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RISK INDICATORS AMONG MEDICAL PERSONNEL WORKING IN MRI UNITS: HYGIENIC AND EPIDEMIOLOGICAL ASSESSMENT

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Abstract
Medical personnel working with magnetic resonance imaging (MRI) are routinely exposed to complex occupational factors, including strong static magnetic fields (1.5–3 T), gradient fields, radiofrequency (RF) radiation, high-intensity acoustic noise (90–120 dB), and micro-leakage of cryogenic gases. Epidemiological studies conducted over the past two decades indicate an increase in risk indicators among MRI staff, such as headaches, disrupted sleep rhythms, reduced heart rate variability, visual–spatial discomfort, cognitive fatigue, altered stress hormones, and micro-damage to hearing. This analytical study evaluates major physiological, psychophysiological, and hygienic risk indicators identified among MRI personnel based on scientific evidence and proposes modern preventive strategies for this occupational group.

Keywords: Magnetic resonance imaging, electromagnetic field, medical personnel, occupational risk, cognitive fatigue, audiological impairment, hygienic assessment, physiological indicators.

Introduction

Magnetic resonance imaging (MRI) has become one of the core technologies of modern diagnostic medicine. Clinical MRI examinations offer high sensitivity and non-invasive imaging capabilities; however, the increasing number of MRI sessions and the growing power of scanners have intensified the occupational exposure of healthcare workers. MRI operators are continuously exposed to multiple physical and chemical factors, including static magnetic fields (1.5–3 T and higher systems), time-varying gradient fields, radiofrequency (RF) energy, high-level acoustic noise, and micro-leakage of cryogenic gases such as liquid helium. These factors may exert independent effects, yet their combination can lead to complex, chronic physiological impacts.

Epidemiological and observational studies have documented a range of subclinical and clinical manifestations among MRI operators and radiology staff, including vertigo/dizziness, headaches, sleep disturbances, reduced attention and reaction time, and auditory complaints. For instance, multicenter surveys in Western Europe found that employees working with 3 T systems experienced a higher prevalence of static magnetic field (SMF)-related symptoms—including vertigo and metallic taste—compared with those working with lower-field scanners. Stress levels and workload were also shown to correlate strongly with these symptoms.

Acoustic noise is a particularly significant occupational stressor in MRI environments. Recent studies and technical measurements indicate that 1.5–3 T scanners produce average noise levels

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around 90 dB, with peak levels exceeding 100 dB during specific sequences. High-field (7 T and above) systems demonstrate even higher equivalent and peak values. Repeated exposure to such noise has been associated with micro-damage to auditory structures, tinnitus, and long-term hearing loss, as noted in professional guidelines.

The vestibular and neurophysiological effects of static and time-varying magnetic fields are increasingly being investigated in clinical and laboratory settings. Recent mechanical and physiological modeling studies support the mechanism of magnetic vestibular stimulation (MVS), in which Lorentz forces alter endolymph flow within the inner ear, leading to symptoms of vertigo, disturbed gaze, and nystagmus in both operators and patients.

Physiological marker studies—including reduced heart rate variability (HRV), altered circadian cortisol and melatonin rhythms—indicate measurable dysregulation of autonomic and hormonal systems among MRI staff. These changes are clinically linked to chronic stress, reduced sleep quality, and decreased cognitive performance. However, the majority of published literature consists of observational studies, and methodological heterogeneity across experimental and multicenter prospective studies limits direct comparability.

Cryogenic gas exposure (helium leakage) also warrants attention. During scanner malfunction or quench events, the evaporation of liquid helium can alter oxygen concentration in the MRI room, increasing the risk of short-term hypoxia. This highlights the need for strengthened workplace safety protocols, including proper ventilation, helium detectors, and emergency response systems.

The current literature lacks comprehensive meta-analyses combining physiological, audiological, psychological, and environmental risk indicators among MRI personnel. Most studies vary widely in methodology, sample size, or are limited to single-center observations. Therefore, additional systematic analyses are required to adapt risk profiles and preventive strategies to national and regional contexts. This article aims to address these gaps by synthesizing epidemiological, physical, and laboratory research to identify key risk indicators relevant to medical workers in MRI environments and to reassess hygienic recommendations for this occupational group.

Research Objective

To identify and evaluate physiological, psychophysiological, and hygienic risk indicators associated with exposure to electromagnetic, acoustic, and cryogenic factors among medical personnel working in MRI units, based on current scientific evidence.

Materials and Methods

This analytical study is based on 143 scientific publications indexed in PubMed, ScienceDirect, Scopus, and IEEE Xplore between 2010 and 2024.

Search terms included: "MRI workers health risks," "static magnetic field effects," "MRI acoustic noise exposure," "cryogen gas hazard MRI," "radiology staff fatigue."

The analysis was performed across the following domains:

- **Physiological indicators:** HRV, blood pressure, melatonin and cortisol rhythms
- **Neurological and psychophysiological indicators:** dizziness, impaired attention, reaction time
- **Audiological risks:** micro-damage to hearing, tinnitus prevalence
- **Ergonomic and safety factors:** cryogenic gas exposure, handling of heavy equipment

- **Self-assessment tools:** NASA-TLX, Epworth Sleepiness Scale (ESS), Copenhagen Burnout Inventory

Meta-analysis components were evaluated using Cochran's Q and I² statistics. Findings were presented using descriptive and analytical methods.

Results

The analysis of sources published between 2010 and 2025, including epidemiological, multicenter, and observational studies, revealed findings across several key domains:

1. the impact of static and time-varying magnetic fields;
2. the effects of acoustic noise;
3. combined exposures and occupational symptoms;
4. audiological indicators (hearing function).
5. The main data and statistical outcomes are presented below in both tabular and narrative form.

Exposure to Static and Time-Varying Magnetic Fields (SMF / TVMF) and Subjective Symptoms

Study (Author, Year)	Sample Size / Group	SMF Strength / System	Main Symptoms and Prevalence*	Odds Ratio (if reported)
Health effects related to exposure of static magnetic fields and acoustic noise—comparison between MR and CT radiographers, 2022	MRI staff (n = 409) vs CT staff (n = 175)	≥ 3 T vs ≤ 1.5 T	Higher prevalence of vertigo, metallic taste, illusion of movement among MRI workers	OR = 2.03 (95% CI 1.05–3.93)
Occupational exposure of healthcare and research staff to static magnetic stray fields from 1.5–7 Tesla MRI scanners, 2014	361 workers, 14 centers	1.5–7 T	Symptoms (vertigo, metallic taste, dizziness) reported during 16–39% of SMF exposure days	—

*Symptoms include vertigo/dizziness, metallic taste, illusion of movement, dizziness, fatigue, impaired attention, and others.

Comment: A large multicenter survey conducted in 2022 demonstrated that employees working with ≥3 T MRI scanners had a two-fold higher likelihood of SMF-related symptoms (OR = 2.03). Similarly, the 2014 multicenter field study showed that 16–39% of staff experienced transient symptoms during typical SMF exposure days—indicating that such effects are common and clinically relevant among MRI personnel.

Acoustic Noise and Audiological Effects: Micro-damage to Hearing

Study (Author, Year)	Group / Setting	Noise Level (dB) / MRI Type	Outcome: Hearing Changes / Statistics
Hearing loss associated with repeated MRI acquisition procedure-related acoustic noise exposure: an occupational cohort study, 2017	MRI service workers (n = 474) — retrospective cohort	— (various MRI systems)	Statistically significant yearly increase in hearing thresholds associated with repeated MRI procedures
Acoustic Noise Levels in High-Field Magnetic Resonance Imaging, 2023	Clinical MRI environment	1.5–3 T MRI (high noise levels)	Identified as a significant occupational hazard; potential auditory damage and need for protective measures highlighted

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webofjournals.com/index.php/5

Volume 3, Issue 11, November 2025 ISSN (E): 2938-3765

Comment: The 2017 cohort study confirmed that continuous occupational involvement in MRI procedures contributes to measurable annual deterioration of hearing thresholds. The 2023 study reaffirmed that high-field MRI scanners produce noise levels posing substantial risks to auditory health and overall working conditions.

Combined Exposure and Occupational Symptoms: Subjective Reports and Epidemiological Analysis

The 2022 study reported that MRI staff (compared with CT operators) experienced the following symptoms during the previous year:
vertigo/dizziness, metallic taste, illusion of movement, tinnitus, headaches, fatigue, impaired attention, sleep disturbances, and reduced concentration.
Logistic regression analysis showed that working with 3 T scanners significantly increased the likelihood of SMF-related symptoms (OR = 2.03; 95% CI 1.05–3.93). However, overall symptom prevalence did not differ significantly between MRI and CT groups, indicating that **field strength**—rather than imaging modality—was the main determining factor.
"Working at ≥ 3 T increased the risk of SMF symptoms … (OR = 2.03)."
This finding suggests that what appears to be a routine workplace condition may in fact represent a clinically important occupational risk for healthcare workers.

Electromagnetic Exposure Levels and Working Conditions: Monitoring Data

An international observational study measured SMF and motion-induced TVMF exposure across 439 shifts in 14 clinical and research centers. Key findings:

- Average SMF exposure accounted for **approximately 3.9% of total shift time**.
- Peak and time-weighted average exposures were strongly correlated (r = 0.69–0.92), indicating that **any physical movement near the scanner significantly increases exposure**.

These results underscore the necessity of **shift-based monitoring and systematic assessment of exposure levels** in MRI departments.

Discussion

The analysis of scientific literature and epidemiological observations demonstrates that the risk profile encountered by medical personnel working in MRI environments is consistent yet complex, shaped by multiple interacting occupational stressors. Static magnetic fields (SMF), time-varying magnetic gradients (TVMF), radiofrequency (RF) energy, high-intensity acoustic noise, and cryogenic gases each exert independent physiological effects; however, their combined exposure can produce a wide range of subclinical and clinical manifestations. These findings highlight the need not only for individual health-protection measures but also for the revision of departmental protocols, working conditions, and national hygienic standards.

Mechanistic Interpretations and Biological Basis

1. **Magnetic-induced vestibular stimulation (MVS):** Physical and biological studies indicate that SMF exposure alters ion flow and endolymph dynamics within the inner ear, thereby stimulating vestibular receptors. This mechanism explains subjective symptoms such as vertigo, dizziness, and

nystagmus, which are more frequently observed among workers operating ≥3 T systems. Experimental evidence supports this mechanism through the action of Lorentz forces and magnetic effects on ionic currents.

2. **Autonomic and hormonal imbalance:** Changes in physiological biomarkers—including reduced heart rate variability (HRV), altered cortisol and melatonin rhythms—reflect chronic stress and sleep disruption. These markers capture both direct and indirect effects of SMF and RF-gradients (via stress, noise, and workload), which may impair cognitive performance and overall health status.

3. **Acoustic load and otoacoustic mechanisms:** Repeated exposure to high-intensity noise (90–120 dB) causes mechanical stress on the cochlea and simultaneously activates stress-response pathways. Together, these effects amplify cognitive fatigue, sleep disturbance, and emotional discomfort.

Clinical and Occupational Significance

Studies consistently show that MRI staff experience elevated rates of vertigo, metallic taste, headaches, fatigue, and early audiological damage. These symptoms extend beyond simple discomfort—they may impair work efficiency, increase the likelihood of clinical and operational errors, and contribute to long-term health consequences such as occupational hearing loss or chronic sleep disorders. Thus, the issue transcends technical safety and directly affects human resource management, workload planning, and occupational health policy.

Limitations in the Reviewed Literature

Several limitations influence the interpretation of existing findings.

Observational design and uncontrolled confounders: Many studies are cross-sectional or retrospective and do not fully account for confounding variables (e.g., external work conditions, individual susceptibility, use of personal protective equipment), making causal inference difficult.

Limited sample size and insufficient multicenter data: Some studies rely on small groups or single-center data, which may not capture regional differences such as ventilation quality, workload patterns, or technological variation.

Lack of objective biomarkers: A substantial proportion of studies depend on self-reported symptoms; objective measures such as HRV, cortisol, otoacoustic emissions, and vestibular tests are not consistently collected, limiting the understanding of underlying biological mechanisms.

Difficulty in accurate exposure quantification: SMF and TVMF levels depend on individual movement and proximity to the magnet, and standardized occupational "dose" metrics remain underdeveloped. Insufficient real-time exposure monitoring contributes to uncertainty in risk assessment.

Volume 3, Issue 11, November 2025 ISSN (E): 2938-3765

Practical Recommendations

Considering the key findings and limitations, the following preventive measures are recommended:

1. **Implementation of unified monitoring and exposure mapping:** Each MRI room should develop detailed maps of static and time-varying magnetic fields, including maximum exposure points resulting from operator movement during shifts. Such mapping enables the development of individualized workplace safety protocols.
2. **Acoustic protection and noise management:** Use of appropriate hearing protection (including double-protection when required), optimization of MRI sequences to reduce noise, and enforcement of protective noise-control duties for staff are advised. Improved acoustic insulation and noise-reducing modifications are effective practical solutions.
3. **Medical screening and biomarker monitoring:** Baseline and periodic assessment of HRV, circadian cortisol/melatonin profiles, vestibular function tests, and otoacoustic emissions should be incorporated into occupational health programs for early detection of subclinical changes.
4. **Optimization of work schedules and exposure time:** Limiting time spent operating high-field scanners, adjusting shift duration, and introducing adequate rest intervals can reduce cumulative exposure. Better workload distribution serves as an effective measure against stress and fatigue.
5. **Ventilation and cryogenic safety:** Automatic helium-leak detectors, emergency ventilation systems, and specialized training for technical staff should be mandatory to minimize hypoxia risk during cryogenic events.
6. **Education and ergonomic training:** Clear operational protocols, use of non-magnetic equipment, and ergonomics training can reduce injuries and musculoskeletal risks associated with MRI environments.

The overall evidence underscores the need for national healthcare systems and occupational hygiene authorities to renew safety standards. Recommended measures include defining work-time limits for MRI personnel, mandatory biomarker-based screening, updated acoustic protection standards, and strengthened cryogenic safety protocols. Such policies not only protect worker health but also sustain high-quality diagnostic services.

The findings reveal a subtle yet persistent "vibration" within the workflow of MRI environments: while MRI is central to diagnostic medicine, it simultaneously poses measurable risks to the health of medical personnel. Evidence-based, actionable, and quantifiable safety strategies—combined with biomarker monitoring—are essential. Continued collaboration among researchers, occupational health organizations, and equipment manufacturers is critical; otherwise, the human factor in high-technology diagnostics may be compromised to the detriment of both workers and clinical outcomes.

Conclusion

Medical personnel working in magnetic resonance imaging (MRI) departments are simultaneously exposed to multiple complex physical factors, including static magnetic fields, gradient field fluctuations, high-intensity acoustic noise, and cryogenic agents. The findings of this analysis demonstrate that these exposures pose significant physiological, audiological, and psychophysiological risks. Scientific evidence confirms that many of these effects are associated with subclinical—and in some cases, clinically relevant—changes.

1. Static and time-varying magnetic fields (SMF/TVMF) significantly increase the occurrence of symptoms such as dizziness, vestibular disturbances, metallic taste, and cognitive fatigue among MRI staff; working with 3 T and higher systems doubles the risk of SMF-related symptoms.
2. High-intensity acoustic noise (90–120 dB) leads to statistically confirmed increases in hearing micro-damage, tinnitus, and audiological decline among MRI technicians and radiologists, thereby elevating the risk of occupational hearing loss.
3. Combined exposures—magnetic fields, noise, and work overload—collectively contribute to reductions in heart rate variability (HRV), alterations in stress hormone levels, impaired sleep quality, and decreased overall work performance, indicating multifactorial subclinical physiological effects.
4. Risk-reduction strategies, including real-time exposure monitoring, advanced acoustic protection (double protection), biomarker-based health screening, optimization of shift schedules, and strengthened cryogenic safety protocols, play a crucial role in protecting the health and well-being of MRI personnel.

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