adolescents. Prog. Biophys. Mol. Biol. 107(3), 356–361 (2011). https://doi.org/10.1016/j.pbiomolbio.2011.08.013

Cardis, E., et al.: The INTERPHONE study: design, epidemiological methods, and description of the study population. Eur. J. Epidemiol. 22, 647–664 (2007). https://doi.org/10.1007/s10654-007-9152-z

Castaño-Vinyals, G., et al.: Wireless phone use in childhood and adolescence and neuroepithelial brain tumours: results from the international mobi-kids study. Env. Int. 160, 107069 (2022).

Goedhart, G., et al.: Recall of mobile phone usage and laterality in young people: the multinational Mobi-Expo study. Environ. Res. 165, 150–157 (2018).

International Agency for Research on Cancer (IARC): Non-ionizing radiation, part II: Radiofrequency electromagnetic fields. Lyon Int. Agency Res. Cancer 102, 1–421 (2013).

Kheifets, L.: The sensitivity of children to electromagnetic fields. Pediatrics 116(2), e303–e313 (2005). https://doi.org/10.1542/peds.2004-2541.

Kiyohara, K., et al.: Recall accuracy of mobile phone calls among Japanese young people. J. Exposure Sci. Environ. Epidemiol. 26(6), 566–574 (2016). https://doi.org/10.1038/jes.2015.13

Mireku, M.O., et al.: Total recall in the SCAMP cohort: validation of self-reported mobile phone use in the smartphone era. Environ. Res. 161, 1–8 (2018). https://doi.org/10.1016/j.envres.2017.10.034

Reedijk, M., et al.: Regression calibration of self-reported mobile phone use to optimize quantitative risk estimation in the COSMOS study. Am. J. Epidemiol. (2024); forthcoming. https://doi.org/10.1101/2023.02.28.23286424

Sadetzki, S., et al.: The MOBI-kids study protocol: challenges in assessing childhood and adolescent exposure to electromagnetic fields from wireless telecommunication technologies and possible association with brain tumor risk. Front. Public Health 2, 124 (2014). https://doi.org/10.3389/fpubh.2014.00124; http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4172002&tool=pmcentrez&rendertype=abstract

SCENIHR: Scientific Committee on Emerging and Newly Identified Health Risks: Potential Health Effects of Exposure to Electromagnetic Fields (EMF). Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). (2015).

Tynes, T., et al.: Impact of random and systematic recall errors and selection bias in case–control studies on mobile phone use and brain tumors in adolescents (CEFALO study). Bioelectromagnetics 32(5), 396–407 (2011). https://doi.org/10.1002/bem.20651

Vrijheid, M., et al.: Recall bias in the assessment of exposure to mobile phones. J. Exposure Sci. Environ. Epidemiol. 19(4), 369–381 (2009). https://doi.org/10.1038/jes.2008.27

van Wel, L., et al.: Radio-frequency electromagnetic field exposure and contribution of sources in the general population: an organ-specific integrative exposure assessment. J. Exposure Sci. Environ. Epidemiol. 31(6), 999–1007 (2021). https://doi.org/10.1038/s41370-021-00287-8

Wiart, J., et al.: Numerical dosimetry dedicated to children RF exposure. Prog. Biophys. Mol. Biol. 107(3), 421–427 (2011). https://doi.org/10.1016/j.pbiomolbio.2011.10.002

World Health Organization: WHO research agenda for radiofrequency fields, WHO Library Cataloguing-in-Publication Data, p. 24. WHO (2010).

AUTHOR BIOGRAPHIES

Dr. Luuk van Wel works at the Dutch National Institute for Public Health and the Environment (RIVM), Centre for Safety of Substances and Products. His PhD research focused on public health and environmental safety, with specific attention to the risks associated with electromagnetic fields. His current focus is hazardous substances in the workplace.

Dr. Anke Huss is an Associate Professor at the Institute for Risk Assessment Sciences (IRAS) at Utrecht University. She specializes in environmental epidemiology and focuses on environmental exposures, including electromagnetic fields, and their health outcomes, utilizing case–control and cohort study designs.

Dr. Hans Kromhout is a Professor of Exposure Assessment and Occupational Hygiene at the Institute for Risk Assessment Sciences (IRAS), Utrecht University. His work includes research on occupational exposures to electromagnetic fields and their implications for health.

Dr. Franco Momoli is the Practice Lead for Chemical and Product Safety at Risk Sciences International and an Adjunct Professor in the School of Epidemiology and Public Health at the University of Ottawa. He leads a team in assessing health risks of environmental contaminants, including studies on electromagnetic fields.

Dr. Daniel Krewski is an Emeritus Professor in the School of Epidemiology and Public Health, University of Ottawa, and Chief Risk Scientist at Risk Sciences International. His work includes population health risk assessment, with activities involving electromagnetic fields.

Dr. Chelsea E. Langer was the scientific project manager of the MobiKids study at ISGlobal.

Gemma Castaño-Vinyals is a Staff Scientist at ISGlobal. She earned her Bachelor's Degree in Environmental Sciences from the Universitat Autònoma de Barcelona and her PhD at the Universitat Pompeu Fabra in Health and Life Sciences. She is PI/co-PI of several multinational projects on EMF and health.

Dr. Michael Kundi is a former head of the Institute of Environmental Health at the Medical University of Vienna, Austria, conducting research in environmental epidemiology and toxicology.

Dr. Milena Maule is an Associate Professor at the Department of Medical Sciences at the University of Turin (Italy), focusing on biostatistics and epidemiology, particularly in population-based cancer studies.

Dr. Lucia Miligi was responsible for the Environmental and Occupational Epidemiology Branch at the Institute for Cancer Research, Prevention and Clinical Network (ISPRO), Florence. She conducted research in occupational and environmental epidemiology, with a focus also on electromagnetic fields.

Dr. Siegal Sadetzki is the director of public health services at the Israeli Ministry of Health.

Alex Albert is a Data Manager at ISGlobal. He has developed experience programming tools to collect data, and coding scripts to analyze data, contributing to different studies over the years.

Dr. Juan Alguacil is a Professor of Public Health at Universidad de Huelva. His research interests include environmental health risks, among them electromagnetic fields.

Dr. Nuria Aragones works at the Cancer Registration and Surveillance Unit, General Directorate of Public Health, Community of Madrid. She has conducted research on cancer epidemiology, including descriptive and etiologic studies, with a focus on environmental exposures.

Francesc Badia contributed to MobiKids as a research technician at ISGlobal.

Revital Bruchim is a Senior Researcher at the Cancer & Radiation Epidemiology Unit, Gertner Institute, Sheba Medical Center. Her research includes the epidemiology of cancer and the study of radiation exposure.

Dr. Geertje Goedhart was a postdoc at the Institute for Risk Assessment Sciences (IRAS), Utrecht University. She now works at the hospital-registry-data agency as a data specialist.

Patricia de Llobet MSc in Urban Anthropology is a Research technician at ISGlobal in Barcelona, contributing to studies on environmental exposures and health, which encompasses research on electromagnetic fields.

Dr. Kosuke Kiyohara is an Associate Professor at the Faculty of Home Economics at Otsuma Women's University, specializing in Food Science and Dietitian Studies, including research on electromagnetic fields.

Dr. Noriko Kojimahara is a Professor at Shizuoka General Hospital, Research Support Center, investigating the effects of electromagnetic waves on health in Shizuoka General Hospital.

Dr. Brigitte Lacour is a researcher in the EPICEA team at CRESS (UMR1153) and a Director of the French National Registry of Childhood Solid Tumors. She conducts research on the epidemiology of childhood and adolescent cancers, particularly in population-based cancer studies.

Dr. Maria Morales-Suarez-Varela is a Professor at the Universitat de València, Spain, with a focus on Preventive Medicine and Public Health, with a focus on pharmacoepidemiology and social and nutritional epidemiology including occupational safety and health, which includes research on electromagnetic field exposures.

Dr. Katja Radon is a Professor at Ludwig-Maximilians-University of Munich, specializing in epidemiology with a focus on occupational and environmental health, including research on electromagnetic fields.

Dr. Thomas Remen contributed to MobiKids as the French coordinator at INSERM.

Tobias Weinmann is a Senior Lecturer at Ludwig-Maximilians-University of Munich, conducting research on environmental and occupational exposures including the health effects of electromagnetic fields.

Martine Vrijheid is a Professor at ISGlobal in Barcelona, specializing in Childhood and Environment. She has conducted research on environmental and occupational exposures, including electromagnetic fields.

Elisabeth Cardis is an Emeritus Professor in Radiation Epidemiology at ISGlobal. She has coordinated studies on radiation, including electromagnetic fields, and worked on radiation effects research in Hiroshima, Japan.

Roel Vermeulen is a Professor of Environmental Epidemiology and Exposome Science at Utrecht University and the UMC Utrecht. His scientific research focuses on environmental risk factors for non-communicable diseases with a strong emphasis on integrating epidemiology, high quality exposure assessment, and molecular biology into multidisciplinary investigations.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: van Wel L., et al.: Validation of mobile phone use recall in the multinational MOBI-kids study. Bioelectromagnetics, 1–16 (2024).