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Kwee, Thomas C.; Almaghrabi, Maan T.; Kwee, Robert M.

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Research article

Which factors are associated with fraud in medical imaging research?

Thomas C. Kwee [a,*], Maan T. Almaghrabi [a], Robert M. Kwee [b]

[a] Medical Imaging Center, Department of Radiology, University of Groningen, University Medical Center Groningen, The Netherlands
[b] Department of Radiology, Zuyderland Medical Center, Heerlen/Sittard/Geleen, The Netherlands

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ABSTRACT

Purpose: To investigate the determinants of fraud in medical imaging research.
Method: This study analyzed aggregated survey data on scientific integrity completed by 877 corresponding authors who published in imaging journals in 2021. Multivariate regression analyses were performed to determine the association of scientific fraud with the following variables: survey participants' age (<18, 18–24, 25–34, 35–44, 45–54, 55–64, or > 65 years), gender (male, female, or other), Corruption Perceptions Index (CPI) of their country of work (linear 0–100 scale), academic degree (medical doctor or other), academic position (none, fellow/resident, instructor/ lecturer, assistant professor, associate professor, full professor, or other), and years of research experience (<5, 5–10, or > 10 years).
Results: Thirty-seven survey participants (4.2%) indicated they had committed scientific fraud in the past 5 years, and 223 (25.4%) indicated they had witnessed or suspected scientific fraud by departmental colleagues in the past 5 years. Instructors/lecturers were significantly more likely ($P = 0.029$) and fellows/residents were nearly significantly more likely ($P = 0.050$) to have committed scientific fraud, with odds ratios (ORs) of 4.954 and 5.156, respectively (Nagelkerke R^2 of 0.114). Survey participants > 65 years of age and survey participants working in less corrupt countries were significantly less likely ($P = 0.022$ and $P = 0.044$, respectively) to have witnessed or suspected scientific fraud committed by their departmental colleagues, with ORs of 0.412 and 0.988 (per unit increase in CPI), respectively (Nagelkerke R^2 of 0.064).
Conclusions: Fraud in medical imaging research appears to be more common among junior faculty and in more corrupt countries.

1. Introduction

Scientific fraud, defined as fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results [1], is an unethical and potentially harmful phenomenon. Fraudulent data may mislead other researchers to spend time and efforts to conduct subsequent scientific studies that are not meaningful, and they may give rise to erroneous clinical management decisions.

The exact prevalence of scientific fraud remains unclear [2]. However, four recent survey studies on this topic in the field of medical imaging consistently showed that 3–6% of respondents admitted to having committed fraud and 21–28% of respondents witnessed or suspected scientific fraud by anyone from their department in the last 5 years [3–6]. Although these data shed some light on the magnitude of the problem in medical imaging research, it still remains unclear which factors may lead to scientific fraud. This knowledge may potentially be useful in actually preventing scientific fraud.

Publications and acquisition of research funds are used as criteria for academic promotions [7], but they are also recognized as factors that may trigger fraudulent researches [8–11]. It can be hypothesized that researchers in the beginning of their academic career may be more prone to engage in such practices. Furthermore, it seems plausible that in countries in which it is more common to abuse entrusted power for private gain (i.e. corruption [12]), scientific fraud is also more frequent.

The purpose of this study was to investigate the determinants of fraud in medical imaging research.

Abbreviations: CI, confidence interval; CPI, Corruption Perceptions Index; NA, not available; NC, not calculable; OR, odds ratio; SPSS, Statistical Package for the Social Sciences.

* Corresponding author at: Medical Imaging Center, Department of Radiology, University Medical Center Groningen, University of Groningen, Hanzeplein 1, P.O. Box 30.001, 9700 RB Groningen, The Netherlands.
E-mail address: thomaskwee@gmail.com (T.C. Kwee).

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2. Materials and methods

2.1. Study design

This study used data from four previous survey studies on scientific integrity in the fields of general radiology [3], nuclear medicine [4], cardiovascular imaging [5], and neuroradiology [6]. These four studies investigated researchers' experience with scientific fraud, publication bias, and honorary authorship [3–6]. The characteristics of the participants in these surveys were aggregated to answer the research question of the present study. This work was approved by the institutional review board of the University Medical Center Groningen (Groningen, The Netherlands, 16 February 2022, METc 2022/086) [3–6].

2.2. Data collection

Corresponding authors who published in general radiology, nuclear medicine, cardiovascular imaging, and neuroradiology journals in 2021, were invited to participate in survey studies on scientific fraud in 2022 [3–6]. Participation was on a voluntary and anonymous basis. Respondents were asked to indicate their age, their gender, their country of work, their academic degree and position, and how many years of research experience they had. For each country of work, the Corruption Perceptions Index (CPI) was retrieved from Transparency International [13]. The CPI is the most authorative global corruption ranking in the world and measures how corrupt each country's public sector is perceived to be, according to experts and businesspeople [14]. The CPI is expressed on a scale of 0–100, where 0 means highly corrupt and 100 means very clean [14]. Subsequently, the participants were asked if they had committed any of the following in the past 5 years: data fabrication, data manipulation/ falsification, misleading (e.g. selective) reporting, plagiarism, duplicate/redundant publication, or any other type of publication fraud. Any of these acts was regarded as scientific fraud. Participants were also asked to indicate if they had witnessed or suspected that anyone from their department had committed any of these acts in the past 5 years.

2.3. Data analysis

The characteristics of the survey participants and their experience with scientific fraud were descriptively analyzed. Logistic regression analyses were performed to determine the association of scientific fraud with the following variables: survey participants' age (<18, 18–24, 25–34, 35–44, 45–54, 55–64, or > 65 years), gender (male, female, or other), CPI of their country of work (linear 0–100 scale), academic degree (medical doctor or other), academic position (none, fellow/resident, instructor/ lecturer, assistant professor, associate professor, full professor, or other), and years of research experience (<5, 5–10, or > 10 years). The category with the highest number of counts was used as reference category for each variable. Variables that were significant on univariate analysis and with a variance influence factor (VIF) of < 10 were subjected to multivariate analysis. *P*-values < 0.05 were considered statistically significant. Analyses were done separately for scientific fraud committed by the survey participants and for witnessed or suspected scientific fraud committed by departmental colleagues. Nagelkerke R^2 values were calculated to measure the variance explained by the models. Statistical analyses were executed using IBM Statistical Package for the Social Sciences (SPSS) version 23.

3. Results

3.1. Participants

A total of 877 corresponding authors who published in general radiology journals (n = 221), nuclear medicine journals (n = 254), cardiovascular imaging journals (n = 161), and neuroradiology journals (n = 241) in 2021, participated. Their characteristics are displayed in Table 1. Most participants were aged 35–44 years (31.9%), were male (76.6%), worked in the United States (25.4%), had a medical doctor degree (72.9%), were full professor (33.6%), and had > 10 years of research experience (70.7%). The median CPI of the countries of work of the participants was 69 (range: 25–90).

3.2. Reported frequencies of scientific fraud

Thirty-seven survey participants (4.2%) indicated they had committed scientific fraud in the past 5 years, of whom 9 committed more than one type of scientific fraud (Table 2). Two-hundred and twenty-three survey participants (25.4%) indicated they had witnessed or suspected scientific fraud committed by departmental colleagues in the past 5 years, of whom 94 allegedly committed more than one type of scientific fraud (Table 2).

3.3. Determinants of scientific fraud committed by survey participants

Age, academic position, and years of research experience were significantly associated with scientific fraud committed by survey participants on univariate logistic regression (Table 3). VIFs of these variables ranged between 1.015 and 1.928, indicating no multicollinearity. Only academic position remained significant on multivariate logistic regression (Table 3). Instructors/lecturers were significantly more likely ($P = 0.029$) to have committed scientific fraud, with an odds ratio (OR) of 4.954 (95% confidence interval [CI]: 1.181–20.791). Fellows/residents were nearly significantly more likely ($P = 0.050$) to have committed scientific fraud, with an OR of 5.156 (95% CI: 1.003–26.502). The Nagelkerke R^2 of the multivariate model was 0.114.

3.4. Determinants of suspected or witnessed scientific fraud committed by departmental colleagues

Survey participants' age, CPI of their country of work, academic position, and years of research experience were significantly associated with suspected or witnessed scientific fraud committed by departmental colleagues (Table 4). VIFs of these variables ranged between 1.015 and 1.938, indicating no multicollinearity. Only survey participants' age and CPI of their country of work remained significant on multivariate regression (Table 4). Survey participants > 65 years of age were significantly less likely ($P = 0.022$) to have witnessed or suspected scientific fraud committed by their departmental colleagues, with an OR of 0.412 (95% CI: 0.193–0.878). Survey participants working in less corrupt countries were also significantly less likely ($P = 0.044$) to have witnessed or suspected scientific fraud committed by their departmental colleagues, with an OR of 0.988 (95% CI: 0.977–1.000) per unit increase in CPI. The Nagelkerke R^2 of the multivariate model was 0.064.

4. Discussion

Our results suggest that instructors/lecturers and fellows/residents are particularly prone to engage in scientific misconduct in medical imaging research. These two groups, who are on the lower steps of the academic ladder, were approximately 5 times more likely to have committed scientific fraud in the past 5 years compared to full professors. However, contrary to our a priori hypothesis, researchers who admitted to have committed scientific fraud were not more frequently employed in more corrupt countries. On the other hand, survey participants working in more corrupt countries did more frequently report to have suspected or witnessed scientific fraud committed by departmental colleagues in the past 5 years. For example, in a country with 58 CPI points less than another country, the likelihood of suspected or witnessed scientific fraud committed by departmental colleagues was statistically two times higher. Interestingly, survey participants aged > 65 years were less likely to have suspected or witnessed scientific fraud

Table 1
Characteristics of 877 survey participants.

Variable	Category	Count	Percentage
Age	<18 years	1	0.1%
	18–24 years	2	0.2%
	25–34 years	112	12.8%
	35–44 years	280	31.9%
	45–54 years	229	26.1%
	55–64 years	165	18.8%
	>65 years	88	10.0%
Gender	Male	672	76.6%
	Female	201	22.9%
	Other	4	0.5%
Country of work[a]	Argentina (CPI: 38)	4	0.5%
	Australia (CPI: 75)	9	1.0%
	Austria (CPI: 71)	9	1.0%
	Belgium (CPI: 73)	22	2.5%
	Brazil (CPI: 38)	14	1.6%
	Canada (CPI: 74)	36	4.1%
	Chile (CPI: 67)	5	0.6%
	China (CPI: 45)	33	3.8%
	Colombia (CPI: 39)	3	0.3%
	Cyprus (CPI: 52)	1	0.1%
	Czechia (CPI: 56)	1	0.1%
	Denmark (CPI: 90)	11	1.3%
	Egypt (CPI: 30)	4	0.5%
	Finland (CPI: 87)	2	0.2%
	France (CPI: 72)	55	6.3%
	Germany (CPI:79)	61	7.0%
	Greece (CPI: 52)	10	1.1%
	Hungary (CPI: 42)	1	0.1%
	India (CPI: 40)	23	2.6%
	Indonesia (CPI: 34)	1	0.1%
	Iran (CPI: 25)	4	0.5%
	Israel (CPI: 63)	2	0.2%
	Italy (CPI: 56)	85	9.7%
	Japan (CPI: 73)	22	2.5%
	Jordan (CPI: 47)	1	0.1%
	Korea (CPI: 63)	15	1.7%
	Malaysia (CPI: 47)	3	0.3%
	Mexico (CPI: 31)	3	0.3%
	Moldova (CPI: 39)	2	0.2%
	Monaco (CPI: NA)	1	0.1%
	Norway (CPI: 84)	1	0.1%
	Oman (CPI: 44)	2	0.2%
	Poland (CPI: 55)	5	0.6%
	Portugal (CPI: 62)	9	1.0%
	Russia (CPI: 28)	1	0.1%
	Saudi Arabia (CPI: 51)	1	0.1%
	Singapore (CPI: 83)	4	0.5%
	Slovenia (CPI: 56)	4	0.5%
	South Africa (CPI: 43)	1	0.1%
	Spain (CPI: 60)	30	3.4%
	Sweden (CPI: 83)	13	1.5%
	Switzerland (CPI: 82)	16	1.8%
	Taiwan (CPI: 68)	3	0.3%
	Thailand (CPI: 36)	2	0.2%
	The Netherlands (CPI: 80)	54	6.2%
	Tunisia (CPI: 40)	1	0.1%
	Turkey (CPI: 36)	16	1.8%
	United Kingdom (CPI: 73)	46	5.2%
	United States (CPI: 69)	223	25.4%
Academic degree	Medical doctor (MD)	639	72.9%
	Other degree(s)	238	27.1%
Academic position	None	69	7.9%
	Fellow/resident	58	6.6%
	Instructor/lecturer	63	7.2%
	Assistant professor	137	15.6%
	Associate professor	167	19.0%
	Full professor	295	33.6%
	Other	88	10.0%
Years of research experience	<5 years	88	10.0%
	5–10 years	169	19.3%
	>10 years	620	70.7%

Notes:
Abbreviations:
CPI: Corruption Perceptions Index.
NA: not available.

[a] Not indicated by 2 respondents.

Table 2
Scientific fraud committed by survey participants and witnessed or suspected scientific fraud committed by departmental colleagues in the past 5 years (absolute numbers are displayed in each cell).

Type of scientific fraud	Survey participants	Departmental colleagues
Data fabrication	3	36
Data manipulation/ falsification	8	65
Misleading reporting	14	118
Plagiarism	10	55
Duplicate/redundant publication	12	94
Other type of publication fraud	4	15

committed by departmental colleagues compared to those 35–44 years old. This can be explained by the fact that researchers aged > 65 years are frequently retired and have no or a less active role in their department. Consequently, they are not or less aware of what actually happened in their department in the past 5 years. Finally, it should be noted that the predictor variables only explained a small fraction of the variability in predicting the outcome of scientific fraud (Nagelkerke R^2 values of 0.114 for admitted scientific fraud and 0.064 for suspected or witnessed scientific fraud). This indicates that there are still unknown factors that affect the occurrence of scientific fraud.

The results of this study may have several implications. First, special attention should be paid to junior researchers in preventing them from engaging in scientific fraud. This may be achieved by educating them about the potential harms of scientific fraud at an early stage and the necessity to adhere to ethical research codes to uphold scientific integrity. The higher frequency of scientific fraud among junior faculty also re-emphasizes the need for society and the scientific community to reflect on the current academic reward system that pressures researchers to acquire a high number of impactful publications (that are usually required to be both novel and to yield positive results) and to bring in a lot of money through research grants, which may act as incentives to commit fraud [8–11]. Furthermore, our results reinforce the necessity for countries to take measures against both corruption and scientific fraud. Science can be regarded as a vital means for countries and human society as a whole to develop, and the degree of corruption in a country and scientific fraud appear to be correlated. Finally, more research is necessary to understand why certain medical imaging researchers decide to engage in scientific fraud and under which circumstances.

So far, the topic of scientific fraud has been relatively underexposed in the medical imaging field. However, there are several previous survey studies that have explored which factors are associated with fraud in other scientific disciplines [15–17]. Being a junior researcher and publication pressure were commonly reported determinants of scientific fraud in these previous surveys [15–17], which resonates with the results of the present study. Of interest, in a previous study by Haven et al. [18] the potential causes of scientific fraud were categorized into three groups: individual-related factors (e.g. gender or academic rank), climate factors (e.g. perceptions of research-related norms and fairness of supervision, and the quality of supportive resources), and publication factors (e.g. perceived publication stress and researchers' attitudes). In a survey by Haven et al. [18] among 1298 researchers, individual, climate and publication factors combined explained 34% of variance in perceived frequency of research misbehavior [18]. Individual factors explained 7%, climate factors explained 22%, and publication factors 16% [18]. Haven et al. [18] concluded that the perceptions of the research climate play a substantial role in explaining variance in research misbehavior, and speculated that efforts to improve departmental norms might have a salutary effect on behavior. We completely

Table 3
Association of variables with scientific fraud committed by survey participants in the past 5 years (significant *P*-values are marked in bold italics).

Variable	Category	Univariate analysis			Multivariate analysis		
		OR	95% CI	*P*-value	OR	95% CI	*P*-value
Age[a]	<18 years	NC	NC	1.000	NC	NC	1.000
	18–24 years	NC	NC	0.999	NC	NC	1.000
	25–34 years	0.970	0.394–2.391	0.948	1.172	0.380–3.616	0.782
	45–54 years	0.595	0.262–1.352	0.215	0.680	0.279–1.657	0.397
	55–64 years	0.089	0.012–0.671	***0.019***	0.122	0.015–1.012	0.051
	>65 years	0.167	0.022–1.272	0.084	0.246	0.029–2.095	0.199
Gender[b]	Female	0.545	0.209–1.424	0.215	–	–	–
	Other	7.122	0.719–70.514	0.093	–	–	–
CPI country of work	NA	0.982[f]	0.960–1.005[f]	0.127	–	–	–
Academic degree[c]	Degree other than medical doctor	1.310	0.647–2.651	0.453	–	–	–
Academic position[d]	None	2.636	0.615–11.308	0.192	2.261	0.449–11.370	0.322
	Fellow/resident	5.472	1.531–19.556	0.009	5.156	1.003–26.502	0.050
	Instructor/lecturer	6.105	1.802–20.686	***0.004***	4.954	1.181–20.791	***0.029***
	Assistant professor	3.597	1.154–11.207	***0.027***	2.547	0.671–9.665	0.169
	Associate professor	2.537	0.792–8.125	0.117	1.852	0.501–6.853	0.356
	Other	2.047	0.479–8.741	0.333	1.845	0.377–9.029	0.449
Years of research experience[e]	<5 years	0.959	0.281–3.274	0.947	0.265	0.059–1.195	0.084
	5–10 years	2.078	1.006–4.290	***0.048***	0.649	0.260–1.621	0.355

Table 4
Association of variables with suspected or witnessed scientific fraud committed by departmental colleagues of the survey participants in the past 5 years (significant *P*-values are marked in bold italics). Note that the variables belong to the survey respondents who suspected or witnessed fraud committed by their departmental colleagues, and not to the departmental colleagues themselves who were alleged of scientific fraud.

Variable	Category	Univariate analysis			Multivariate analysis		
		OR	95% CI	*P*-value	OR	95% CI	*P*-value
Age[a]	<18 years	NC	NC	1.000	NC	NC	1.000
	18–24 years	6.333	0.371–108.171	0.202	8.217	0.461–146.361	0.152
	25–34 years	2.646	1.272–5.500	0.009	1.204	0.661–2.191	0.544
	45–54 years	2.808	1.452–5.430	***0.002***	0.796	0.512–1.237	0.311
	55–64 years	2.099	1.065–4.137	***0.032***	0.631	0.362–1.099	0.104
	>65 years	1.583	0.772–3.248	0.210	0.412	0.193–0.878	***0.022***
Gender[b]	Female	0.935	0.649–1.348	0.720	–	–	–
	Other	0.967	0.100–9.359	0.977	–	–	–
CPI country of work	NA	0.986[f]	0.975–0.998[f]	***0.018***	0.988[f]	0.977–1.000[f]	***0.044***
Academic degree[c]	Degree other than medical doctor	0.847	0.597–1.201	0.352	–	–	–
Academic position[d]	None	0.855	0.440–1.662	0.644	0.628	0.301–1.307	0.213
	Fellow/resident	1.657	0.890–3.087	0.112	1.282	0.575–2.858	0.544
	Instructor/lecturer	2.117	1.181–3.796	***0.012***	1.503	0.775–2.913	0.228
	Assistant professor	1.923	1.227–3.014	***0.004***	1.393	0.815–2.381	0.226
	Associate professor	1.317	0.846–2.051	0.222	1.038	0.638–1.689	0.880
	Other	0.757	0.406–1.409	0.379	0.644	0.326–1.274	0.206
Years of research experience[e]	<5 years	0.972	0.571–1.655	0.917	0.570	0.279–1.168	0.125
	5–10 years	1.773	1.228–2.559	***0.002***	1.131	0.705–1.814	0.609

agree with their conclusion, and, based on our results, would like to add that norms and values extend beyond a single department to a country's society.

The present study had some limitations. First, the results only apply to medical imaging researchers and their experience with scientific fraud between 2018 and 2022. The results may have been different for previous years, but this was beyond the scope of this work. Second, although several individual-related factors were investigated (age, academic position, and years of research experience), climate factors (except CPI of the country of work) and publication factors were not explored as potential determinants. Third, although we identified potential determinants of scientific fraud, it remains to be investigated if certain interventions would be effective in reducing scientific fraud.

In conclusion, fraud in medical imaging research appears to be more common among junior faculty and in more corrupt countries.

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CRediT authorship contribution statement

Thomas C. Kwee: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Maan T. Almaghrabi:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Robert M. Kwee:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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