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Team size and retracted citations reveal the patterns of retractions from 1981 to 2020

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Abstract
The growth of the retraction databases reveals the disturbing trend in science and also the rising trend of citations of retracted papers is a serious concern. The objective of the study is to investigate the patterns of retractions through the team size and retracted citations. The publication records of 12,231 retracted papers indexed by Web of Science (WoS) are analyzed to investigate (i) the patterns of retraction associated with collaboration and team size; and (ii) the impact of retracted papers on the papers that are citing the retracted papers (retracted citations). The study demonstrates the collaboration patterns of retracted publications where 61.5% of authors have only one and 24.6% have two retracted papers; however, 2% of authors have more than retracted papers. Also, the temporal evolution of the team size reveals that teams smaller in size have more retractions. The impact of citing retracted papers reveals that 55.2% of retracted papers have been cited at least once. 1*/4th* of the citations to the retracted papers are self-citations which themselves are retractions. On average 71.4% citations are the non-retracted citations and 28.6% citations are retracted citations which are mostly the self-citations. Last, the variation in average team size and average retracted citations in various research areas (having high retraction) is presented. Retracted publications in high-impact journals are highly cited.

Keywords Retracted publications · Bibliometric analysis · Collaboration patterns · Retracted citations · Team size

Introduction

In 2000, Jan Hendrik Schön's became famous for his work on coax materials into superconductors, and he published eight papers in Science and Nature. Julia Hsu and Lynn Loo accidentally stumbled across duplicated data used in one of the Schön's papers while verifying the experimental progress of their work. That raised an alarm bell to bring the attention of the scientific community towards the Schön's work and they found evidence of scientific misconduct in at least 16 of them. It raised questions on the

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publication policies of these high-impact journals too. Scandals like Hwang Woo-Suk's fake stem cell lines (Saunders & Savulescu, 2008) or Jan Hendrik Schön's duplicated graphs (Service, 2003) showed how easily scientist can publish fabricated data and put human health at risk along with wasting millions of dollars of government research money. In 2009, the fraud committed by Scott S. Reuben in his 21 major publications over a period of 15 years shocked the scientific community. Bornemann-Cimenti et al. (2016) mentioned in his finding the fraudulent case of Scott S. Reuben where 25 of his publications being retracted due to data fabrication. Later, two other scandals excelled at Reuben's fraud. Yoshitaka Fujii and Joachim Boldtwere, researchers of anesthesia study found guilty of scientific misconduct in 183 and 90 publications, respectively (Tramèr, 2013; Wise, 2013). These scandals raised questions on the role and responsibility of coauthors and reviewers of scientific articles. Similarly, a Japanese bone-health researcher, named Yoshihiro Sato, fabricated data, plagiarized work, and forged authorship in more than 60 studies from 1996 to 2013 (Else, 2019; Kupferschmidt, 2018).

There are multiple reasons behind the retraction of the papers including duplicate publication, falsification of the data, fabrication of the data, ethical or legal misconduct, etc. (Steen et al., 2013; Bohannon, 2016). Some time back Chinese journal found 31% of submissions plagiarized (Mallapaty, 2020; Zhang, 2010). Grieneisen and Zhang (2012) have discussed the reasons and proportion of retractions as research misconduct (20%), questionable data or interpretation (42%), and publishing misconduct (47%). A published research work completely depends on the trust that a reader built with a writer where a reader expects honesty and fairness in the results reported by writer (Rennie et al., 1997). With the rise in scientific collaborations, the number of retractions also increased from the last two decades (van Noorden, 2011; Tang et al., 2020). Although, scientific collaborations increase research productivity by using an individual's knowledge and research skill set; however, a wrong collaboration can create distrust among peers and spoil the reputation (Abramo et al., 2011; Mongeon and Larivi`ere, 2016; Brainard & You, 2018). Bennett and Taylor (2003) have shown in their study that how unethical practices in the authorship of scientific papers have increased over the past few decades. Teamwork is essential in research to produce qualitative and creative work. The role of every member of the team is important for the successful complication of the project (Wuchty et al., 2007). Also, the reputation of every individual is reflected on the team as the fraud attempted by any member will be reflected on the team (Jin et al., 2019). In this empirical analysis, I study the team sizes and the retracted citations along with the research disciplines.

The trend of retractions is sharp in medical sciences (Foo, 2011; Samp et al., 2012; Zhang & Grieneisen, 2013; Rosenkrantz, 2016; Rai & Sabharwal, 2017; King et al., 2018; Wang et al., 2019). Most of the fraud is happening in the medical field and many studies have highlighted the sci entific misconduct in medicine (Steen, 2011a; Cass˜ao et al., 2018). There is a large number of authors who keep on publishing fraud research (Fanelli, 2009; Kuroki & Ukawa, 2018; Steen, 2011a). Does this raise a serious concern on authors that are deliberately committing research fraud (Steen, 2011b)? Halevi and Bar-Ilan (2016) have explored the post retraction citations to retracted papers and found that the majority of the citations are positive and the citing papers usually fail to mention that the cited article was retracted. Bar-Ilan and Halevi (2018) reported that there was an increase of more than 30% in the number of citations within a period of 3.5 years. Earlier studies highlight that a journal's retraction rate and its retractions for fraud are positively associated with the journal's impact factor (Fang & Casadevall, 2011; Fang et al., 2012). Trikalinos et al. (2008) stated in their study that falsified papers in high-impact journals were slow to retract.

Over the years, a number of studies has been conducted to explain the characteristics of scientific misconduct (He, 2013), the rise of retractions and its causes (Cokol et al., 2008; Steen, 2011a), effect of collaborations (Asubiaro, 2019; Franceschet & Costantini, 2010; Sharma & Khurana, 2021; Zhang et al., 2020), behavior of author (Martinson et al., 2005), impact on authors' career (Mongeon and Larivi`ere, 2016), the ongoing citations of retracted papers (Neale et al., 2010), highly cited retracted papers (da Silva and Dobr´anszki, 2017), etc. My study provides a systematic view on the growth of the team sizes in retracted papers, a relationship between the authors' collaboration and retractions (Tang et al., 2020), and an association between retractions and retracted citations. The study is organized as follows: "Data description" section describes the data. Results are explained in "Results" section. Finally, the concluding remarks are presented in "Discussion and conclusions" section.

Data description

The Web of Science (WoS) data managed by Clarivate Analytics (https://apps.webofknowledge.com/) is used for the study and the choice of data is arbitrary. I have searched for the papers where *Document Type* is *Retracted Publication* or *Retraction* from 1981 to 2020. The given condition filtered 12231 retracted publications that includes articles, proceedings, book chapters, etc. The metadata contains a paper unique ID, author's name, affiliation, journal name, document type, research area, number of citations, etc. The metadata contains information of 27822 authors, 3127 journals, and 146 research areas. Further, I have looked for those publications that have received at least one citation and filtered 6754 publications with at least one citation each. Now, I have looked for the citations received by all 6754 publications and checked the document type (retraction or retracted publication) of each and every citation. This condition narrowed down the search on retracted publications and filtered 3110 publications that received at least one citation as a retraction. The schematic representation of the data filtration is shown in Fig. 1.

Results

Retraction trend with respect to team size and author's collaboration

The growth of the number of retracted papers as per the number of authors (team size) from 1981 to 2020 is shown in Fig. 2a. The trend is shown for teams of size 1, 2, 3–5, 6–10, >10, and the total number of retractions. There is a sharp rise and fall in the number of retractions from 2010 to 2012. During 2010–2011 there is a rise in the number of retractions and then a fall is noticed immediately after in 2012. Further, during 2015–16 again a sharp rise happened in the number of retractions. Decade-wise number of retractions; 1981–1990 (0.2%), 1991–2000 (2.7%) 2001–2010 (20.4%), and 2011–2020 (76.7%) is shown in Fig. 2a inset. The papers written by more than 3 and less than 10 authors in collaboration have a large retraction count. Fig. 2b also shows that larger teams have a lesser number of retracted papers as compared to shorter teams. Single author papers have 13.3% and two authors' papers have 13.9% of retractions. Teams of size 3–5 have 42.3% and teams of size 6–10 have 25.7% of retracted papers. The percentage of retracted papers decreases with an increase in team size while 69.5%

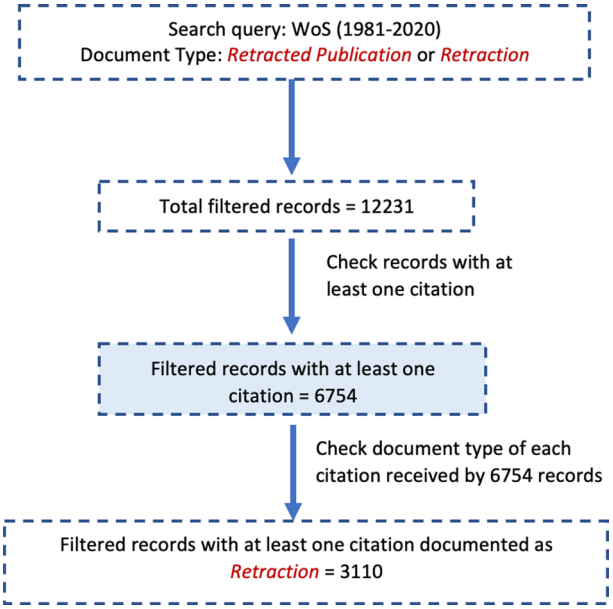

Fig. 1 Schematic representation of the data collection process of retracted publications during 1981–2020

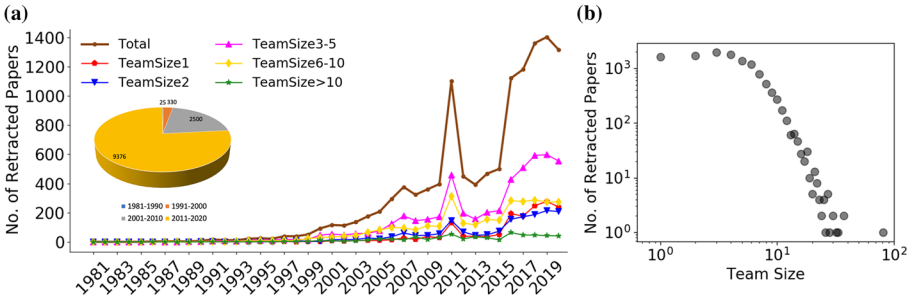

Fig. 2 **a** The number of papers retracted from 1981 to 2020. The trend line colored in brown represents the total number of retracted papers. Other trend lines show the team size (number of authors) in retracted papers. Decade-wise number of retractions is shown in the inset. **b** A number of retracted papers corresponding to varying team sizes. The minimum team size is a team of 2 authors and the maximum is a team of 81 authors

of retraction is from teams smaller than 5 authors. This highlights that a larger number of authors write individually or tend to collaborate with a few others. Steen et al. (2013) has also studied the growth of scientific retractions and authors with multiple retractions; however, I demonstrated the authors' collaboration patterns in retracted papers.

Demonstration of countries with the number of retreated papers is shown in Fig. 3a. Authors from China have higher retractions (25.7%), followed by the USA (16.1%), India (5.3%), Japan (5.2%), Iran (4.4%), Germany (3.2%), England (2.8%), South Korea (2.6%), Italy (2.4%) and so on. The co-authorship network has 27822 authors and 167645 collaborations among authors. Fig. 3b shows the trend of the number of retracted papers with respect to authors. The relationship between the authors and the

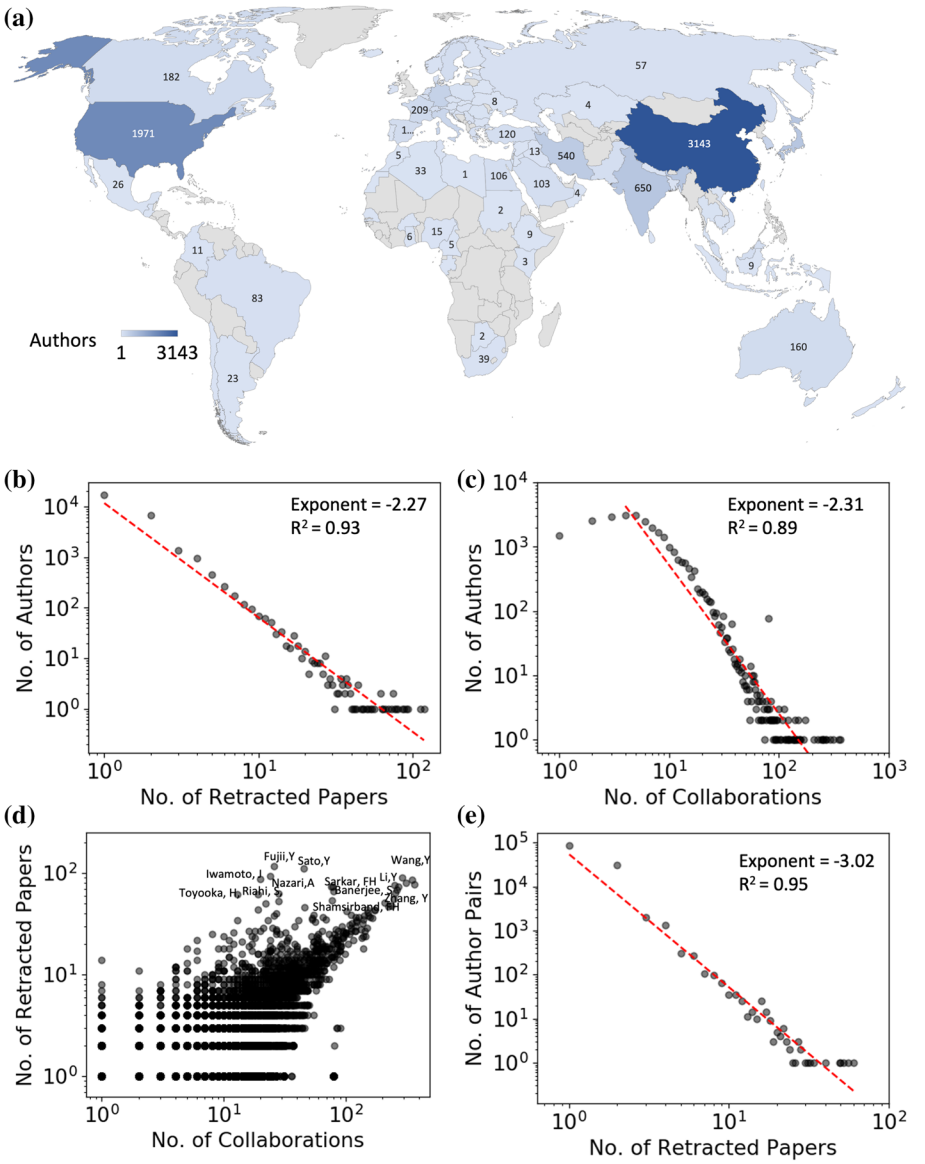

Fig. 3 **a** Demonstration of country-wise number of retracted publications. China has produced a large number of authors with retracted papers followed by the USA, India, Japan, and Iran with more than 500 authors. The grey area in the map specifies no record. The number of papers retracted by authors follows a power law, $f(x) = x^{-k}$ with exponent -2.27 and $R^2 = 0.93$. **c** The number of collaborations shared by authors follows a power law with exponent -2.31 and $R^2 = 0.89$. **d** Authors with a number of collaborations and a number of retracted papers. **e** The number of papers retracted by pair of authors follows a power law with exponent -3.02 and $R^2 = 0.95$. A few author pairs have a higher retraction rate

number of retracted papers follows a power law with exponent −2.27. Out of 27822 authors, 61.5% of authors have owned only one, and 24.6% have owned two retracted papers; however, 65.4% of retracted papers are owned by 27 individual's (0.1%). The

number of collaborations refers to the degree of the author in the authors' collaboration network. The share of collaborations among authors also follows a power law with exponent −2.31 as shown in Fig. 3c. A large number of authors worked within a closed group. 74% of authors have degrees less than 10, i.e., less than 10 collaborations and 1% has a degree greater than 50. Fig. 3d represents the individual author with a degree of collaboration and the number of retractions. The authors who share large collaboration also have a large number of retracted papers. A few names of such authors are marked in the figure. Fig. 3e represents how many pairs of authors have large retractions. The pair of authors with a number of retracted papers follows a power law with exponent −3.02. 71.1% of authors' pairs have only one retraction, 25.2% have two retractions and 12 individual pairs have more than 25 retractions. Table 1 shows the list of author pairs having more than 20 retractions. This analysis shows how the same set of authors and pair of authors committing fraud again and again. Also, the relationship among authors and retractions shows a scale-free behavior with exponent varies between 2 and 3.

Impact of retracted citations

Retracted citations are those where retracted publications received citations and those citations turned out to be retractions. da Silva and Dobr´anszki (2017) have mentioned in their study that why citing retracted papers can be a problem for academia. Da Silva and Bornemann-Cimenti (2017) also tried to explain the reason behind the retracted citations. I have analyzed the citations received by all retracted papers where 55.2% (6754) of retracted papers have received at least one citation. In contrast, 25.4% (3110) papers are those whose citations have at least one retraction. On average, citations

Table 1 List of authors' pairs with the number of retractions (#R) more than 20

No.	Author1	Author2	#R	No.	Author1	Author2	#R
1	BANERJEE,S	SARKAR,FH	60	19	PRASAD,S	AGGARWAL,BB	23
2	FUJII,Y	TANAKA,H	56	20	SCHON,JH	KLOC,C	23
3	NAZARI,A	RIAHI,S	52	21	YADAV,VR	AGGARWAL,BB	23
4	FUJII,Y	TOYOOKA,H	50	22	AHMAD,A	SARKAR,FH	22
5	IWAMOTO,J	TAKEDA,T	49	23	ELAHI,AS	GHORANNEVISS,M	22
6	IWAMOTO,J	SATO,Y	40	24	IWAMOTO,J	YEH,JK	22
7	SATO,Y	HONDA,Y	34	25	SAITOH,Y	TANAKA,H	22
8	ZHONG,H	YANG,XM	32	26	WANG,Z	SARKAR,FH	22
9	TANAKA,H	TOYOOKA,H	30	27	ZHONG,H	LUO,QY	22
10	SAITOH,Y	TOYOOKA,H	28	28	PATRA,S	MADHURI,R	21
11	WANG,ZW	SARKAR,FH	28	29	PATRA,S	SHARMA,PK	21
12	ALI,S	SARKAR,FH	27	30	SCHON,JH	BATLOGG,B	21
13	SATO,Y	OIZUMI,K	27	31	WANG,ZW	BANERJEE,S	21
14	SATO,Y	SATOH,K	27	32	HOSODA,T	ANVERSA,P	20
15	BOLDT,J	HEMPELMANN,G	26	33	KLOC,C	BATLOGG,B	20
16	IWAMOTO,J	MATSUMOTO,H	25	34	LI,YW	SARKAR,FH	20
17	MADHURI,R	SHARMA,PK	24	35	LIU,T	ZHU,JY	20
18	TAKEDA,T	SATO,Y	24	36	SUNG,B	AGGARWAL,BB	20

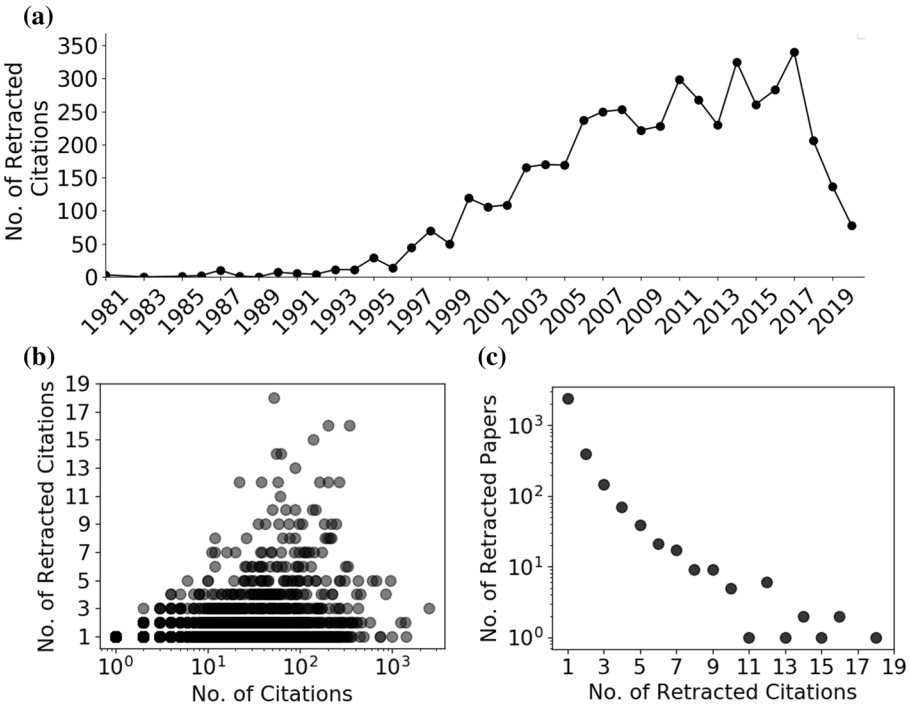

Fig. 4 **a** The trend of the number of retracted citations from 1981 to 2020. **b** The number of citations received by retracted papers and the number of retracted citations. **c** The number of retracted citations and the number of retractions

received by 3110 papers is 33.4 and the average retracted citation is 1.5. Fig. 4 shows the analysis of 3110 retracted citations. The trend of the number of retracted citations from 1981 to 2020 is shown in Fig. 4a. After 2017 there is a continuous decay in the count of retracted citations. The relationship between the number of citations received by retracted papers and the retracted citations is plotted in Fig. 4b. There are a few papers with a large number of retracted citations as shown in Fig. 4c. On average 71.4% citations are non-retracted citations and 28.6% citations are retracted citations. Two possible reasons could be behind this pattern (i) People who cited the paper were unaware of the authenticity of the work, or the cited paper had been retracted later; and (ii) the authors who cited the retracted papers are one of the authors from the retracted papers. I investigated that most of the retracted citations are self-citations.

Figure 5a displays those research areas where the number of retractions is $>1\%$. Major retractions are from *Biochemistry & Molecular Biology* (9.5%), *Oncology* (8.8%), *Ecology* (8.7%), *Energy* (8%), and *Science and Technology* (7.6%). The average team size of first 20 research areas with high retractions is shown in Fig. 5b. The red vertical line is plotted at value 10. *Biochemistry & Molecular Biology*, *Science & Technology*, *Chemistry*, *Research & Experimental Medicine*, *General & Internal Medicine*, and *Cardiovascular System & Cardiology* has average team size above 10. The results highlight that teams smaller in size have more retractions. Figure 5c shows the average retracted

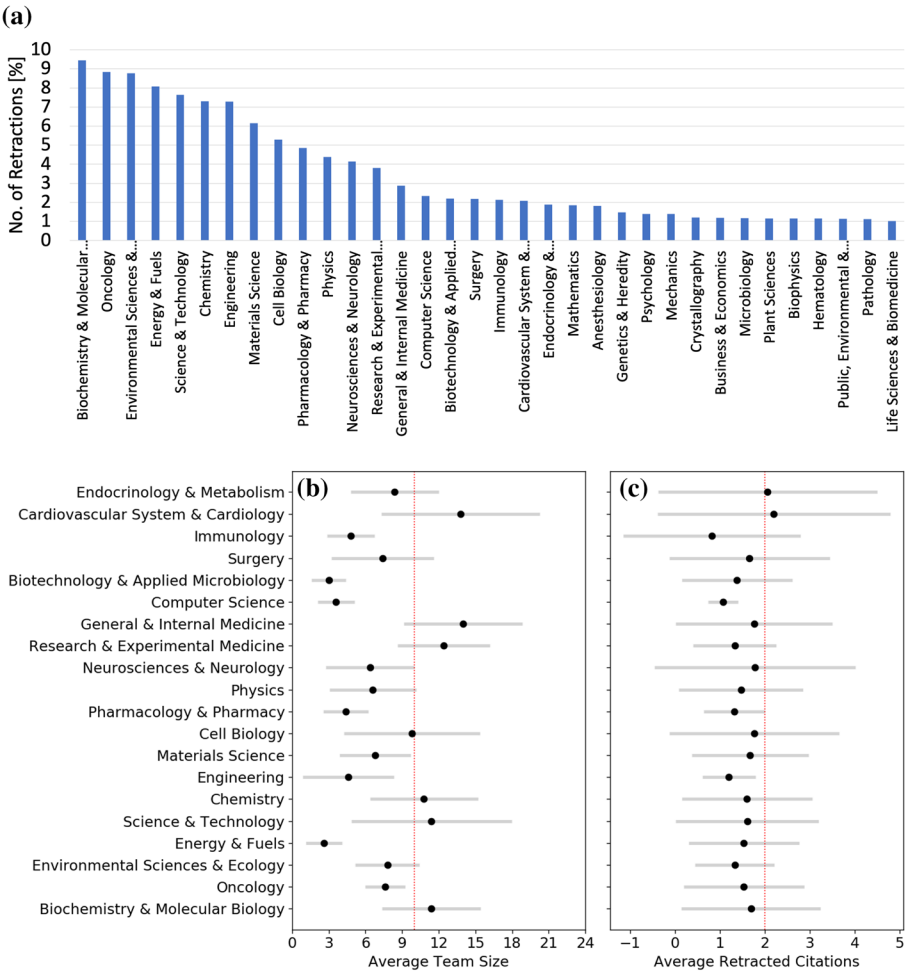

Fig. 5 **a** Research areas with more than 1% of retractions (arranged in ascending order). Results for the first 20 research areas with high retractions: **b** average team size; **c** average number of retracted citations

citations. Publications in Cardiovascular System & Cardiology, and Endocrinology & Metabolism have on average retracted citations above 2.

Journal wise retractions

Figure 6a shows the cumulative growth of the number of retracted papers in journals having more than 100 retractions since 1981. *International Conference on Energy and Environmental Science 2011* (ICEES) has a large number of retracted papers (6.2%) with an average citation 0.24, whereas *Journal of Biological Chemistry* (JBC) has 2.7% of retracted papers with average citation of 28.4. *Plos One* has 2.5% of retracted papers with average citations of 4.7 and *Tumor Biology* has 2.4% of retracted papers with average citations of 6.8. Details of the journals based on the number of retractions (> 100) are listed

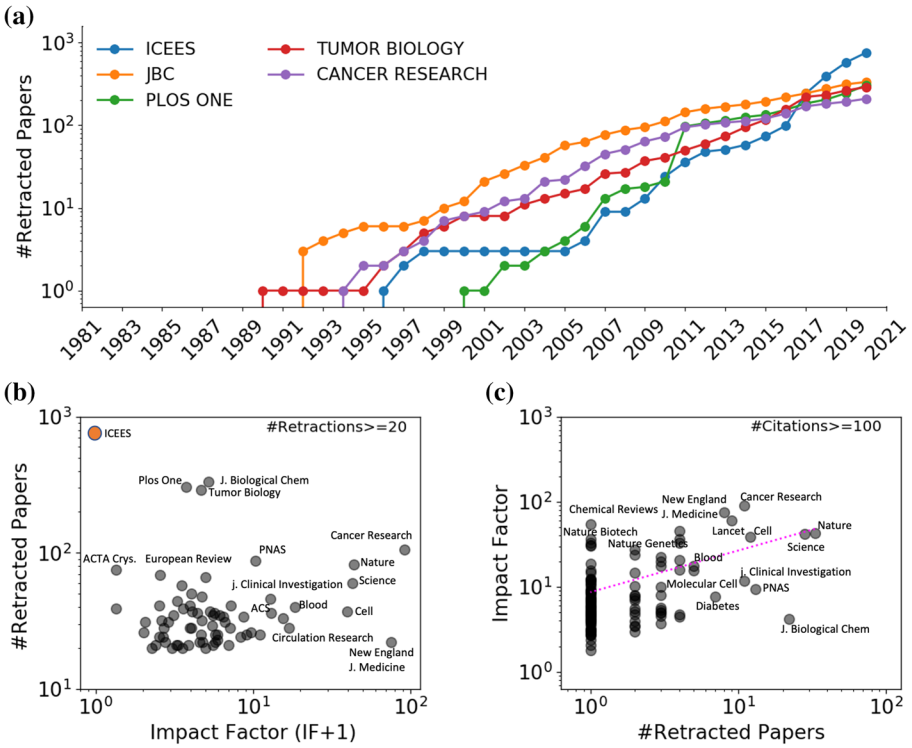

Fig. 6 **a** The cumulative growth of retractions in journals with more than 100 retracted papers. **b** Relationship between journal impact factor and the count of the retracted publications in the journal where the number of retractions is ≥ 20. The orange-colored dot is the conference proceeding with the highest retraction count. **c** Relationship between journal impact factor and the count of the retracted publications in the journal where the number of citations is ≥ 100. The magenta line shows the trend with an exponent of 0.45

Table 2 List of journals with more than 100 retracted papers from 1981 to 2020

Journal	Impact Factor	#Retraction	Avg. Citations	Avg. Team Size
ICEES	–	760	0.24	3.0
JBC	4.23	334	28.4	6.5
PLOS ONE	2.74	306	4.8	4.7
Tumor Biology	3.65	291	6.9	4.6
Cancer Research	91.3	106	46	6.6

in Table 2. Figure 6b shows the scattered plot of journals with more than 20 retractions. Conference proceedings with the highest retraction count do not have any impact factor. To include conference proceeding, the impact factor of all the journals has been increased by 1. The number of retractions is independent of the journal impact factor (Atlas, 2004; Resnik et al., 2015). Similarly, the scattered plot of journals where the retracted papers have received more than 100 citations is shown in Fig. 6c. The trend line shows that the publications in high-impact journals are highly cited.

Discussion and conclusions

This is the first meta-analysis investigating the patterns of retractions by analyzing the team sizes and the retracted citations in the retracted publications. Inspired by the earlier findings (Zhang et al., 2020), the present research brought a new perspective—team sizes and retracted citations—on the retraction patterns to the scientific literature and provide empirical pieces of evidence for the same. The study found that the teams smaller in size are more prone to retractions. The majority of the retractions are from teams with the number of authors < 10. The majority of the retracted papers (65.4%) are from 27 individuals. On the other hand, 61.5% of authors have owned only one and 24.6% have owned two retracted papers. A handful of authors' pairs are more prone to scientific misconduct and account for a large number of retractions. This trend follows a power law.

Bar-Ilan and Halevi (2018) showed that the retracted articles are continued to be cited. This study has further analyzed those citations and found that 55.2% of retracted papers have received at least one citation and out of these citations on retracted papers, 25.4% papers are those whose citations have at least one retraction. Further, the study has analyzed those retracted citations and found that the majority of the retraced citations are self-citations. One of the possible reasons could be to gain visibility even after they were identified as fraudulent. Lu et al. (2013) has claimed that if an author does not self-cite the works, then the citation counts to those publications decrease. On average 71.4% citations are non-retracted citations and 28.6% citations are retracted citations. The team sizes and the retracted citations are not the same in all disciplines. Major retracted citations are from Biochemical or Medical fields. Journals that have listed a large number of retractions do not have a significant association with its impact factor; however, the retractions that happened in high-impact journals receive more citations. Further, one can extend the study by investigating the members of teams and the period of the collaboration. Also, one can investigate the citations of retracted publications like on what context scholars are citing the work.

The rise in the number of retractions raises concern in the scientific community about the degree of responsibility of coauthors, reviewers, and editors of the of scientific articles (Lievore et al., 2021). However, the scientific community is more attentive, doing checks and taking appropriate actions against such frauds. Further investigation is required on those publications those cited the retracted papers and are not retractions themselves. Databases like RetractionWatch is also providing scope to publishers and editors to examine the citations to retracted articles whether the author mentioned the appropriate reason behind such citations. Also, it raises an open question to social scientists or other scientific communities to investigate the rationale or psychology behind such frauds.

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Declarations

Conflict of interest The author declares no conflict of interest.

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