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Green radiography: Exploring perceptions, practices, and barriers to sustainability

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ABSTRACT

Introduction: Previous research has delved into the attitudes and behaviors of diverse professions regarding environmental sustainability. However, there needs to be more research specifically targeting radiographers. This study aims to survey radiographers' perceptions, practices, and barriers to change concerning environmental sustainability in radiology.
Methods: Institutional ethical approval was obtained (IRB–COHS–FAC-110-2024) and data collection was conducted using Google Forms (Google Inc., Mountain View, CA). The survey targeted 104 practicing radiographers across several countries. Questions were structured around five domains to gather insights into demographics, training in global warming and climate change, perceptions of sustainability and climate change, sustainability barriers, and current radiology practices on sustainability. Data analysis utilized descriptive and d inferential statistics.
Results: One hundred and four radiographers completed the study. Females had a significantly higher attendance rate in environmental protection campaigns ($P = 0.01$). The majority of respondents (68%) believe in climate change's knowledge and impact on the natural world. Our survey findings demonstrate that 74% of respondents believe there's a need to improve sustainability practices. The most commonly used strategies to decrease energy consumption and emissions were low-energy lighting (60%), real-time power monitoring tools (41%), and energy-efficient heating systems (32%). A significant concern regarding sustainability emerges among respondents: time (50%) and lack of leadership (48%) are prevalent concerns among the identified barriers.
Conclusion: Participants are recognising the importance of environmental sustainability in radiology, but lack of leadership, support, authority, and facility limitations hinder their adoption.
Impact on practice: Radiology must prioritize environmental sustainability by providing resources and training for radiographers and collaborating with healthcare professionals, policymakers, and environmental experts to develop comprehensive strategies for a sustainable healthcare system.

Introduction

Green radiography represents a contemporary approach within radiology, aiming to mitigate waste and adverse environmental effects while promoting sustainability. Radiological procedures typically involve energy and resource consumption for operating machinery, conducting examinations, and producing images. Moreover, the chemicals, pharmaceuticals, and equipment utilised in these processes include environmental hazards, necessitating careful handling to minimise contamination. By adopting green radiology practices, healthcare facilities can not only reduce their ecological impact but also potentially lower healthcare costs. This shift towards environmental responsibility is essential for promoting both cost efficiency and environmental sustainability in the face of climate change.[1–3] Environmental sustainability and climate

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change have become focal points of significant scholarly and societal interest in recent years. This heightened attention is fueled by a growing awareness of the adverse effects of human activities on the environment.[1–3] Within this context, the healthcare sector has emerged as a critical arena for discussions on environmental sustainability. As healthcare facilities undergo expansion and technological advancements, there is a palpable concern regarding their environmental impact, thereby stimulating scholarly discourse on sustainability within this domain. Efforts are being made to reduce the impact of healthcare activities on climate change through various initiatives and strategies aimed at promoting environmentally responsible practices.[1–3] Climate change is altering the survival conditions for humanity and adversely affecting various health outcomes.[4] For instance, there is a global increase in food insecurity and respiratory illnesses,[5] underscoring the urgency of addressing these issues.[4] Moreover, the rising number of climate refugees, who are forced to flee due to famine, drought, flooding, and wildfires, further emphasises the need for immediate action.[5]

Healthcare professionals, particularly radiographers, have considerable potential to collectively or individually contribute to climate change mitigation and advocate for climate action.[6–9] Radiographers, in their daily practices, are consumers of a range of materials, including contrast media, radiopharmaceuticals, various types of radiographic films, and compact discs (CDs).[6,7] However, in many healthcare settings, these products often go unused, are partially used, or expire, leading to wastage.[8,9] Furthermore, a significant portion of healthcare equipment is designed for single-use purposes. Additionally, some consumables are excessively packaged, thereby exacerbating the healthcare sector's carbon footprint.[6–9]

Radiographers, vital in healthcare for their operation of diagnostic imaging equipment, contribute significantly to energy consumption and environmental implications.[10–12] Thus, comprehending radiographers' perspectives on environmental sustainability is imperative for implementing effective strategies to mitigate the environmental footprint of diagnostic imaging services across several countries. Several environmentally responsible practices among radiographers have been documented in the literature. These include actions such as shutting down computers when not in use[13] optimizing the utilization of contrast media,[14] utilizing shared transport services,[15] replacing in-person staff meetings with teleconferencing,[16] employing digital technology,[17] submitting reports electronically rather than printing them,[17,18] utilizing waste paper for draft printing,[18] and utilizing energy-saving equipment, particularly in computed tomography (CT) and magnetic resonance imaging (MRI).[7,8,19,20] By integrating these strategies into daily radiography operations, healthcare facilities can reinforce their commitment to sustainability while simultaneously enhancing patient care and staff efficiency. Embracing environmental sustainability in radiography practice is not only ethically responsible[21,22] but also essential for long-term environmental preservation[19,20] and resource conservation within the evolving healthcare landscape.[19–22]

Mitigating the effects of ionizing radiation on patients and employees is deemed a suitable application of radiation protection principles. Additionally, unnecessary radiographic examinations make a significant contribution to energy consumption and can have a substantial environmental impact. Hence, efficient radiation control and justification of examinations are pivotal elements of environmentally conscious radiology. It should be emphasized that radiology has more extensive legislation and safety measures in place, particularly regarding ionizing radiation, when compared to any other medical technique[7,8,19,20].

Previous research has delved into the attitudes and behaviors of diverse professions regarding environmental sustainability in other domains.[18,23,24] However, there needs to be more research specifically targeting radiographers. Understanding attitudes, behaviors, and barriers to change among radiographers is crucial for formulating effective strategies aimed at promoting environmental sustainability within the field of radiography. Hence, this study aimed to survey radiographers' perceptions, practices, and barriers to change about environmental sustainability across several countries.

Methods

Ethical approval

The study has been approved by the Ethics Committee of Gulf Medical University (IRB–COHS–FAC-110-2024). Participants were required to provide informed consent after receiving a detailed explanation of the study's objectives. To maintain confidentiality, participants were not asked to disclose their identities. Data collection occurred from January 10, 2024, to March 20, 2024. The research team had exclusive access to the securely stored and anonymized data throughout the study.

Participants

The study involved diagnostic radiographers (DRs) currently working in various countries with recent clinical experience, either presently or within the past five years. Participation in the survey was voluntary, and only individuals who met the inclusion criteria were invited to participate. To be included, individuals had to be certified diagnostic radiographers with a valid license, currently employed or employed within the past five years in a clinical radiology setting, and proficient in English, which was the primary language of the survey. The exclusion criteria included radiographers who were not currently practicing or had not practiced within the past five years, radiographers without a valid certification, and radiographers who were not proficient in English. The participant recruitment process used non-probability sampling methods, such as convenience sampling and snowball sampling. The survey was advertised and distributed through professional radiology associations, as well as on social media platforms like LinkedIn and Facebook groups. In snowball sampling, initial participants were encouraged to share the survey link with eligible colleagues. The questionnaire was administered through a secure online survey platform, and participants were obliged to provide informed consent before proceeding with the survey. Response and completion rates were calculated and reported following the CHERRIES guidelines for e-surveys.[26]

Questionnaire development

An online Google Forms questionnaire (uGoogle Inc, Mountain View, CA) was designed following a comprehensive review of the literature, focusing on the attitudes and behaviors of diverse professions regarding environmental sustainability in other domains and aligned with the CHERRIES checklist.[26] Elements from previously employed questionnaires that investigated sustainability attitudes among healthcare professionals[23–25] were also incorporated.

Questionnaire structure

The open survey, consisting of 36 closed-ended questions spread across six pages, meticulously ensured clarity and neutrality while avoiding bias in question construction. Employing professional language tailored to the study's target population, it covered various formats including multiple-choice, text entry, and drop-down options. The questionnaire delved into five principal domains: demographics, exposure to global warming and climate change training, attitudes towards sustainability practices, barriers to sustainability, and radiology practices. Before its official launch, the questionnaire underwent a pilot phase which involved three experienced radiographers from the research team. During this phase, we evaluated the format, layout, and logical coherence of the question. Subsequent modifications were made based on feedback collected from a pilot study conducted with five local radiographers before the online deployment of the questionnaire for data collection. Notably, respondents were allowed to review and amend their answers through a Review step, which displayed a summary of their responses, ensuring accuracy and completeness. This feature was complemented by JavaScript functionality, mandating completion of all required fields before submission and prompting participants to address any omissions post-submission to maintain data integrity. Additionally, the survey system implemented an IP address check to identify potential duplicate entries from the same user.

Reliability

The questionnaire's reliability was assessed using the test-retest method.[27] Internal consistency was verified through this approach. Three respondents completed the questionnaire twice, with a two-week gap between trials. The resulting Pearson correlation coefficient was 0.82, indicating strong internal consistency (>0.8) and reliability in assessing and measuring the intended parameters. Notably, these participants were not included in the study sample.

Data analysis

Data were analyzed using IBM SPSS software package version 20.0. (IBM Corp, Armonk, NY). Categorical data were represented as numbers and percentages. The Chi-square test was applied to investigate the association between categorical variables. Alternatively, the Fisher Exact or Monte Carlo correction test was applied when more than 20% of the cells had an expected count of less than 5. Quantitative data were expressed as range (minimum and maximum), mean, standard deviation, and median. The significance of the obtained results was judged at the 5% level.

Results

104 radiographers, aged 20 to 65, completed the questionnaire. Participants were recruited from 14 different countries: UAE (58.7%), Egypt (19.2%), Jordan (5.8%), the Philippines (2.9%), Lebanon (1.9%), Nigeria (1.9%), Pakistan (1.9%), Syria (1.9%), Saudi Arabia (1.0%), Portugal (1.0%), Palestine (1.0%), Ireland (1.0%), Guyana (1.0%), and Australia (1.0%). 51% of the participants were female. The academic qualifications of the participants were as follows: 81% held a BSc degree, 10% held an MSc degree, 5% held a PhD degree, and 5% held a Diploma. The participants had an average of 6.4 years of experience, with a standard deviation of 8.1 (ranging from 1 to 42 years). 52.9% of the respondents had 1–3 years of experience, while 17.3% had 4–6 years of experience, and 6.7% had 7–9 years of experience. 23.1% of radiographers had over 9 years of experience. The participants worked in different settings: university hospitals (48%), private hospitals (31%), and public or government hospitals (21%). The main subspecialties among radiographers were General Radiography (40%), MRI (21%), CT (17%), and other areas (20%).

Sustainability training

Less than half of the participants enrolled in sustainability courses 48 (46%), and a comparable proportion attended recycling courses 50 (48%). The primary source of information about sustainability and recycling was the Internet 66 (64%) followed by news (34%) and training courses (32%). Upon comparing genders and their training backgrounds and information sources, a notable finding emerged: females may demonstrate a significantly higher attendance rate in environmental protection campaigns ($P = 0.01$). No other significant correlations were found (see Table 1)."

Perceptions of global warming and local climate change

The majority of respondents (68%) expressed confidence in their knowledge about climate change and its impact on the natural world. An even larger percentage (73%) believed that climate change is happening at a regional level (69%). It is worth noting that 42.3% of respondents expressed concerns about the negative consequences of global climate change. When asked about the causes of global warming, respondents identified serious pollution (68%)

Table 1
Relation between gender and sustainability background and training (n = 104).

Sustainability background and training	Total (n = 104)	Gender		χ^2	p
		Male (n = 51)	Female (n = 53)		
I attended advanced training courses about Sustainability					
No	56 (53.8%)	26 (51.0%)	30 (56.6%)	0.331	0.565
Yes	48 (46.2%)	25 (49.0%)	23 (43.4%)		
I attended advanced training courses about Recycling					
No	54 (51.9%)	26 (51.0%)	28 (52.8%)	0.036	0.850
Yes	50 (48.1%)	25 (49.0%)	25 (47.2%)		
How did you get to know more about sustainability and recycling?					
Training courses	33 (31.7%)	17 (33.3%)	16 (30.2%)	0.119	0.731
Conferences	24 (23.1%)	10 (19.6%)	14 (26.4%)	0.678	0.410
Internet	66 (63.5%)	28 (54.9%)	38 (71.7%)	3.162	0.075
Friends or Family	18 (17.3%)	6 (11.8%)	12 (22.6%)	2.148	0.143
News	35 (33.7%)	17 (33.3%)	18 (34.0%)	0.005	0.946
Radio	9 (8.7%)	3 (5.9%)	6 (11.3%)	0.972	$^{FE}p = 0.489$
Environmental protection campaign	21 (20.2%)	5 (9.8%)	16 (30.2%)	6.702[a]	0.010[a]
Personal involvement in environmental protection activities	13 (12.5%)	6 (11.8%)	7 (13.2%)	0.049	0.824

χ^2: **Chi square test** FE**: Fisher Exact**.
p: p value for Relation between **gender** and **sustainability background and training**.
[a] Statistically significant at $p \le 0.05$.

and population explosion (66%) as the primary factors. Other factors mentioned were changes in the atmosphere (55%), greenhouse effect (38%), destruction of forests and farmland (58%), rapid development of the industry (5%), the process of rural urbanization (30.8%), deterioration of the ecological environment (36%), increasing motor vehicles (58%), and others (3%). Furthermore, there was a statistically significant difference between genders in terms of willingness to participate in efforts to mitigate climate change ($\chi2 = 9.539$, $p = 0.025$), willingness to provide individual benefits to address existing sustainability problems ($\chi2 = 10.949$, $p = 0.013$), and perception of climate change currently occurring in their local region ($\chi2 = 8.912$, $p = 0.030$) (Table 2).

The majority of participants expressed strong agreement with various concerns. Specifically, 88% strongly agreed that climate change would result in extreme weather events like droughts, storms, floods, and hurricanes. Additionally, 91% believed that human health would be adversely affected, 86.5% believed that agricultural production would be impacted, and 84% thought climate change would lead to a natural ecological crisis. Furthermore, 83% of respondents acknowledged the potential emergence and re-emergence of infectious diseases due to climate change. Similarly, 83% agreed that rising sea levels would submerge low-lying areas. However, no significant differences were noted between genders in terms of their perception of the impact of climate change (Table 2).

Table 2
Relation between gender and perception of climate change and global warming (n = 104).

Climate change and Global warming	Total (n = 104)	Gender		χ2	p
		Male (n = 51)	Female (n = 53)		
I am well-informed about climate change and the impact that human action has on the natural world					
Strongly disagree	8 (7.7%)	5 (9.8%)	3 (5.7%)	1.632	MCp= 0.834
Disagree	7 (6.7%)	4 (7.8%)	3 (5.7%)		
Neutral	18 (17.3%)	9 (17.6%)	9 (17.0%)		
Agree	40 (38.5%)	17 (33.3%)	23 (43.4%)		
Strongly agree	31 (29.8%)	16 (31.4%)	15 (28.3%)		
I am concerned about the climate change and the impact people are having on the environment					
Strongly disagree	7 (6.7%)	4 (7.8%)	3 (5.7%)	2.828	MCp= 0.626
Disagree	3 (2.9%)	1 (2.0%)	2 (3.8%)		
Neutral	23 (22.1%)	9 (17.6%)	14 (26.4%)		
Agree	40 (38.5%)	23 (45.1%)	17 (32.1%)		
Strongly agree	31 (29.8%)	14 (27.5%)	17 (32.1%)		
What do you think are the reasons for global warming?					
Population explosion	69 (66.3%)	31 (60.8%)	38 (71.7%)	1.386	0.239
Changes in the atmosphere	57 (54.8%)	27 (52.9%)	30 (56.6%)	0.141	0.708
Serious pollution	71 (68.3%)	28 (54.9%)	43 (81.1%)	8.255[a]	0.004[a]
Greenhouse effect	39 (37.5%)	16 (31.4%)	23 (43.4%)	1.603	0.205
Forest, and farmland destroyed	60 (57.7%)	23 (45.1%)	37 (69.8%)	6.503[a]	0.011[a]
Rapid development of the industry	54 (51.9%)	25 (49.0%)	29 (54.7%)	0.338	0.561
Process of rural urbanization	32 (30.8%)	11 (21.6%)	21 (39.6%)	3.977[a]	0.046[a]
Ecological environment deterioration	37 (35.6%)	18 (35.3%)	19 (35.8%)	0.003	0.953
Motor vehicles increasing	60 (57.7%)	28 (54.9%)	32 (60.4%)	0.319	0.572
Others	3 (2.9%)	2 (3.9%)	1 (1.9%)	0.384	FEp = 0.614
Human activities (compared to natural factors) are the main cause of climate change					
Strongly disagree	1 (1.0%)	0 (0.0%)	1 (1.9%)	2.515	MCp= 0.760
Disagree	1 (1.0%)	1 (2.0%)	0 (0.0%)		
Neutral	19 (18.3%)	9 (17.6%)	10 (18.9%)		
Agree	42 (40.4%)	19 (37.3%)	23 (43.4%)		
Strongly agree	41 (39.4%)	22 (43.1%)	19 (35.8%)		
Global warming has already occurred					
Strongly disagree	1 (1.0%)	1 (2.0%)	0 (0.0%)	1.364	0.976
Disagree	2 (1.9%)	1 (2.0%)	1 (1.9%)		
Neutral	24 (23.1%)	11 (21.6%)	13 (24.5%)		
Agree	45 (43.3%)	22 (43.1%)	23 (43.4%)		
Strongly agree	32 (30.8%)	16 (31.4%)	16 (30.2%)		
Do you think developed countries or developing countries need to take greater responsibility for global climate change?					
The former	20 (19.2%)	10 (19.6%)	10 (18.9%)	2.626	0.667
The latter	1 (1.0%)	0 (0.0%)	1 (1.9%)		
Both responsibilities fairly	62 (59.6%)	29 (56.9%)	33 (62.3%)		
Differentiated responsibilities	12 (11.5%)	8 (15.7%)	4 (7.5%)		
Unable to explain clearly	9 (8.7%)	4 (7.8%)	5 (9.4%)		
Climate change be avoided					
Strongly disagree	1 (1.0%)	0 (0.0%)	1 (1.9%)	5.456	0.214
Disagree	8 (7.7%)	5 (9.8%)	3 (5.7%)		
Neutral	34 (32.7%)	14 (27.5%)	20 (37.7%)		
Agree	33 (31.7%)	14 (27.5%)	19 (35.8%)		
Strongly agree	28 (26.9%)	18 (35.3%)	10 (18.9%)		
If someone called for it, I would like to join the actual efforts to mitigate climate change.					
Strongly disagree	2 (1.9%)	1 (2.0%)	1 (1.9%)	9.539[a]	0.025[a]
Disagree	2 (1.9%)	2 (3.9%)	0 (0.0%)		
Neutral	25 (24.0%)	7 (13.7%)	18 (34.0%)		
Agree	53 (51.0%)	26 (51.0%)	27 (50.9%)		
Strongly agree	22 (21.2%)	15 (29.4%)	7 (13.2%)		

(continued on next page)

Table 2 (*continued*)

Climate change and Global warming	Total (n = 104)	Gender		χ2	p
		Male (n = 51)	Female (n = 53)		
I am willing to sacrifice some individual benefit to solve existing problems					
Strongly disagree	2 (1.9%)	2 (3.9%)	0 (0.0%)	10.945[a]	0.013[a]
Disagree	3 (2.9%)	2 (3.9%)	1 (1.9%)		
Neutral	26 (25.0%)	9 (17.6%)	17 (32.1%)		
Agree	50 (48.1%)	21 (41.2%)	29 (54.7%)		
Strongly agree	23 (22.1%)	17 (33.3%)	6 (11.3%)		
I do participate in some environmental protection activities related to climate change					
Strongly disagree	4 (3.8%)	3 (5.9%)	1 (1.9%)	6.141	MCp= 0.180
Disagree	6 (5.8%)	2 (3.9%)	4 (7.5%)		
Neutral	35 (33.7%)	13 (25.5%)	22 (41.5%)		
Agree	38 (36.5%)	19 (37.3%)	19 (35.8%)		
Strongly agree	21 (20.2%)	14 (27.5%)	7 (13.2%)		
Climate change has happened in my local region					
Strongly disagree	1 (1.0%)	1 (2.0%)	0 (0.0%)	8.912[a]	MCp= 0.030[a]
Disagree	2 (1.9%)	0 (0.0%)	2 (3.8%)		
Neutral	29 (27.9%)	12 (23.5%)	17 (32.1%)		
Agree	45 (43.3%)	19 (37.3%)	26 (49.1%)		
Strongly agree	27 (26.0%)	19 (37.3%)	8 (15.1%)		
What kind of impacts climate change will bring to us?					
None	4 (3.8%)	2 (3.9%)	2 (3.8%)	4.970	MCp= 0.167
Positive effects	17 (16.3%)	12 (23.5%)	5 (9.4%)		
Negative effects	44 (42.3%)	22 (43.1%)	22 (41.5%)		
Both positive effects and negative effects	39 (37.5%)	15 (29.4%)	24 (45.3%)		
How did you perceive your well-being during climate change					
Lethargy	32 (30.8%)	13 (25.5%)	19 (35.8%)	1.309	0.253
Work Fatigue and low efficiency	69 (66.3%)	31 (60.8%)	38 (71.7%)	1.386	0.239
Affects contact with others	33 (31.7%)	18 (35.3%)	15 (28.3%)	0.587	0.444
Decreased appetite	35 (33.7%)	18 (35.3%)	17 (32.1%)	0.121	0.728
Rising energy fee	30 (28.8%)	17 (33.3%)	13 (24.5%)	0.982	0.322
Outdoor activity affected	58 (55.8%)	26 (51.0%)	32 (60.4%)	0.930	0.335
Poor personal comfort	49 (47.1%)	27 (52.9%)	22 (41.5%)	1.363	0.243
Not sleep well	25 (24.0%)	12 (23.5%)	13 (24.5%)	0.014	0.905
Influences of climate change					
Increasing extreme weather (storms, floods, droughts, hurricanes, etc.)					
Strongly disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)	3.049	MCp= 0.356
Disagree	2 (1.9%)	0 (0.0%)	2 (3.8%)		
Don't Know	11 (10.6%)	6 (11.8%)	5 (9.4%)		
Agree	46 (44.2%)	20 (39.2%)	26 (49.1%)		
Strongly agree	45 (43.3%)	25 (49.0%)	20 (37.7%)		
Affecting human health					
Strongly disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)	3.135	MCp= 0.240
Disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)		
Don't Know	9 (8.7%)	5 (9.8%)	4 (7.5%)		
Agree	54 (51.9%)	22 (43.1%)	32 (60.4%)		
Strongly agree	41 (39.4%)	24 (47.1%)	17 (32.1%)		
Affecting agricultural production					
Strongly disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)	3.840	MCp= 0.233
Disagree	1 (1.0%)	1 (2.0%)	0 (0.0%)		
Don't Know	13 (12.5%)	6 (11.8%)	7 (13.2%)		
Agree	47 (45.2%)	19 (37.3%)	28 (52.8%)		
Strongly agree	43 (41.3%)	25 (49.0%)	18 (34.0%)		
Initiating natural ecological crisis					
Strongly disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)	2.608	0.271
Disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)		
Don't Know	17 (16.3%)	8 (15.7%)	9 (17.0%)		
Agree	46 (44.2%)	19 (37.3%)	27 (50.9%)		
Strongly agree	41 (39.4%)	24 (47.1%)	17 (32.1%)		
Sea-level rise and submerge low-lying area					
Strongly disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.938	0.625
Disagree	0 (0.0%)	0 (0.0%)	0 (0.0%)		
Don't Know	18 (17.3%)	8 (15.7%)	10 (18.9%)		
Agree	38 (36.5%)	17 (33.3%)	21 (39.6%)		
Strongly agree	48 (46.2%)	26 (51.0%)	22 (41.5%)		
The increasing threat of infectious diseases					
Strongly disagree	1 (1.0%)	1 (2.0%)	0 (0.0%)	5.620	MCp= 0.157
Disagree	1 (1.0%)	0 (0.0%)	1 (1.9%)		
Don't Know	16 (15.4%)	8 (15.7%)	8 (15.1%)		
Agree	44 (42.3%)	17 (33.3%)	27 (50.9%)		
Strongly agree	42 (40.4%)	25 (49.0%)	17 (32.1%)		

χ^2: **Chi-square test** FE**: Fisher Exact** MC: **Monte Carlo**.
p: p-value for Relation between **gender**, **climate change and global warming**.
[a] Statistically significant at $p \leq 0.05$.

Sustainability practices in radiology

74% of the respondents believe that there is a need for improvement in sustainability practices in their department or clinic. The most commonly employed strategies to reduce energy consumption and emissions include the use of low-energy lighting (60%), real-time power monitoring tools (41%), and energy-efficient heating systems (32%). Notable efforts to promote environmentally friendly transportation options, such as cycling (33%) and public transport (30%), are also selected. Proactive adoption of renewable energy sources, such as solar panel electricity (30%), and the implementation of policies to reduce emissions (29%) demonstrate commitment to sustainability. Initiatives such as water-saving measures through the use of sensor sensors (25.0%) and carpooling incentives (25%) contribute to the conservation of resources. Regarding waste reduction practices in radiography departments and clinics, various strategies are employed to minimize environmental impact. These include sustainable printing practices such as double-sided printing (50%) and the reuse of clinic equipment whenever possible (44.2%). Other efforts to reduce waste include optimizing procurement processes by scheduling orders to minimize the frequency of delivery (39%) and conducting waste audits (39%). A comprehensive approach to sustainability is demonstrated through recycling initiatives for clinic waste (35%), and the procurement of recycled office supplies (31%). The recycling of contrast media waste (26.0%) and the composting of food waste (24%) further illustrate a comprehensive waste management strategy (Table 3).

46% of the respondents have a designated sustainability position, while 44% provide staff training to improve sustainability. Furthermore, 39% discuss sustainability during meetings, and 38% have channels for receiving suggestions from patients and staff. Lastly, 25% of the respondents take steps to offset carbon emissions. Regarding change in personal behavior in response to climate change concerns, 75% of respondents agreed or strongly agreed. Moreover, a majority (72%) of respondents recognized the responsibility of radiographers to consider the environmental impact of imaging services, and 72% expressed agreement or strong agreement. Regarding recycling habits, a significant portion of respondents (60%) reported actively recycling at home. However, opinions on recycling practices within the hospital setting varied, with 44% agreeing or strongly agreeing that imaging and contrast media waste is typically recycled. Additionally, there seems to be a desire among respondents to expand recycling efforts to include radiographic waste, as 63% expressed agreement or strong agreement with this sentiment. In particular, no significant differences were observed between the genders in terms of their practice of climate change (Table 3).

Sustainability practices in radiology across workplaces

Several statistically significant differences were found in the analysis of sustainability practices in radiology across workplaces. (54.5%) Public and (42.0%) university hospitals were more likely to schedule orders to reduce delivery frequency than (21.9%) private hospitals ($p = 0.041$). University hospitals also showed a higher likelihood of composting food waste ($p = 0.018$) and providing avenues for sustainability suggestions from patients and staff ($p = 0.037$). Additionally, university hospitals had stronger agreement that concern for climate change influenced personal behavior ($p = 0.011$). Radiographers in university and public hospitals were more likely to strongly agree on the responsibility of being aware of the environmental impact of imaging services ($p = 0.022$). Lastly, differences were noted in recycling practices for imaging and contrast media waste, as well as recycling of radiographic waste, with university hospitals showing higher agreement compared to other workplace settings ($p = 0.003$ for both practices) (Table 4).

Barriers to sustainable practices in radiology

Among the barriers identified, the lack of leadership emerges as a prevalent concern 48% Additionally, the lack of support from colleagues (42%) and the lack of authority to initiate change (45%) are identified as significant barriers. Safety concerns (36%) and facility limitations (32%) can also contribute to sustainability initiatives' complexity. Time constraints (50%) and financial implications (51%) further compound the challenges, with staffing attitudes (54%) and insufficient training and information (36%) exacerbating the situation. When asked to identify the greatest barrier to sustainability, lack of leadership (20%) emerged as the most significant concern, followed by staff attitude (17%) and inadequate training and information (19%). In efforts to improve recycling practices within radiology departments, respondents expressed a willingness to contribute resources. The majority (74%) are willing to allocate time for self-education. Additionally, a substantial portion (58%) are prepared to dedicate time to educating others. However, financial support for educational initiatives is less enthusiastically endorsed, with fewer respondents willing to allocate funds for either personal (27%) or collective (30%) educational initiatives. In particular, no significant differences were observed between the genders in terms of their barriers (Table 5).

Workplace settings and barriers

The analysis of barriers to sustainability in radiology departments revealed significant differences across various workplace settings. Public and government hospitals reported a higher incidence of lack of leadership as a barrier to sustainability (72.7%) compared to private (40.6%) and university hospitals (42.0%) ($p = 0.033$). On the other hand, university hospitals were more likely to encounter a lack of support from colleagues (56.0%) than private (25.0%) and public hospitals (36.4%) ($p = 0.018$). Time constraints were more frequently reported as a barrier in public hospitals (68.2%) compared to private (31.3%) and university hospitals (54.0%) ($p = 0.021$). When considering the greatest barrier to sustainability, lack of leadership was most frequently cited overall, particularly in public hospitals (31.8%) compared to private (18.8%) and university hospitals (16.0%) ($p = 0.006$). These findings indicate that the type of hospital significantly influences the specific barriers to implementing sustainable practices in radiology, with public and government hospitals facing challenges related to leadership and university hospitals dealing with issues of collegial support (Table 6).

Discussion

Over the past two decades, there has been a significant increase in the use of medical imaging procedures.[28] Concurrently, the healthcare sector, which is known for its substantial contribution to environmental pollution primarily through energy inefficiencies, is now facing the reality that medical imaging practices have emerged as a significant environmental concern. Several studies[6,9,29–32] have highlighted this growing environmental issue. Currently, radiography and its associated reporting processes have transitioned entirely into the digital realm, with the traditional film radiography method undergoing phased elimination since the latter part of 2007,[33] particularly within high-income and technologically advanced nations. Despite this transition, the use of film radiography still persists in low-income countries, perpetuating the utilization of an inherently wasteful material.[34,35] Although there are

Table 3
Relation between gender and sustainability practices in radiology (n = 104).

Sustainability Practices in Radiology	Total (n = 104)	Gender		χ2	p
		Male (n = 51)	Female (n = 53)		
Your department/clinic could do more to improve its sustainability					
Strongly disagree	1 (1.0%)	0 (0.0%)	1 (1.9%)	7.601	MCp=
Disagree	2 (1.9%)	0 (0.0%)	2 (3.8%)		0.066
Neutral	26 (25.0%)	14 (27.5%)	12 (22.6%)		
Agree	46 (44.2%)	18 (35.3%)	28 (52.8%)		
Strongly agree	29 (27.9%)	19 (37.3%)	10 (18.9%)		
Does your department/clinic do any of the following to reduce energy and emissions?					
Use of a real-time power monitoring tool	43 (41.3%)	21 (41.2%)	22 (41.5%)	0.001	0.973
Use of low-energy lighting	62 (59.6%)	29 (56.9%)	33 (62.3%)	0.315	0.575
Energy-efficient heating	33 (31.7%)	19 (37.3%)	14 (26.4%)	1.410	0.235
Energy-efficient appliances	31 (29.8%)	12 (23.5%)	19 (35.8%)	1.885	0.170
Retrofitting of insulation and/or double glazing	16 (15.4%)	9 (17.6%)	7 (13.2%)	0.394	0.530
Use of solar panel electricity	31 (29.8%)	15 (29.4%)	16 (30.2%)	0.007	0.931
Sensor taps to reduce water use	26 (25.0%)	11 (21.6%)	15 (28.3%)	0.628	0.428
Provide information about public transport	20 (19.2%)	9 (17.6%)	11 (20.8%)	0.162	0.688
Encourage staff to car-pool	26 (25.0%)	14 (27.5%)	12 (22.6%)	0.321	0.571
Encourage staff to use public transport	31 (29.8%)	15 (29.4%)	16 (30.2%)	0.007	0.931
Encourage staff to cycle	34 (32.7%)	21 (41.2%)	13 (24.5%)	3.274	0.070
Emission reduction policy	30 (28.8%)	16 (31.4%)	14 (26.4%)	0.311	0.577
Use of electricity providers that use renewable sources	23 (22.1%)	13 (25.5%)	10 (18.9%)	0.662	0.416
Audits of energy use or emission	19 (18.3%)	9 (17.6%)	10 (18.9%)	0.026	0.872
Others	3 (2.9%)	1 (2.0%)	2 (3.8%)	0.305	FEp = 1.000
Does your department/clinic do any of the following to reduce waste?					
Re-use clinic equipment where appropriate	46 (44.2%)	27 (52.9%)	19 (35.8%)	3.078	0.079
Schedule orders to reduce the frequency of deliveries	40 (38.5%)	20 (39.2%)	20 (37.7%)	0.024	0.877
Buy recycled office supplies	32 (30.8%)	17 (33.3%)	15 (28.3%)	0.309	0.578
Use double-sided printing	52 (50.0%)	24 (47.1%)	28 (52.8%)	0.346	0.556
Audit their waste production	40 (38.5%)	24 (47.1%)	16 (30.2%)	3.125	0.077
Recycle clinic waste	36 (34.6%)	21 (41.2%)	15 (28.3%)	1.903	0.168
Compost food waste	25 (24.0%)	11 (21.6%)	14 (26.4%)	0.334	0.563
Recycle Contrast Media waste	27 (26.0%)	12 (23.5%)	15 (28.3%)	0.308	0.579
Which of the following statements apply to your department/clinic?					
We have an acknowledged position on sustainability	48 (46.2%)	24 (47.1%)	24 (45.3%)	0.033	0.856
Staff are offered training to improve department/clinic sustainability	46 (44.2%)	24 (47.1%)	22 (41.5%)	0.324	0.569
Sustainability is discussed at department/clinic meetings	41 (39.4%)	19 (37.3%)	22 (41.5%)	0.197	0.657
Patients and staff have avenues to suggest ways to improve sustainability	39 (37.5%)	17 (33.3%)	22 (41.5%)	0.741	0.389
We offset carbon emissions in some way	26 (25.0%)	12 (23.5%)	14 (26.4%)	0.115	0.734
My concern about climate change has made me change my behaviors in my personal life					
Strongly disagree	8 (7.7%)	7 (13.7%)	1 (1.9%)	8.771	MCp=
Disagree	3 (2.9%)	1 (2.0%)	2 (3.8%)		0.056
Neutral	44 (42.3%)	17 (33.3%)	27 (50.9%)		
Agree	34 (32.7%)	16 (31.4%)	18 (34.0%)		
Strongly agree	15 (14.4%)	10 (19.6%)	5 (9.4%)		
Radiographers have a responsibility to be aware of the environmental impact of Imaging services					
Strongly disagree	5 (4.8%)	4 (7.8%)	1 (1.9%)	3.885	MCp=
Disagree	3 (2.9%)	1 (2.0%)	2 (3.8%)		0.424
Neutral	21 (20.2%)	12 (23.5%)	9 (17.0%)		
Agree	46 (44.2%)	19 (37.3%)	27 (50.9%)		
Strongly agree	29 (27.9%)	15 (29.4%)	14 (26.4%)		
I recycle at home					
Strongly disagree	4 (3.8%)	4 (7.8%)	0 (0.0%)	8.640	MCp=
Disagree	10 (9.6%)	5 (9.8%)	5 (9.4%)		0.066
Neutral	28 (26.9%)	11 (21.6%)	17 (32.1%)		
Agree	43 (41.3%)	18 (35.3%)	25 (47.2%)		
Strongly agree	19 (18.3%)	13 (25.5%)	6 (11.3%)		
Imaging and contrast media waste are usually recycled in the hospital I work in					
Strongly disagree	10 (9.6%)	8 (15.7%)	2 (3.8%)	7.024	0.135
Disagree	23 (22.1%)	10 (19.6%)	13 (24.5%)		
Neutral	34 (32.7%)	13 (25.5%)	21 (39.6%)		
Agree	23 (22.1%)	11 (21.6%)	12 (22.6%)		
Strongly agree	14 (13.5%)	9 (17.6%)	5 (9.4%)		
I would like to recycle Radio graphic waste					
Strongly disagree	9 (8.7%)	8 (15.7%)	1 (1.9%)	8.347	MCp=
Disagree	4 (3.8%)	2 (3.9%)	2 (3.8%)		0.073
Neutral	26 (25.0%)	9 (17.6%)	17 (32.1%)		
Agree	37 (35.6%)	17 (33.3%)	20 (37.7%)		
Strongly agree	28 (26.9%)	15 (29.4%)	13 (24.5%)		

χ^2: **Chi square test** FE**: Fisher Exact** MC: **Monte Carlo**.
p: p value for Relation between **gender** and **sustainability practices in Radiology**.
*: Statistically significant at $p \leq 0.05$.

Table 4
Relation between workplace and sustainability practices in radiology (n = 104).

Sustainability practices in Radiology	Total (n = 104)	Workplace			χ^2	p
		Private Hospital (n = 32)	Public/ Government Hospital (n = 22)	University Hospital (n = 50)		
Your department/clinic could do more to improve its sustainability						
Strongly disagree	1 (1.0%)	0 (0.0%)	0 (0.0%)	1 (2.0%)	10.658	MCp= 0.137
Disagree	2 (1.9%)	1 (3.1%)	0 (0.0%)	1 (2.0%)		
Neutral	26 (25.0%)	8 (25.0%)	3 (13.6%)	15 (30.0%)		
Agree	46 (44.2%)	10 (31.3%)	11 (50.0%)	25 (50.0%)		
Strongly agree	29 (27.9%)	13 (40.6%)	8 (36.4%)	8 (16.0%)		
Does your department/clinic do any of the following to reduce energy and emissions?						
Use of a real time power monitoring tool	43 (41.3%)	13 (40.6%)	10 (45.5%)	20 (40.0%)	0.197	0.906
Use of low energy lighting	62 (59.6%)	19 (59.4%)	14 (63.6%)	29 (58.0%)	0.203	0.904
Energy efficient heating	33 (31.7%)	10 (31.3%)	5 (22.7%)	18 (36.0%)	1.247	0.536
Energy efficient appliances	31 (29.8%)	8 (25.0%)	5 (22.7%)	18 (36.0%)	1.797	0.407
Retrofitting of insulation and/or double glazing	16 (15.4%)	6 (18.8%)	2 (9.1%)	8 (16.0%)	0.901	MCp = 0.675
Use of solar panel electricity	31 (29.8%)	6 (18.8%)	7 (31.8%)	18 (36.0%)	2.829	0.243
Sensor taps to reduce water use	26 (25.0%)	4 (12.5%)	7 (31.8%)	15 (30.0%)	3.879	0.144
Provide information about public transport	20 (19.2%)	3 (9.4%)	3 (13.6%)	14 (28.0%)	4.920	0.085
Encourage staff to car-pool	26 (25.0%)	9 (28.1%)	7 (31.8%)	10 (20.0%)	1.379	0.502
Encourage staff to use public transport	31 (29.8%)	6 (18.8%)	6 (27.3%)	19 (38.0%)	3.542	0.170
Encourage staff to cycle	34 (32.7%)	14 (43.8%)	6 (27.3%)	14 (28.0%)	2.572	0.276
Emission reduction policy	30 (28.8%)	8 (25.0%)	8 (36.4%)	14 (28.0%)	0.854	0.653
Use of electricity providers that use renewable sources	23 (22.1%)	9 (28.1%)	5 (22.7%)	9 (18.0%)	1.167	0.558
Audits of energy use or emission	19 (18.3%)	6 (18.8%)	4 (18.2%)	9 (18.0%)	0.007	0.996
Others	3 (2.9%)	0 (0.0%)	1 (4.5%)	2 (4.0%)	1.471	MCp = 0.590
Does your department/clinic do any of the following to reduce waste?						
Re-use clinic equipment where appropriate	46 (44.2%)	15 (46.9%)	11 (50.0%)	20 (40.0%)	0.750	0.687
Schedule orders to reduce frequency of deliveries	40 (38.5%)	7 (21.9%)	12 (54.5%)	21 (42.0%)	6.389[a]	0.041[a]
Buy recycled office supplies	32 (30.8%)	6 (18.8%)	7 (31.8%)	19 (38.0%)	3.409	0.182
Use double sided printing	52 (50.0%)	13 (40.6%)	12 (54.5%)	27 (54.0%)	1.627	0.443
Audit their waste production	40 (38.5%)	16 (50.0%)	7 (31.8%)	17 (34.0%)	2.631	0.268
Recycle clinic waste	36 (34.6%)	13 (40.6%)	8 (36.4%)	15 (30.0%)	1.011	0.603
Recycle Contrast media waste	5 (4.8%)	0 (0.0%)	1 (4.5%)	4 (8.0%)	2.466	MCp = 0.232
Compost food waste	25 (24.0%)	2 (6.3%)	7 (31.8%)	16 (32.0%)	8.010[a]	0.018[a]
Recycle theatre waste	27 (26.0%)	8 (25.0%)	3 (13.6%)	16 (32.0%)	2.703	0.259
Which of the following statements apply to your department/clinic?						
We have an acknowledged position on sustainability	48 (46.2%)	14 (43.8%)	11 (50.0%)	23 (46.0%)	0.206	0.902
Staff are offered training to improve department/clinic sustainability	46 (44.2%)	11 (34.4%)	10 (45.5%)	25 (50.0%)	1.948	0.378
Sustainability is discussed at department/clinic meetings	41 (39.4%)	12 (37.5%)	6 (27.3%)	23 (46.0%)	2.315	0.314
Patients and staff have avenues to suggest ways to improve sustainability	39 (37.5%)	9 (28.1%)	5 (22.7%)	25 (50.0%)	6.582[a]	0.037[a]
We offset carbon emissions in some way	26 (25.0%)	5 (15.6%)	5 (22.7%)	16 (32.0%)	2.867	0.238
My concern about climate change has made me change my behaviors in my personal life						
Strongly disagree	8 (7.7%)	4 (12.5%)	3 (13.6%)	1 (2.0%)	17.550[a]	MCp= 0.011[a]
Disagree	3 (2.9%)	1 (3.1%)	1 (4.5%)	1 (2.0%)		
Neutral	44 (42.3%)	10 (31.3%)	4 (18.2%)	30 (60.0%)		
Agree	34 (32.7%)	10 (31.3%)	10 (45.5%)	14 (28.0%)		
Strongly agree	15 (14.4%)	7 (21.9%)	4 (18.2%)	4 (8.0%)		
Radiographers have a responsibility to be aware of the environmental impact of Imaging services						
Strongly disagree	5 (4.8%)	3 (9.4%)	2 (9.1%)	0 (0.0%)	15.777[a]	MCp= 0.022[a]
Disagree	3 (2.9%)	0 (0.0%)	2 (9.1%)	1 (2.0%)		
Neutral	21 (20.2%)	7 (21.9%)	1 (4.5%)	13 (26.0%)		
Agree	46 (44.2%)	11 (34.4%)	9 (40.9%)	26 (52.0%)		
Strongly agree	29 (27.9%)	11 (34.4%)	8 (36.4%)	10 (20.0%)		
I recycle at home						
Strongly disagree	4 (3.8%)	2 (6.3%)	1 (4.5%)	1 (2.0%)	8.645	MCp= 0.342
Disagree	10 (9.6%)	3 (9.4%)	2 (9.1%)	5 (10.0%)		
Neutral	28 (26.9%)	9 (28.1%)	2 (9.1%)	17 (34.0%)		
Agree	43 (41.3%)	12 (37.5%)	10 (45.5%)	21 (42.0%)		
Strongly agree	19 (18.3%)	6 (18.8%)	7 (31.8%)	6 (12.0%)		
Imaging and contrast media waste are usually recycled in the hospital I work in						
Strongly disagree	10 (9.6%)	5 (15.6%)	1 (4.5%)	4 (8.0%)	22.760[a]	0.003[a]
Disagree	23 (22.1%)	8 (25.0%)	9 (40.9%)	6 (12.0%)		
Neutral	34 (32.7%)	5 (15.6%)	3 (13.6%)	26 (52.0%)		
Agree	23 (22.1%)	8 (25.0%)	4 (18.2%)	11 (22.0%)		
Strongly agree	14 (13.5%)	6 (18.8%)	5 (22.7%)	3 (6.0%)		
I would like to recycle Radiographic waste						
Strongly disagree	9 (8.7%)	6 (18.8%)	3 (13.6%)	0 (0.0%)	21.400[a]	0.003[a]
Disagree	4 (3.8%)	1 (3.1%)	0 (0.0%)	3 (6.0%)		
Neutral	26 (25.0%)	3 (9.4%)	3 (13.6%)	20 (40.0%)		
Agree	37 (35.6%)	14 (43.8%)	8 (36.4%)	15 (30.0%)		
Strongly agree	28 (26.9%)	8 (25.0%)	8 (36.4%)	12 (24.0%)		
Imaging and contrast media waste are usually recycled in the hospital I work in						
Strongly disagree	10 (9.6%)	5 (15.6%)	1 (4.5%)	4 (8.0%)	22.760[a]	0.003[a]
Disagree	23 (22.1%)	8 (25.0%)	9 (40.9%)	6 (12.0%)		

(*continued on next page*)

Table 4 (*continued*)

Sustainability practices in Radiology	Total (n = 104)	Workplace			χ^2	p
		Private Hospital (n = 32)	Public/ Government Hospital (n = 22)	University Hospital (n = 50)		
Neutral	34 (32.7%)	5 (15.6%)	3 (13.6%)	26 (52.0%)		
Agree	23 (22.1%)	8 (25.0%)	4 (18.2%)	11 (22.0%)		
Strongly agree	14 (13.5%)	6 (18.8%)	5 (22.7%)	3 (6.0%)		
I would like to recycle Radiographic waste						
Strongly disagree	9 (8.7%)	6 (18.8%)	3 (13.6%)	0 (0.0%)	21.400[a]	0.003[a]
Disagree	4 (3.8%)	1 (3.1%)	0 (0.0%)	3 (6.0%)		
Neutral	26 (25.0%)	3 (9.4%)	3 (13.6%)	20 (40.0%)		
Agree	37 (35.6%)	14 (43.8%)	8 (36.4%)	15 (30.0%)		
Strongly agree	28 (26.9%)	8 (25.0%)	8 (36.4%)	12 (24.0%)		

c^2: **Chi square test** MC: **Monte Carlo**.
p: p value for Relation between **Workplace** and **Sustainability practices in Radiology**.
[a] Statistically significant at $p \leq 0.05$.

documented environmental benefits associated with this transition to digital processes[33,] the issue remains a pressing concern for the healthcare sector. It has been argued that the more widespread use of digital technology such as CT and MRI has increased energy consumption within departments and has reduced or simply displaced certain types of waste like contrast media.[7,8,20] With global economic conditions, the push to make further changes in practice toward sustainability is likely driven by a combination of environmental ethics and cost-saving measures. Awareness of the practices in which changes are needed and identifying potential adequate replacements or optimization for current procedures are essential to reduce the environmental impact. Changes implemented must not result in reduced quality of service or increased risk to patients. Therefore, this survey is an investigation of the perceptions, practices, and barriers facing radiographers from several countries about environmental sustainability.

Climate change is causing significant environmental impacts on public health and the healthcare sector, with approximately 10% of the sector's carbon footprint attributed to clinical radiology and radiotherapy waste. Factors such as energy consumption, data generation, radiotherapy treatment activities, travel, and waste from clinical consumables contribute to the eco-footprint. The healthcare industry is calling for sustainable practices and strategies to reduce carbon footprints and waste production. Therefore, there is a need for a comprehensive guide to promote greener clinical practice and research.[36] Our findings align with existing literature.[36] The present study on public perceptions of global warming and climate change provides valuable insights into how the general population views this critical issue. The majority of respondents (68%) expressed confidence in their knowledge about climate change. It is worth noting that 42.3% of respondents expressed concerns about the negative consequences of global climate change.

Table 5
Relation between gender and barriers to sustainability (n = 104).

Barriers to sustainability	Total (n = 104)	Gender		χ^2	p
		Male (n = 51)	Female (n = 53)		
Which of the following is a potential barrier to sustainability in radiology departments					
Lack of leadership	50 (48.1%)	26 (51.0%)	24 (45.3%)	0.338	0.561
Lack of support from colleagues	44 (42.3%)	22 (43.1%)	22 (41.5%)	0.028	0.867
Lack of Authority to make change	47 (45.2%)	19 (37.3%)	28 (52.8%)	2.546	0.111
Safety	37 (35.6%)	22 (43.1%)	15 (28.3%)	2.496	0.114
Facility	33 (31.7%)	16 (31.4%)	17 (32.1%)	0.006	0.939
Time	52 (50.0%)	24 (47.1%)	28 (52.8%)	0.346	0.556
Cost	53 (51.0%)	26 (51.0%)	27 (50.9%)	0.000	0.997
Staff attitude	56 (53.8%)	31 (60.8%)	25 (47.2%)	1.938	0.164
Inadequate training and information	37 (35.6%)	15 (29.4%)	22 (41.5%)	1.660	0.198
Which of the following is the greatest barrier to sustainability in radiology departments					
Lack of leadership	21 (20.2%)	13 (25.5%)	8 (15.1%)	7.522	MCp= 0.495
Lack of support from colleagues	3 (2.9%)	2 (3.9%)	1 (1.9%)		
Lack of authority to make change	11 (10.6%)	4 (7.8%)	7 (13.2%)		
Safety	12 (11.5%)	5 (9.8%)	7 (13.2%)		
Facility	4 (3.8%)	1 (2.0%)	3 (5.7%)		
Time	7 (6.7%)	2 (3.9%)	5 (9.4%)		
Cost	8 (7.7%)	3 (5.9%)	5 (9.4%)		
Staff attitude	18 (17.3%)	12 (23.5%)	6 (11.3%)		
Inadequate training and information	20 (19.2%)	9 (17.6%)	11 (20.8%)		
To increase recycling in Radiology departments I am willing to provide the following					
Time to educate others	60 (57.7%)	29 (56.9%)	31 (58.5%)	0.028	0.867
Time to educate myself	77 (74.0%)	36 (70.6%)	41 (77.4%)	0.620	0.431
Funds (donations from personal income) for the purpose of educating others.	31 (29.8%)	17 (33.3%)	14 (26.4%)	0.595	0.441
Funding (donations from personal income) for my education.	28 (26.9%)	18 (35.3%)	10 (18.9%)	3.564	0.059
None of the above	11 (10.6%)	5 (9.8%)	6 (11.3%)	0.063	0.801

χ^2: **Chi square test** MC: **Monte Carlo**.
p: p-value for Relation between **gender** and **barriers to sustainability**.

Table 6
Relation between workplace and barriers to sustainability (n = 104).

Barriers to sustainability	Total (n = 104)	Workplace			χ^2	p
		Private Hospital (n = 32)	Public/ Government Hospital (n = 22)	University Hospital (n = 50)		
Which of the following is a potential barrier to sustainability in radiology departments						
Lack of leadership	50 (48.1%)	13 (40.6%)	16 (72.7%)	21 (42.0%)	6.807[a]	0.033[a]
Lack of support form colleagues	44 (42.3%)	8 (25.0%)	8 (36.4%)	28 (56.0%)	8.086[a]	0.018[a]
Lack of Authority to make change	47 (45.2%)	14 (43.8%)	11 (50.0%)	22 (44.0%)	0.261	0.878
Safety	37 (35.6%)	14 (43.8%)	5 (22.7%)	18 (36.0%)	2.521	0.283
Facility	33 (31.7%)	9 (28.1%)	6 (27.3%)	18 (36.0%)	0.815	0.665
Time	52 (50.0%)	10 (31.3%)	15 (68.2%)	27 (54.0%)	7.729[a]	0.021[a]
Cost	53 (51.0%)	17 (53.1%)	8 (36.4%)	28 (56.0%)	2.444	0.295
Staff attitude	56 (53.8%)	16 (50.0%)	15 (68.2%)	25 (50.0%)	2.307	0.315
Inadequate training and information	37 (35.6%)	6 (18.8%)	9 (40.9%)	22 (44.0%)	5.774	0.056
Which of the following is the greatest barrier to sustainability in radiology departments						
Lack of leadership	21 (20.2%)	6 (18.8%)	7 (31.8%)	8 (16.0%)	29.472[a]	MCp= 0.006[a]
Lack of support form colleagues	3 (2.9%)	2 (6.3%)	0 (0.0%)	1 (2.0%)		
Lack of authority to make change	11 (10.6%)	2 (6.3%)	2 (9.1%)	7 (14.0%)		
Safety	12 (11.5%)	1 (3.1%)	1 (4.5%)	10 (20.0%)		
Facility	4 (3.8%)	1 (3.1%)	1 (4.5%)	2 (4.0%)		
Time	7 (6.7%)	1 (3.1%)	1 (4.5%)	5 (10.0%)		
Cost	8 (7.7%)	5 (15.6%)	1 (4.5%)	2 (4.0%)		
Staff attitude	18 (17.3%)	12 (37.5%)	3 (13.6%)	3 (6.0%)		
Inadequate training and information	20 (19.2%)	2 (6.3%)	6 (27.3%)	12 (24.0%)		
To increase recycling in Radiology departments I am willing to provide the following						
Time to educate others	60 (57.7%)	14 (43.8%)	15 (68.2%)	31 (62.0%)	3.920	0.141
Time to educate myself	77 (74.0%)	20 (62.5%)	19 (86.4%)	38 (76.0%)	4.055	0.132
Funds (donations from personal income) for the purpose of educating others.	31 (29.8%)	10 (31.3%)	6 (27.3%)	15 (30.0%)	0.100	0.951
Funding (donations from personal income) for my education.	28 (26.9%)	9 (28.1%)	6 (27.3%)	13 (26.0%)	0.047	0.977
None of the above	11 (10.6%)	6 (18.8%)	1 (4.5%)	4 (8.0%)	2.983	MCp = 0.236

c^2: **Chi square test** MC: **Monte Carlo**.
p: p value for Relation between **Workplace** and **Barriers to sustainability**.
[a] Statistically significant at $p \leq 0.05$.

Radiology is the most waste-intensive field, with interventional procedures generating the highest amount of solid waste due to their short duration and the use of disposable products. Audits have shown that on average 8 kg of waste is produced per case, with coiling and embolization procedures being the most significant contributors. Carbon dioxide emissions associated with these procedures can be attributed to several factors, including indoor climate control, disposable surgical items, electricity use, staff transportation, waste disposal, linen production, and the use of gas anesthetics. In addition, diagnostic imaging devices such as MRI, CT scans, X-rays, ultrasounds, and heating ventilation, and air conditioning systems consume a significant amount of energy, leading to substantial waste and placing a burden on the electrical grid. It is estimated that ordering imaging exams more judiciously could result in energy savings of 24-24 million kWh per year in the United States alone.[36–38] To promote a sustainable future in radiology, the American College of Radiology (ACR) is spearheading an environmental sustainability campaign. This initiative emphasizes the importance of collaboration between radiologists, local environmental experts, energy and waste management specialists, and engineers. Together, they can work toward achieving sustainability goals and develop more environmentally friendly imaging and interventional radiology equipment. Through this collaborative effort, new industrial standards can be established to ensure the creation of sustainable equipment that meets the needs of both the medical field and the environment. Moving forward, healthcare institutions must prioritize environmental sustainability and provide the resources and training necessary for radiographers to adopt sustainable practices.[18,23,24] The observed gap between the percentage of respondents who claimed attending recycling training courses (48.1%) and those attributing their knowledge of sustainability and recycling to such courses (31.7%). This difference emphasizes the diverse range of sources individuals use to learn about sustainability. For instance, the discovery that 23.1% of participants gained knowledge from attending conferences underscores the importance of broader educational platforms beyond traditional courses. Conferences may offer workshops, panel discussions, or interactive sessions focused on sustainability, enriching participants' understanding. Hence, it's crucial to acknowledge the various avenues through which people access sustainability education, extending beyond formal training programs.

The survey showed that participants (68%) felt confident in their knowledge of climate change and the effect that has on the environment. This highlights widespread recognition of climate change and its potential consequences. The results also stressed the need for collective action and engagement from individuals, communities, and policymakers to address and mitigate the effects of climate change. Additionally, the survey revealed possible gender differences in perceptions of climate change and willingness to take action, which can inform targeted interventions and awareness campaigns. The results demonstrate an increasing awareness of climate change and the importance of participation from individuals, communities, and policymakers. By integrating sustainability principles into healthcare practices, including radiology, we can contribute to mitigating climate change and creating a healthier environment for current and future generations.

Radiology practices should utilize sustainable practices to minimize the energy that they consume and waste generated. Strategies include reduction in energy use, biodegradable materials, minimal or no waste, and recycling. Radiologists must collaborate with suppliers to have eco-friendly strategies. Additionally, advanced imaging technologies can help reduce energy consumption. Other procedures that save energy are switching off monitors and utilizing efficient lighting systems. In addition to this, sustainability and climate change guidelines (PPGs) need to be implemented as standardized protocols and practice guidelines within radiology departments. These guidelines will improve patient care during imaging procedures while minimizing the environmental impact. Hence, by developing and implementing standardized methods, Radiology Departments can reduce resource utilization, waste production, and carbon emissions from radiological processes. However, it is also important that these recommendations are collectively defined and validated across several clinical settings to establish evidence-based practices that prioritize sustainability.[38] Such an approach ensures protocol efficacy as well as leads.

The analysis of sustainability practices in the field of radiology reveals significant variations among different types of hospitals. Public and university hospitals tend to be more inclined to employ strategies aimed at reducing waste. These strategies include optimizing scheduling to minimize delivery frequency and implementing food waste composting. Additionally, these institutions provide more opportunities for patients and staff to contribute suggestions for enhancing sustainability. They also demonstrate a stronger integration of personal concerns about climate change into their actions. Specifically, university hospitals foster a culture of participation that encourages feedback on sustainability, and they exhibit greater adherence to recycling practices for imaging and radiographic waste compared to private hospitals. These findings suggest that academic and public settings may offer more supportive environments for the adoption of comprehensive sustainability practices. This is driven by institutional policies and a commitment to environmental stewardship. However, there remains a need for broader and more standardized implementation of these practices across all types of hospitals. This will amplify the overall impact of sustainability initiatives in the field of radiology. Our research contributes to the existing body of literature supporting waste reduction and consumption reduction. To gain a deeper understanding of the environmental implications of clinical radiology and radiotherapy, it is essential to prioritize efforts to enhance research, education, and awareness. This approach will foster the development of a sustainable mindset within the healthcare industry.[36] Another study has shown that significant financial savings, improved efficiency, and minimized environmental impact can be achieved through waste reduction, maximizing equipment utilization, and adopting energy-efficient technologies. However, various obstacles must be addressed, including a lack of leadership, misconceptions, and resistance to change. To overcome these challenges, it is crucial to implement a comprehensive educational program involving all staff members.[39]

Participants in the study have identified multiple barriers to achieving sustainability, providing valuable insights into the challenges faced when adopting environmentally friendly practices. Key barriers include staff attitudes and a lack of leadership, which are consistent with challenges observed in other medical fields such as ophthalmology, surgery, anesthesia technology, and public health.[23–25] However, a significant proportion were ready to invest in educational initiatives indicating a desire to surmount obstacles through proactive participation and knowledge exchange. The analysis of sustainability barriers across different radiology work settings reveals significant differences. Public and government hospitals encounter notable challenges related to leadership deficiencies, while university hospitals face obstacles in terms of colleague support. Time constraints also emerge as a prevalent obstacle in public hospitals. Overall, these findings highlight the influence of hospital type on specific obstacles in implementing sustainable practices within radiology, emphasizing leadership issues in public and government hospitals, as well as challenges in collegial support in university settings.

The present study is subject to several limitations that warrant attention. Firstly, the study relied on voluntary participation from radiographers and utilized snowball sampling, potentially introducing self-selection bias. The fact that participating radiographers identified a lack of support from colleagues as a significant barrier suggests that those who took part may possess a higher level of environmental awareness. This finding is further reinforced by the discovery that nearly half of the participants attended advanced training courses on sustainability and recycling. Consequently, it is imperative to recognize that the findings of this study may not accurately represent radiographers as a whole. Moreover, the utilization of an online survey format may impose constraints in terms of geographical or technical access, thereby impacting the generalizability of the findings. In addition, the low number of participants from certain countries hindered meaningful comparisons between them. Therefore, exercising caution when extrapolating these results to a broader population is essential.

In conclusion, the study presents perspectives from radiographers across various countries on the eco-friendliness of medical imaging practices. Radiographers recognize the importance of incorporating sustainable practices into their daily work, as this can effectively mitigate the environmental impact of radiological operations However, barriers such as lack of leadership emerging as a consistent concern, lack of support from colleagues, lack of authority to initiate change, and facility limitations were identified as obstacles to the implementation of eco-friendly initiatives. Moving forward, healthcare institutions should prioritize environmental sustainability and provide the resources and training necessary for radiographers to adopt sustainable practices. The analysis of sustainability practices in radiology reveals disparities among hospital types. Public and university hospitals show greater commitment to waste reduction and sustainability initiatives. These findings emphasize the significance of collaboration between healthcare professionals, policymakers, and environmental experts is crucial in developing comprehensive strategies that promote a more sustainable healthcare system. In addition, raising awareness and fostering a culture of sustainability among radiographers will be crucial to achieving environmentally conscious healthcare practices.

Conflict of interest statement

None.

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