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MRI-related magnetic field exposures and risk of commuting accidents – A cross-sectional survey among Dutch imaging technicians

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ABSTRACT

Background: Imaging technicians working with magnetic resonance imaging (MRI) may experience acute effects such as vertigo or dizziness when being exposed. A previous study also reported an increased risk of accidents in MRI exposed staff.

Objectives: We aimed at evaluating commuting accident risk in Dutch imaging technicians.

Methods: Of invited imaging technicians, 490 (29%) filled in a questionnaire pertaining to (near) accidents when driving or riding a bike, health, lifestyle and work practices. We used logistic regression to evaluate the association between exposure to MRI-related electromagnetic fields and risk of commuting (near) accidents in the year prior to the survey, adjusted for a range of potential confounders.

Results: Our cross-sectional study indicated an increased risk of (near) accidents if imaging technicians had worked with MRI in the year prior to the survey (odds ratio OR 2.13, 95%CI 1.23 − 3.69). Risks were higher in persons who worked with MRI more often (OR 2.32, 95%CI 1.25–4.31) compared to persons who worked sometimes with MRI (OR 1.91, 95%CI 0.98 − 3.72), and higher in those who had likely experienced higher peak exposures to static and time-varying magnetic fields (OR 2.18, 95%CI 1.06–4.48). The effect was seen on commuting accidents that had occurred on the commute from home to work as well as accidents from work to home or elsewhere.

Conclusion: Imaging technicians working with MRI scanners may be at an increased risk of commuting (near) accidents. This result needs confirmation and potential risks for other groups (volunteers, patients) should be investigated.

1. Introduction

MRI scanners have rapidly increased in numbers, but also in usage and in field strength over the last decades. For example, the number of annual scan procedures in the Netherlands had nearly tripled by 2008 compared to 1996–2000 (Schaap et al., 2013). As a consequence, there has been an increase in the number of exposed MRI technicians, as well as in exposure levels to static magnetic fields and motion-induced time-varying magnetic fields (Schaap et al., 2013, 2014a). While several surveys have reported acute health effects when working with or close to MRI scanners (de Vocht et al., 2015; Schaap et al., 2016b; Wilen and de Vocht, 2011; Zanotti et al., 2016), there is only very limited information regarding potential non-acute, or longer-term effects (Feychting, 2005). Triggered by reports of acute effects of the exposure on vertigo (Mian et al., 2013), disturbed visual perception and hand-eye coordination and effects on balance (van Nierop et al., 2012), one previous study evaluated accident risk in general and during commuting in a retrospective cohort study among workers from an imaging device manufacturing facility in the Netherlands. They reported increased risks of having (near) accidents during the commute from home to work in persons with high recent and career static magnetic field exposure. Risks were more pronounced for accidents leading to injury, compared to near-accidents (Bongers et al., 2016). Given this previous observation, the rationale of our study was to assess whether we could reproduce these findings in a survey among Dutch imaging technicians (radiographers) also exposed to MRI-related stray fields.

2. Methods

2.1. Study design

We invited registered imaging technicians in the Netherlands to participate in a cross-sectional survey. We sent invitation letters to all members of the Dutch Society of Medical Imaging and Radiotherapy

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(Nederlandse Vereniging Medische Beeldvorming en Radiotherapie, NVMBR). Participants were asked to fill in an online questionnaire inquiring about accidents, lifestyle, sleep, health, perceived stress at work and work practices, in particular frequency of nightshifts. The survey was announced with the aim: "to gain insight into the occurrence of health issues among radiographers and how they relate to underlying factors such as general health status, lifestyle and the work environment, with a specific focus lying on the role of working with MRI-scanners and associated exposures to electromagnetic fields". Of 1637 invited imaging technicians, 490 persons (29%) responded to the invitation, and filled in the questionnaire in 2013.

2.2. Exposure

In our survey, we evaluated different proxies for exposure. Radiographers accessing the MRI scanner room will be exposed to static magnetic fields (SMF) together with motion-induced time-varying magnetic fields (TvMF)(Schaap et al., 2014a). During image acquisition radiographers may be additionally exposed to time-varying magnetic fields from the switched gradient fields (SGF), and possibly to some low-level radiofrequency fields (RF) when they are very close to the bore of the MRI magnet (Gourzoulidis et al., 2015). We asked study participants if they had ever worked with or near an MRI scanner during the year prior to the survey and if so, approximately on many days they had done so. In the questionnaire, this was asked as: "During the past 12 months, did you work in an MRI scanner room?" 'Scanner room' was further explained as "this is the room in which the MRI scanner is placed". If the response was positive, the follow-up question was "On how many days did you work in an MRI scanner room during the past 12 months? (provide an estimate)". In addition, we asked on how many days during the past year they had been present in the MRI room during image acquisition of the scanner. This was asked as: "During the past 12 months, did you work inside an MRI scanner room during image acquisition?". Image acquisition was further explained as: "This is the moment when a scanner is busy taking an 'image'; i.e. the actual moment of scanning. If you are not familiar with this process: the moment of acquisition can usually be recognized by the hard (buzzing or pulsating) sound produced by the MRI scanner". If the response was positive, the follow-up question was "On how many days did you work inside (or access) an MRI scanner room during image acquisition during the past 12 months? (provide an estimate)".

We also asked the respondents at what strength (in Tesla) the MRI scanner(s) they worked with operated at, and which type of MRI scanner these were (closed bore, open bore, extremity scanner, upright scanner, other). We used a previous measurement survey among MRI staff (Schaap et al., 2016a) to group our participants into different SMF exposure groups, based on the scanners: low (working only with extremity scanners, or with closed-bore or open-bore scanners below 1.5 T); medium (working with closed-bore or open-bore scanners at 1.5 T) and high (working with any scanners stronger than 1.5 T, or with upright scanners). Only 14 participants were in the "low" exposure group, and we therefore merged them with the "medium" exposed group. Most technicians reported working with more than one scanner. Since we did not gather information on how much time the radiographers spent with the different types of scanners, our classification captures the potential for peak exposures that our study participants had experienced during the past 12 months rather than the SMF and TvMF exposure levels they experienced on average.

2.3. Outcome

In our questionnaire we asked radiographers if they had ever had a (near) accident while commuting from home to work or while commuting from work to home (or elsewhere). These included accidents with motorized transport, but also bicycle accidents. Accidents when walking were not included. The question was asked as: "Have you ever had a traffic accident (or near-accident) driving a car, a bike or bicycle during your commute (from home to work or from work to home or elsewhere)". In the following, we refer to "accidents", which includes the reported "near accidents". If participants reported an accident, we further inquired how many accidents they had. If there had been just one accident, we asked to report the year the accident had happened. In the case of multiple accidents, we asked for the earliest and latest year in which these accidents had occurred. We subsequently classified our participants as having had at least one accident in the year prior to the survey if any of the accidents had taken place in 2012 or 2013.

2.4. Statistical analysis

We compared participant characteristics between persons unexposed or exposed to MRI-related electromagnetic fields during the past year. We used Student's *t*-test for the variables age and the MOS sleep scale (Hays et al., 2005), Chi-square tests for all categorical variables, and a Wilcoxon rank sum test on average number of nightshifts participants reported.

In our primary analysis, we used logistic regression to evaluate the risk of having had at least one accident in the year prior to the survey. We explored exposure-response associations with the amount of days participants reported working with or near an MRI scanner during the past year, the interquartile range was 25–100 days, the median was 67 and the maximum reported days was 230. In our analysis, we used the median among exposed radiographers as a cut-off to group them as being "sometimes" (1–66 days during past year) or "often" exposed (67–230 days during past year), compared to unexposed radiographers. Regarding the MRI-related exposure when being present during image acquisition, we again used the median of exposed persons to classify radiographers as "1–3 days per year" or "4–140 days" exposed. We evaluated associations with the potential for maximum SMF and TvMF exposure (based on strength and type of the MRI-scanners participants had reported to work with in the year prior to the survey).

We adjusted our models for age and a squared term of age, sex, self-reported physical, emotional and general work stress using tertiles of the respective stress scores ("During the past four weeks, to which degree did you experience work-related stress/ emotional stress/ physical strain"; answered on a 5-point Likert scale ranging from "very low degree" to "very high degree"). We had missing information on work-related stress scores for 41 (8%) participants and imputed these scores based on their reported age, general health status, smoking status, amount of alcohol and caffeine consumption, BMI and sleep duration. We additionally adjusted for the number of nightshifts they worked (none, maximally once per month, twice per month or more often), the overall MOS scale sleep problem score, caffeine consumption (average coffee, black or green tea, cola or energy drink consumption per day, weighted by average caffeine content and grouped in tertiles) and for average alcohol consumption per week of the past year (none, on average 1–3 glasses per week, 4 or more glasses per week).

We performed several additional analyses: Firstly, in order to reduce the potential to erroneously classify persons into the non-accident group, we excluded persons from our analysis who reported no accidents in the year prior to the survey, but who had an accident in the time frame between 5 years until one year prior to the survey. Secondly, we additionally excluded from the non-accident group those persons reporting any commuting accident until one year prior to the survey. Finally, we separately analyzed accidents in the year prior to the survey that had occurred either on the way from home to work, or accidents that occurred from work to home (or elsewhere). In the analysis of accidents from home to work, we excluded persons without an accident on this part of the commute, but who did report an accident from work to home ($N = 19$). The same procedure was followed for the other part of the commute: we excluded persons if they reported no accident on the commute from work to home or elsewhere but did experience an accident from home to work (N = 32). As for the analyses described above, this was done in order to reduce outcome misclassification.

We also evaluated if risks were different depending on whether people reported to have experienced vertigo during MRI-related work, or if they reported that they had adjusted their work practice because they experienced MRI-work related symptoms. We did this by grouping exposed participants into the following groups: sometimes working with MRI and not experiencing vertigo, sometimes working with MRI and experiencing vertigo, often working with MRI and not experiencing vertigo, often working with MRI and experiencing vertigo, vs unexposed participants. The same procedure was applied for persons who reported that they had adjusted their work practice.

We assessed risks of having had more than one accident in the past, which was based on all commuting accidents the participants reported to have experienced. For this analysis we grouped accidents into none, one, or two or more accidents that had occurred. We used ordered logistic regression, after Brant tests confirmed no violation of the proportionality assumption (Brant, 1990). Ordered logistic regression provides just one risk estimate: if the proportionality assumptions are met, then the coefficients should be the same for each logistic regression. For comparison reasons we additionally performed (polytomous) logistic regression models where we compared risk of one accident compared to no accident, and additionally the risk of 2 or more accidents compared to no accidents. Note that this stratified analysis allows for differences in baseline risk per analysis. Both of these analyses provide information as to whether higher exposure also relates to a higher risk of multiple accidents. Note, however, that because our exposure questions related to the past year, both types of analyses would be expected to have suffered from some degree of exposure misclassification if study participants had been exposed differently in the past.

3. Results

Ninety percent of participants were imaging technicians; the rest included e.g. imaging technicians in training or advanced practitioners. Nearly all, 99% worked in health care (and not e.g. in a research department). In the Netherlands it is not common to specialize on one modality only: In the four weeks prior to the survey, independent of whether they worked with MRI or not, most imaging technicians reporting reported to work with multiple imaging modalities, such as Bucky x-ray, contrast x-ray, CT, ultrasound or others. Roughly half (53%) of participants reported to never work nightshifts. Among participants working nightshifts, the median number of nightshifts per month was two (interquartile range 1–2). About half of the imaging technicians (N = 257, 52%) had worked in an MRI room at least once during the past year. Of these 257 persons, 124 (48%) additionally report to have entered the MRI scanner room during image acquisition. MRI- exposed compared to MRI-unexposed participants were on average four years younger, and reported less physical strain at work (Table 1), this was similar among imaging technicians reporting presence during image acquisition compared to MRI unexposed participants. During the year before the survey, 76 persons (16%) reported a (near) accident during the commute to or from work. Of these, 57 participants had accidents on the way from home to work and 44 from work to home; 25 participants reported accidents on both commutes. Overall, 210 (43%) participants reported ever having had a (near) commuting accident.

We observed increased risks of commuting accidents in MRI-exposed technicians: Participants who had entered the MRI room at least once during the past year had an OR of 2.13 (95% CI 1.23 – 3.69) of having experienced a commuting accident in the year preceding the survey compared to MRI unexposed participants. Risks increased when participants worked more days with MRI and with increasing SMF exposure based on scanner strength and type, but not with presence during image acquisition (Table 2). In general, our risk estimates slightly increased when we accounted for the potential confounders in our regression models, which was primarily due to adjustments based on age, sex and physical strain at work. Risk estimates for the confounders for the main analysis are provided in Table S1.

Table 1
Study population characteristics.

	Never accessed MRI room in past year, N (%)	Ever accessed MRI room in past year, N (%)	p-value
Women: N, %	186 (79.8)	195 (75.9)	0.3
Men: N, %	47 (20.2)	62 (24.1)	
Age, mean (SD)	46.6 (9.9)	42.5 (10.7)	< 0.0001
Work stress: Low	78 (33.5)	80 (31.1)	
Medium	95 (40.8)	101 (39.3)	
High	60 (25.8)	76 (29.6)	0.632
Emotional stress: Low	72 (30.9)	85 (33.1)	
Medium	102 (43.8)	95 (37.0)	
High	59 (25.3)	77 (30.0)	0.281
Physical stress: Low	54 (23.2)	90 (35.0)	
Medium	113 (48.5)	96 (37.4)	
High	66 (28.3)	71 (27.6)	0.009
MOS sleep problem score: Mean (sd)	25. 8 (11.6)	25.9 (11.8)	0.87
Average number nightshifts per month	0.78 (1.1)	0.94 (1.2)	0.094
Average alcohol consumption past month: None	64 (27.5)	65 (25.3)	
Low	94 (40.3)	100 (38.9)	
High	75 (32.2)	92 (35.8)	0.69
Average caffeine consumption: Low	67 (28.8)	81 (31.5)	
Medium	82 (35.2)	81 (31.5)	
High	84 (36.0)	95 (36.95)	0.66

p-values of group differences between participants never vs. ever accessing the MRI room in the past year are based on Student's *t*-test for age and the sleep score, a Wilcoxon ranksum test for nightshifts per month and Chi square tests for all categorical variables.

When we excluded in our additional analyses persons from the non-accident group who had experienced an accident in the 4 years prior to the year preceding the survey, or persons who reported ever having had a commuting accident prior to the year preceding the survey, the ORs further increased (Table S2).

The effect was visible for both types of commuting, i.e. accidents on the commute from home to work as well as accidents from work to home or elsewhere, although risks tended to be slightly higher for the commute from work to home compared to the other way around (Table 3).

Of participants who had worked in an MRI room at least once during the previous year, 84 (33%) reported to have experienced symptoms of vertigo when working with MRI and 47 (18%) reported work practice adjustments. These adjustments were aimed at reducing negative side effects or symptoms when working with MRI; the majority of these adjustments concerned slowing down speed of movements in the vicinity of the scanner. Effects of exposure on accidents in the past year were not significantly different in persons reporting to have experienced vertigo or in persons reporting to have adapted their work practice (data not shown).

Ordinal logistic regression on multiple commuting accidents that had ever occurred clearly indicated increasing risks of multiple accidents with increasing exposure (Table 4), as did polytomous regression (Table S3).

4. Discussion

4.1. Sub-summary of main results

Our cross-sectional study indicated an increased risk of commuting

Table 2
Association between working with MRI scanners, presence during image acquisition, maximum scanner strength and experiencing a commuting accident in the year preceding the survey.

	N t	N c	OR (95%CI)	OR adj (95%CI)[a]
Unexposed	233	27	referent	referent
In MRI room at least once during past year (1–230 days)	257	49	**1.80 (1.08 − 2.99)**	**2.13 (1.23 − 3.69)**
Unexposed	233	27	referent	referent
Sometimes working with MRI (1–66 days)	129	21	1.48 (0.80 − 2.75)	1.91 (0.98 − 3.72)
Often working with MRI (67–230 days)	128	28	**2.14 (1.20 − 3.82)**	**2.32 (1.25 − 4.31)**
Unexposed	233	27	referent	referent
Exposed to MRI but not during image acq.	133	27	**1.94 (1.09 − 3.48)**	**2.66 (1.39 − 5.10)**
Present during image acquisition (1–3 days)	62	10	1.47 (0.67 − 3.22)	1.68 (0.73 − 3.85)
Present during image acquisition (4–140 days)	62	12	1.83 (0.87 − 3.86)	1.77 (0.80 − 3.92)
Unexposed	233	27	referent	referent
Low/medium scanner strength[b]	168	30	1.66 (0.94 − 2.91)	**1.99 (1.08 − 3.66)**
High scanner strength[b]	83	17	**1.97 (1.01 − 3.83)**	**2.18 (1.06 − 4.48)**

[a] Adjusted for age and age squared, work-related stress, work-related physical and emotional strain, sleeping problems, night shifts, caffeine and alcohol consumption. N t: total number of persons in category, N c: Number of cases per category.
[b] Based on scanner strength and type of scanner.

Table 3
Association between working with MRI scanners, presence during image acquisition, maximum scanner strength and accidents that occurred in the year before the survey, on the way from home to work and from work to home (or elsewhere).

	Accidents from home to work			Accidents from work to home or elsewhere		
	N t	N c	OR adj (95%CI) a	N t	N c	OR adj (95%CI)
Unexposed	227	21	referent	221	15	referent
In MRI room at least once during past year (1–230 days)	244	36	**2.00(1.08 − 3.70)**	237	29	**2.32(1.15 − 4.70)**
Unexposed	227	21	referent	221	15	referent
Sometimes working with MRI (1–66 days)	121	14	1.67(0.77 − 3.61)	121	13	2.19(0.94 − 5.11)
Often working with MRI (67–230 days)	122	22	**2.27(1.14 − 4.52)**	116	16	**2.43(1.10 − 5.38)**
Unexposed	227	21	referent	221	15	referent
Exposed to MRI but not during image acq.	125	19	**2.41(1.16 − 5.00)**	121	15	**2.88(1.24 − 6.70)**
Present during image acquisition (1–3 days)	58	6	1.32(0.49 − 3.59)	58	6	1.73(0.61 − 4.92)
Present during image acquisition (4–140 days)	61	11	2.02(0.86 − 4.72)	58	8	2.16(0.82 − 5.68)
Unexposed	227	21	referent	221	15	referent
Low/medium scanner strength[a]	159	21	1.87(0.93 − 3.74)	155	17	2.06(0.94 − 4.51)
High scanner strength[a]	79	13	1.97(0.88 − 4.40)	77	11	**2.68(1.08 − 6.65)**

OR adj: Adjusted for age and age squared, work-related stress, work-related stress and emotional stress, work-related physical strain, sleeping problems, night shifts, caffeine and alcohol consumption. N t: total number of persons in category, N c: Number of cases per category.
[a] Based on scanner strength and type of scanner.

accidents if imaging technicians worked with MRI. Risks increased in persons who worked with MRI more often and who had likely experienced higher peak exposures to static and time-varying magnetic fields in the past year. The effect was seen on commuting accidents that had occurred on the commute from home to work as well as accidents from work to home or elsewhere.

4.2. Strength and limitations

Strengths of our analysis include the size of the study that allowed us to explore risks of accidents with different exposure proxies and exposure-response associations. We were also able to adjust for a wide range of potential confounders, including e.g. individual alcohol consumption, sleep problems and frequency of night shifts. Limitations of our study relate to the cross-sectional design, which may have caused information bias since information used to assess exposure and effect were asked in the same questionnaire, a low participation rate of 29% and self-reporting of the outcomes and thus absence of confirmation of the commuting accidents via other sources. Low participation might have introduced selection bias if participants who had experienced negative effects felt more inclined to respond to our survey. Information bias could be present if participants knew about a potential link between MRI exposure and accidents which could have possibly introduced over-reported exposure or accidents, or both. To the best of our knowledge, however, there has only been one previous study that reported increased risks of accidents in MRI exposed workers, but that study was published after our survey was performed (Bongers et al., 2016).

As our primary analysis, we evaluated accidents that had occurred in the year before the survey since this was also the time frame that our exposure information pertained to. Outcome misclassification could have occurred if persons had experienced previous accidents but they did not happen in the year prior to the survey. In this case a person would have been incorrectly classified as belonging to the no-accident

Table 4
Association between working with MRI scanners, presence during image acquisition, maximum scanner strength and any accidents that study participants reported to have had in the past.

	Nt	Nc	OR (95%CI)[a] (0, 1, > 1 accidents)
Unexposed	233	91	referent
In MRI room at least once during past year (1–230 days)	257	119	**1.71 (1.18 – 2.49)**
Unexposed	233	91	referent
Sometimes working with MRI (1–66 days)	129	55	**1.58 (1.00 – 2.49)**
Often working with MRI (67–230 days)	128	64	**1.87 (1.20 – 2.91)**
Unexposed	233	91	referent
Exposed to MRI but not during image acq.	133	63	**2.12 (1.34 – 3.35)**
Sometimes present during image acquisition (1–3 days)	62	24	1.19 (0.66 – 2.13)
Often present during image acquisition (4–140 days)	62	32	1.68 (0.96 – 2.93)
Unexposed	233	91	referent
Low/medium scanner strength[b]	133	77	**1.63 (1.07 – 2.47)**
High scanner strength[b]	83	39	**1.88 (1.12 – 3.16)**

OR from ordered logistic regression.
[a] Adjusted for age and age squared, work-related stress and emotional stress, work-related physical strain, sleeping problems, night shifts, caffeine and alcohol consumption.
[b] Based on scanner strength and type of scanner.

group. We therefore in a sensitivity analysis excluded persons who had reported accidents that had occurred until one year prior to the survey (but not in the year prior to the survey), and this procedure further increased the risk estimates. Unfortunately we were limited in our ability to analyze the occurrence of multiple accidents during the year prior to the survey, as this was not captured in our questions. When we evaluated commuting accidents to or from work that had occurred at any time point in the past (so not restricted to the year prior to the survey), we observed clearly increased risks of multiple accidents in higher exposed participants compared to having experienced just one accident. Although this analysis also speaks for an association of MRI-related exposure with accidents, the obtained risk estimates are more difficult to interpret, given that we only have reliable MRI-exposure information of the last year. Risk of experiencing accidents increases with age, so older participants will automatically have a higher likelihood of falling into the multiple-accident group. When we stratified our study group by median age (46 years), we still observed clear exposure-response associations with higher risk of multiple accidents in higher exposed persons in both age groups (data not shown).

4.3. Mechanism

We cannot clearly explain why MRI exposed technicians are at an increased risk of accidents. A range of previous studies have shown acute effects of MRI exposure on vertigo, disturbed visual perception and hand-eye coordination and effects on balance, giving rise to our study. Most experimental studies have only evaluated effects during or directly after exposure (de Vocht et al., 2006, 2007; van Nierop et al., 2012, 2013) and not e.g. hours or days after exposure. In previous surveys, however, some affected persons reported symptoms such as tiredness or headaches to clearly outlast exposure by just a few minutes, e.g. tiredness or headaches were most often reported to last for 15–60 min after exposure in the study by Schaap et al. (2014b). Other study reports also mention sleep disorders (de Vocht et al., 2015; Wilen and de Vocht, 2011), which would represent a health effect outlasting the exposure by at least the night following the exposure. In our study, we did not observe that MRI exposure was significantly associated with self-reported sleep quality, as assessed with the MOS scale (Table S1). We observed increased risks of accidents in exposed MRI technicians both for the commutes from home to work as well as from work to home. Although risk estimates tended to be slightly higher for the commute from work to home, these equally elevated risks suggest that MRI exposure-related effects do not disappear within the hour of exposure. As such, our study is in line with the findings by Bongers et al. (Bongers et al., 2016), in showing an increased risk of accidents with higher exposure to static magnetic fields (SMF and TvMF) during the commute from home to work. However, our findings differ from those of Bongers et al. in that we also observed increased risks on the opposite commute, which Bongers et al. did not report. All in all, our study does not support the hypothesis that tiredness from decreased sleep quality is underlying the observed accident risks as a confounder. The specific underlying impairment that causes MRI exposed technicians to be more prone to commuting accidents remains unclear. In addition, it is also not entirely clear which exposure is underlying the observed association with accidents. Imaging technicians accessing the MRI scanner room will be exposed to SMF as well as to motion-induced TvMF. In addition, if imaging technicians get very close to the bore during image acquisition, exposure to SGF as well as to RF may occur. Getting close to the bore during image acquisition might happen in the case of attending a paediatric, anxious, sedated or otherwise high-care patient during scanning. Our data rather point to an effect of working with or close to MRI systems as such and not an effect of image acquisition, although we are limited in our ability to disentangle effects from the different exposures. Imaging technicians who reported presence during image acquisition also reported working with or near MRI systems more frequently than technicians who were not present near the MRI scanner during image acquisition.

4.4. Conclusions

In conclusion, we observed an increased risk of commuting accidents in the past year in persons working with or near MRI scanners during the past year, with increasing risks of these accidents among persons who report more frequently working with or near MRI scanners or who work with MRI scanners that have a potential for higher peak exposure. Presence during image acquisition did not seem to be strongly associated with these increased risks. Given the large increase in number of MRI scanners in use, but also frequency of use and field strength over the last decades and thus the increase in number of exposed technicians and frequency of their exposure, the topic may be of public health relevance. Our findings need confirmation to assess if imaging technicians working with or close to MRIs are indeed at increased risks of accidents. If confirmed, then future research should tackle the underlying mechanisms, in order to be able to prevent such exposure-associated risks.

Competing interests

All authors declare that they have no conflicts of interest.

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Ethics board

The ethics committee of the University Medical Centre Utrecht declared that ethical approval was not necessary for this survey (protocol number 13-066/C).

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2017.04.022.

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