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Interventions to promote medical research integrity: a scoping review

Sihui Liu^{1*}, Yang Yang² and Miqi Li²

Abstract

Objective This study reviewed the current status of interventions for medical research integrity. The forms and methods of interventions, the timing and duration of interventions, outcome indicators, and evaluation methods and time were systematically reviewed. It provided a reference for the development of intervention programs for medical research integrity. So as to improve the integrity awareness and behavior norms of researchers.

Methods Studies related to medical research integrity and intervention measures were retrieved from databases (PubMed, Web of Science, Scopus, EBSCOhost, Sinomed, China National Knowledge Infrastructure, Wangfang Data, VIP Database). The time limit for retrieval extends from the establishment of the database to June 15, 2024. Two researchers independently screened and analyzed the retrieved literature, and the third researcher was asked to decide if there was any doubt.

Results The study included 17 references from 10 countries. A systematic review of the literature found that the intervention of medical research integrity runs through all stages of school and work. There were various forms of intervention measures, including policy intervention, environmental intervention, educational intervention and software intervention. Educational intervention was the most commonly used intervention for medical research integrity. Most interventions were short-lived and lack long-term follow-up and standardized assessments.

Conclusions Different interventions have different characteristics and advantages in promoting the integrity of medical research. At present, there is still a lack of uniform standards and long-term evaluation mechanisms for medical research integrity. In the future, various levels and forms of intervention measures should be formulated to improve the integrity of medical research.

Keywords Medical research integrity, Research integrity, Intervention measures, Review

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Introduction

Research integrity is an evolving concept, although there is currently no uniform definition of it. Medical research integrity is usually considered to follow scientific and ethical norms in medical research [1]. It ensures the authenticity, transparency and repeatability of the research process and results [2]. The core elements of medical research integrity include : data accuracy, transparent reporting of results, adherence to ethical norms, no conflict of interest, and respect for peer review and oversight [3]. Similar concepts to research integrity include research ethics and research misconduct. Research ethics is whether the scientific issues discussed are ethical, whether the methods used to pursue these issues are ethical, and whether the dissemination of research is ethical [4]. Research misconduct refers to intentional breaches of good faith norms, such as fabrication, forgery and plagiarism [5]. Medical research integrity plays a vital role in scientific research. First of all, it is the cornerstone to ensure the quality and reliability of research. The results of the study can only provide an effective basis for clinical application and policy formulation on the basis of authenticity and accuracy. Secondly, scientific research integrity is the key to maintaining public trust [6]. The credibility of research directly affects the wide acceptance of scientific discoveries. Finally, scientific research integrity promotes scientific progress. Only by following the principle of good faith, the research results can be effectively repeated and verified, so as to promote the accumulation and development of science [7].

Although the importance of research integrity has been recognized by the scientific community, violations of research integrity are still common [8]. Common research misconducts include data fraud, plagiarism, data selective reporting, and undisclosed conflicts of interest [9]. This phenomenon leads to inaccurate results in many published studies [10]. About 2% of scientists admitted to falsifying, falsifying or modifying data or results at least once, and an average of more than 14% of scientists observed these behaviors among their colleagues, the study found [11]. The actual number may be higher. The problem of scientific research integrity has been confirmed more seriously in the biomedical field [12–14]. Violating research integrity not only undermines the foundation of scientific research, leading to wrong and unreliable research results, but also consumes a lot of resources, including money, time and manpower [15]. Some studies have pointed out that about 85% of the resources may be wasted on non-repeatable and ineffective research in biomedical research [10]. Begley and Ellis [16] pointed out that in cancer research, only 11% of the research results can be repeated by other researchers. Scientific misconduct is not only a waste of resources, but may even directly endanger human health. Therefore,

in clinical trials, any experiment involving humans or animals must strictly follow the integrity of scientific research. At the same time, it ensures transparency in the design, implementation and results reporting of clinical trials and avoids selective reporting and publication bias [17].

Although the world 's emphasis on research integrity continues to increase, due to the increase in research misconduct, the number of academic journals withdrawn each year is also rising [18]. This phenomenon not only reveals the universality of research misconduct, but also reflects the shortcomings and challenges of existing research integrity interventions. The European Union and national science ministries have launched ambitious initiatives to crack down on misconduct and breaches of research integrity [19]. Although it is necessary to intervene in research integrity, there is still a lack of effective interventions [20]. Many existing measures such as research integrity training courses and policies and regulations have played a role to a certain extent, but their effects are uneven [21]. Organizational climate and culture have also been shown to influence research integrity and research misconduct [22]. And there are many challenges in the implementation of various interventions. Although the content and form of research integrity training are diverse, there is a lack of uniform standards and evaluation mechanisms. This makes the training effect difficult to guarantee. There are also some policies and regulations on scientific research misconduct, but there are often problems of insufficient strength and lack of transparency in the implementation process [23, 24]. In addition, although technical tools can help improve scientific research integrity to a certain extent, their use and popularization are not wide enough [25]. Many research institutions and researchers still need to improve their understanding and application ability of these tools. Finally, few studies have comprehensively analyzed the intervention strategies of medical research integrity. In view of the increasing attention to research misconduct and its adverse effects on scientific credibility, there is an urgent need for evidence-based intervention programs to promote integrity. This study analyzes the existing research integrity interventions, focusing on effective interventions at the policy and organizational levels in the field of medical research, aiming to identify key weaknesses and provide direct inspiration for future design of more targeted interventions.

Methods

This scoping review was guided by the methodological framework proposed by Arksey and O'Malley [26], which consisted of five steps: (1) identified the research questions; (2) searched related research; (3) screened target

literature; (4) extracted the data; (5) collated, summarized, and reported the results.

Identifying the research questions

The subjects of this study were related personnel engaged in medical research, including students, teachers and medical workers. The research topic was to adopt intervention strategies in medical research to promote the improvement of scientific research integrity. The outcome was the change in cognition, attitude or behavior of medical research integrity caused by intervention strategies. This review examined the scope of intervention in medical research integrity to explore the following objectives: (1) What were the intervention strategies of medical research integrity? (2) What was the specific content of the intervention strategies? (3) What was the effect of the application of intervention strategies?

Searching related research

This study systematically searched databases: China National Knowledge Infrastructure, Wanfang Data, and VIP Database, Sinomed, Pubmed, Web of science, Scopus, EBSCOhost. The retrieval was carried out by combining MeSH subject words, free words and Boolean logic operator connectors. Citation traceability was performed when necessary to ensure the integrity of the included studies. The search terms included “Medicine/medical/medical science/health professions education”, “research integrity/scientific integrity/academic integrity”, “intervention/randomized controlled/clinical controlled/before-after controlled/randomized/trial/research/control”. The retrieval time limit was from the establishment of the database to June 15, 2024.

Screening target literature

All the retrieved literature was imported into NoteExpress to remove duplicates. Two researchers independently screened the literature according to the inclusion and exclusion criteria. Firstly, two researchers independently read the titles and abstracts for preliminary screening. Secondly, they further read the full text to further screen and determine the literature included in the study. Finally, the literature with differences was discussed by the third researcher to determine whether to include it. All researchers had received unified and professional training.

A total of 5655 articles were retrieved. Among them, there were 325 articles from China National Knowledge Infrastructure, 594 articles on Wanfang Data, 138 articles on VIP Database, 164 articles on Sinomed, 1386 articles on Pubmed, 1104 articles on Web of science, 1830 articles on Scopus, and 114 articles on EBSCOhost. After removing duplicate literature, 4482 articles remained.

Finally, 17 articles were included for analysis, as shown in Fig. 1.

Extracting the data

Two researchers independently extracted and cross-checked the information in the literature. The content of data extraction included: publication time, research area, research type, research object, sample size (experimental group, control group), intervention forms and methods, timing and duration of intervention, outcome index and evaluation method and time. If there were differences between the two researchers, discuss with the third researcher until the results were agreed upon.

Collating and summarising data

The extracted data were entered into the pre-designed data table to ensure the integrity and consistency of the data. Subsequently, descriptive statistical analysis was performed on the classified data to ensure the accuracy and scientificity of the analysis. Finally, according to the analysis results, the intervention strategies of medical research integrity were systematically summarized and reported to provide scientific basis and reference for future research and practice.

Results

The 17 studies included were published from 2007 to 2024, as shown in Table 1. These studies were conducted in China ($n=4$), Germany ($n=3$), Croatia ($n=2$), the United States ($n=2$), Australia ($n=1$), Qatar ($n=1$), India ($n=1$), Peru ($n=1$) and Canada ($n=1$). Another study was conducted in six European countries: Belgium, Croatia, France, the Netherlands, Spain and the United Kingdom. It should be noted that two studies from Croatia reported the results of pre-experimental and experimental studies of the same intervention, respectively. Fourteen studies used quantitative methods (6 randomized controlled trials, 6 pre-post test studies, and 2 other quantitative studies), and three studies used qualitative methods.

Research object

The intervention studies on medical research integrity spanned across various academic stages, including pre-university students [27, 28], undergraduates [28–34], master students [33, 35–39] and doctoral students [36, 39–41]. Additionally, studies included senior researchers [27, 36, 41] and institutional leaders [42, 43]. All participants were from the medical field. It is evident that current research on medical research integrity mainly focuses on undergraduates and postgraduates, with relatively few studies involving clinical medical professionals.

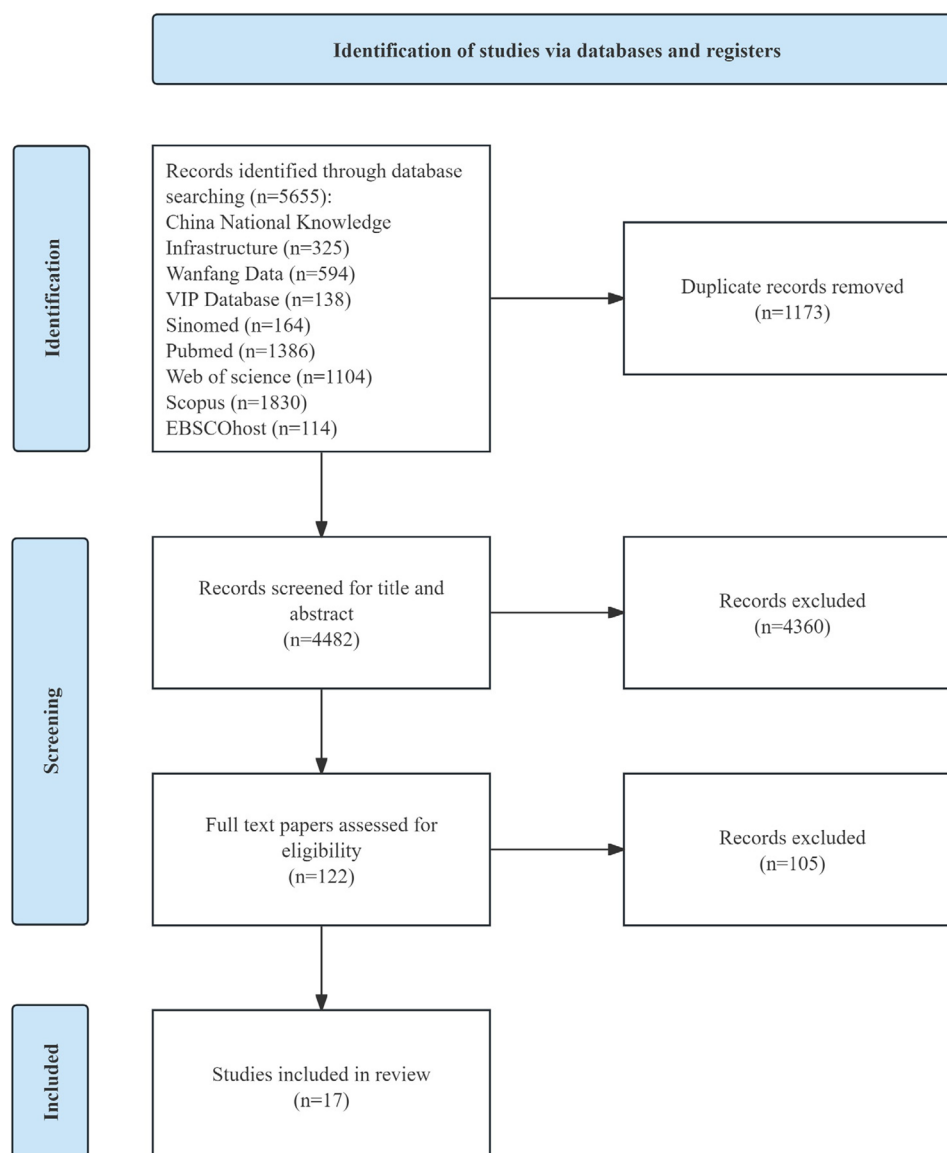


Fig. 1 Flow chart of literature screening

Sample size

A total of 17 studies were included in this review. Andres' [35] research included seven longitudinal cases, while other studies had sample sizes ranging from 13 [41] to 2243 [36]. The studies had small sample sizes [27, 29, 34, 37, 41–43] (less than 100 participants), seven studies had medium sample sizes [28, 30–33, 38, 40] (100–500 participants) and two studies had large sample sizes [36, 39] (more than 500 participants). The studies by Sira [36] and Mahmoud [27] were conducted in two stages.

Forms and methods of intervention

The interventions on medical research integrity were mainly divided into four categories: policy interventions,

educational interventions, environmental interventions, and software interventions, as shown in Table 2.

Policy interventions were implemented through the formulation of policies [27, 35] and reading policies [30, 31, 39]. Universities and institutions created transparent, comprehensive, and unified policies promoting academic integrity. These policies were often self-formulated by institutions [27, 35], usually focusing on punitive measures [35]. Research has shown that clear policies are effective interventions [27]. The reading of policies referred to national laws and regulations [30, 31, 39] and institutional rules and regulations [39].

Educational interventions were the most commonly used method for promoting medical research integrity. These could be further divided into online education

Table 1 General characteristics of the included studies ($n=17$)

Authors	Year	Country	Study Design	Participants	Sample (test/control)	Intervention form/method	Timing/ duration of intervention	Outcome index	Evaluation method/time
Sira et al. [36]	2024	Germany	pre-post test study	CDE	Q1:1267 Q2:976	educational intervention: abcf	one semester	③	questionnaire/after the end of the course
Wang et al. [38]	2024	China	RCT	CDE	68/68	educational intervention: ab	Master, clinical training stage	①②	questionnaire/after the end of training
Song et al. [37]	2024	China	RCT	CDE	12/12	educational intervention: g	Master of Grade 1, 5 years	①	questionnaires and questions/master's graduation
Nguyen et al. [40]	2023	Europe	RCT	D	315/315	environmental Intervention	Doctor.	③	questionnaire/after randomization
Buljan et al. [29]	2023	Croatia	RCT	B	84	educational intervention: e	undergraduates of Grade 1 and Grade 3, 15 min	①	Qualitative assessment/after the end of the course
Hu et al. [33]	2021	China	pre-post test study	BC	378	educational intervention: b	undergraduates and first-year masters	②	questionnaire/after the end of the course
Mahmoud et al. [27]	2020	Qatar	mixing research	AE	Q1:35 Q2:33	policy intervention educational intervention: b software intervention	4 years	③	questionnaires and questions/after 4 years of longitudinal intervention
Fuerholzer et al. [30]	2020	Germany	pre-post test study	B	119	policy intervention educational intervention: ab	undergraduates of Grade 3, 2 h	①②	questionnaire/after the end of the course
Fuerholzer et al. [31]	2020	Germany	pre-post test study	B	239	policy intervention educational intervention: ab	undergraduates of Grade 3, 180 min	①②	questionnaire/after the end of the course
Carnero et al. [35]	2017	Peru	longitudinal case study	C	7	policy intervention educational intervention: bc	Master, 3 years	③	observation/after intervention
Smedley et al. [32]	2015	Australia	pre-post test study	B	150	educational intervention: ac	undergraduates of Grade 1, one semester	①	questions/after the end of the semester
Azulay et al. [28]	2014	United States	pre-post test study	AB	194/161	educational intervention: ab	undergraduates, one day	①②	questionnaire/after the end of the course
Aggarwal et al. [42]	2011	India	RCT	EF	58	educational intervention: abcd	3.5 days to 3.5 weeks	①	knowledge test/ after the end of the course, three months later
Roberts et al. [34]	2007	United States	RCT	B	83	educational intervention: ad	undergraduates, 30 min	②	questionnaires and questions
Zhuo et al. [39]	2024	China	qualitative research	CD	1950	policy intervention educational intervention	/	①②	qualitative comparison
Miron et al. [43]	2021	Canada	qualitative research	F	74	/	/	/	questionnaires
Buljan et al. [41]	2008	Croatia	qualitative research	DE	13	educational intervention: b	Doctors and research experts, 50 min	②	qualitative analysis/after discussion

a: teaching knowledge, b: discussion cases, c: practice test, d: watching video, e: scene simulation, f: autonomous learning, g: Ideological education

①: knowledge, ②: attitude, ③: behavior

A: preparatory university, B: undergraduate, C: master, D: doctor, E: research experts; F: head of institution

Table 2 Intervention Forms and Methods

Intervention category	Content	Delivery method	Target population	Setting	Evaluation method	Outcome or effectiveness
Policy intervention	Formulating and reading policies promoting research integrity	Offline, Online	Researchers, Institutions	Universities, Research Institutions	Policy impact evaluation	Improved awareness of research integrity
Educational intervention - online	Online courses, lectures, modules on research integrity	Online	Undergraduates, Postgraduates, Researchers	Universities, Online Platforms	Knowledge tests, surveys, behavioral assessments	Improved knowledge, awareness, and application of integrity principles
Educational intervention - offline	In-person courses, lectures, Problem-Based Learning (PBL)	Offline	Undergraduates, Postgraduates, Researchers	Universities, Research Institutions	Case discussions, practice tests, knowledge assessments	Improved understanding and application of research integrity
Educational intervention - hybrid	Combination of online and offline educational activities	Hybrid	Undergraduates, Postgraduates, Researchers	Universities, Online Platforms	Knowledge tests, surveys, behavioral assessments	Improved knowledge, awareness, and application of integrity principles
Environmental intervention	Creating a supportive research integrity environment within institutions	Offline	Doctoral Students	Universities, Research Institutions	Impact on research behavior, environmental feedback	Influence on research integrity behavior
Software intervention	Use of anti-plagiarism software (Turnitin) to monitor research misconduct	Online	Students, Researchers	Universities, Online Platforms	Plagiarism detection rates, feedback on research integrity	Reduced plagiarism, improved adherence to integrity norms

[27, 28, 36, 40] and offline education [29–34, 37, 38, 41]. Offline education right included Problem-Based Learning (PBL) [30, 31]. One study used both online and offline education [42], while two studies did not report this aspect [32, 36], and one study did not address it [43]. Specific educational interventions included: (1) Teaching knowledge [28, 30–32, 34, 36, 38, 39, 42]: Experts or scholars transfer course content through oral explanations and demonstrations, covering topics such as academic writing, understanding plagiarism, and correct citation practices. (2) Discussion cases [27, 28, 30, 31, 33, 35, 36, 38, 41, 42]: Participants discussed specific cases to develop problem-solving and analytical skills. (3) Practice test [32, 35, 36, 42]: Homework, practice, and exams were used to test participants' understanding and application of the knowledge. (4) Watching video [34, 42]: Video resources were used to visually display key knowledge points to enhance interest and memory. (5) Scene simulation [29, 40]: Role-playing and practical exercises were used to simulate real-world situations, improving practical skills and coping strategies. (6) Autonomous learning [36]: Students organized their own learning time and schedules, utilizing resources for independent study and exploration. (7) Ideological education [37]: This approach involved moral, ethical and values education to cultivate students' correct behavior norms. In particular, only one Chinese study [37] integrated ideological elements into the education of scientific research integrity. This study conducted a total of three scientific integrity lectures. The control group adopted the traditional scientific research integrity lecture, and the experimental group integrated the designed ideological and political elements on the basis of the lecture. After the lecture, the students were assessed on the basic knowledge of scientific research

integrity. The score of scientific research integrity knowledge assessment in the experimental group was higher than that in the control group. The research showed that the effect of scientific research integrity integrated into ideological and political education was good. This measure could effectively avoid graduate students' dishonesty in scientific research.

Environmental interventions focused on the integrity atmosphere within the organization. The study of Nguyen [40] tested the influence of environmental factors on the research practice of biomedical doctoral students through two independent randomized controlled trials. This was the first study to explore the impact of environmental factors on research practice. In the first experiment, doctoral students faced with research integrity dilemmas were exposed to postdoctoral researchers who had chosen to engage in unethical research practices. In the second experiment, students consulted mentors who did not oppose the unethical practices. The study found that students often choose inappropriate research behaviors, but no evidence suggested that postdoctoral researchers or mentors influenced students' choices. Additionally, the study revealed that nearly half of the doctoral students were under significant pressure to publish, which could affect their research practices [40].

Software interventions involved using plagiarism detection software to monitor dishonest research behavior. A mixed study in Qatar [27] embedded Turnitin anti-plagiarism software into the course website and implemented it in all assignments. When students upload their works, Turnitin immediately reported the similarity score. Higher similarity scores (> 10%) prompted students and teachers to check plagiarism. This score helped

students and teachers to intervene accordingly. The results also confirmed that the use of plagiarism, helping both parties intervene as needed. This intervention proved effective in promoting research integrity.

Timing and duration of interventions

Interventions in medical research integrity spanned all stages, from newly enrolled undergraduates [29, 32] to experienced researchers [41]. The duration of interventions ranged from 15 min [29] to 5 years [37], usually including a complete intervention cycle.

Among the studies with detailed reports, 7 studies focused on undergraduates [28–34], 4 on master's students [33, 35, 37, 38], and 2 on doctoral students or those with doctoral degrees [40, 41]. Notably, many research subjects were first-year and third-year students [29–33, 41], a critical period in medical education. Roberts [34] suggested that first- and second-year medical students are in the preclinical stage, while third- and fourth-year students are in the clinical stage. Therefore, necessary medical research integrity intervention measures should be taken at different key time nodes. Nguyen [36, 40] argued that research integrity training should begin in the early stages of career development, including at the bachelor's and master's levels, and should be provided regularly to update rules and guidelines and maintain a high level of focus on issues. Similarly, Sira [36] showed that raising awareness of the issue of scientific integrity at an early stage seems particularly important.

Intervention Duration varied depending on the specific measures taken. Course or lecture durations ranged from 15 to 180 min [29–31, 34, 41]. The duration of a stage-based intervention could range from one day to 3.5 weeks [28, 42]. The shortest intervention time in the whole stage was one semester [32, 36], and the longest was 3 years [35], 4 years [27] or 5 years [37]. Most researchers noted that due to the short time span before and after the assessment, the intervention was limited to the short-term impact on research integrity. They clearly knew that further research on long-term results is necessary.

Outcome index

Outcome indicators can be summarized into three categories, namely, cognition, attitude and practice of medical research integrity. Cognition refers to the research participants' understanding of medical research integrity knowledge. Nine studies reported cognitive indicators [28–32, 37–39, 42]. Attitude refers to the participants' views and values regarding research integrity. Eight studies reported attitude indicators [28, 30, 31, 33, 34, 38, 39, 41]. Behavioral practice referred to how the research object practices the principle of medical research integrity in actual scientific research work. Four studies reported behavioral indicators [27, 35, 36,

40]. Cognitive indicators usually appear together with attitude indicators, while behavioral practice indicators were often reported separately. Changes in cognitive levels before and after intervention reflect the effectiveness of the intervention measures. Attitude surveys assess the impact of interventions on participants' research integrity values. Behavioral changes demonstrate the specific impact of interventions on participants' actions in actual research work, which is a key indicator of the long-term effectiveness and practical value of these interventions.

Evaluation methods and timing

A total of 12 studies evaluated intervention effectiveness using questionnaires [27, 28, 30, 31, 33, 34, 36–40, 43], accounting for the vast majority of all studies. The questionnaires varied widely and were difficult to standardize. Five studies used questions or tests to evaluate the results [27, 34, 35, 37, 42], including knowledge test, open question and answer. Three studies were evaluated by qualitative comparison or analysis [29, 39, 41]. Longitudinal case studies used observation methods [35]. Evaluations were generally conducted immediately after the intervention, whether it was a course, stage, or the entire student learning cycle. The only exception was that a randomized controlled trial [42] in the United States conducted a knowledge test on students after the end of the intervention course. A second knowledge test was conducted in the third month after the intervention.

Discussion

Intervention theme

Organizational level: creating an atmosphere of integrity

Many countries and research institutions have established detailed research integrity policies, such as those by the National Institutes of Health (NIH) [44] and the National Science Foundation (NSF) [45] require researchers to comply with the norms of research integrity when applying for funding and conducting research. The European Science Foundation (ESF) [46] and the World Health Organization (WHO) [47] aimed at regulating research behavior and ensuring fairness and transparency. However, challenges remain in their application. Firstly, researchers often lack sufficient awareness of these policies, hindering compliance in practice [48]. Secondly, enforcement is often weak, and the lack of uniformity across institutions and countries further complicates adherence.

Despite these challenges, policies present significant potential as an intervention. Systematic training can enhance understanding of research integrity [49], while stronger policy enforcement and international cooperation can promote standardization, improving research integrity worldwide.

Research on organizational teams as an intervention strategy is limited. Effective teamwork plays a crucial role in enhancing research quality and preventing misconduct [50]. Yet, current interventions primarily focus on individual education and technical tools, neglecting the potential of organizational culture and teamwork. A well-functioning team can provide mutual oversight, reducing the likelihood of individual misconduct. Organizational culture, which emphasizes integrity, can guide researchers to adhere to ethical standards [51, 52].

The pressure to publish and the dilemmas of research integrity often lead to misconduct, as researchers may manipulate data or selectively report results to meet career or funding expectations [53, 54]. Such pressures, along with ethical dilemmas, exacerbate moral stress, causing researchers to alter data to achieve desired outcomes. In order to cope with these challenges, various intervention strategies need to be adopted. First of all, we should set up reasonable research objectives, rather than excessive pressure on researchers. Secondly, it is necessary to intervene in people facing the dilemma of research integrity, rather than allowing them to practice harmful research integrity.

Individual level : cultivating moral cognition

Integrating ideological and political education into integrity education is a new approach that enhances moral awareness. Moral education, a long-standing part of education systems, fosters social responsibility and ethical behavior [55]. This integration not only continues this tradition but also adapts to the contemporary context, motivating researchers to follow integrity norms and resist misconduct.

Most medical research integrity interventions focus on education, utilizing various formats to enhance ethical awareness and professionalism in researchers [56]. These interventions aim to ensure compliance with integrity norms in scientific research. Different educational methods offer distinct advantages and challenges [57]. Knowledge-based teaching provides a solid foundation but often lacks engagement and applicability to specific research situations. Case discussions deepen understanding of integrity, but their time-consuming nature may hinder course progress. Practice tests consolidate learning, but they may induce stress, reducing enthusiasm. Video content is engaging but passive, limiting interaction. Autonomous learning caters to individual needs but requires strong self-discipline, which may not always be present. Ouchi's control theory suggests that real-time monitoring and feedback can effectively regulate individual behavior [58]. Anti-plagiarism software and data management tools provide such feedback, aiding in the timely identification and correction of dishonest behavior.

Research integrity training has primarily targeted students, as interventions are easier to implement and show better results during this stage. Additionally, student misconduct is closely linked to later dishonesty in clinical practice [59]. Early training can significantly reduce scientific misconduct [60]. However, many interventions are short-term, lasting only hours to months, such as courses, seminars, and online modules. These interventions aim to quickly enhance integrity awareness but often lack long-term follow-up, making it difficult to assess their lasting impact on researchers' careers. Establishing systematic long-term evaluation mechanisms is recommended to better assess intervention effectiveness and guide future improvements.

Practical enlightenment

Improvement and implementation of policies and regulations

The implementation of the policy is related to the improvement of scientific research integrity [61]. Only research integrity policy is not enough, we must ensure that these policies are strictly implemented in practice. Future intervention strategies should include the establishment of independent monitoring and evaluation mechanisms. This can ensure the effective implementation and supervision of the research integrity policy. In addition, given the global nature of scientific research, future research should promote international cooperation and coordination [62]. Unified standards and guidelines for scientific research integrity can be formulated to reduce the problems of scientific research integrity caused by regional and cultural differences.

Systematic and continuous education

Studies have shown that a single, short-term research integrity training effect is limited. Therefore, future intervention strategies should emphasize systematic and continuous education. Education should start from the undergraduate and master stages and run through the entire career of researchers. Through regular training and re-education, we will continue to strengthen the awareness of scientific research integrity and norms of behavior. The content of education should cover all levels from basic theory to concrete practice, including scientific research ethics, data management, experimental design, conflict of interest handling, etc. Multi-level education can help researchers understand and apply the principle of research integrity at different stages of scientific research. In addition, different and targeted education methods should be used for researchers at different stages, such as undergraduates, postgraduates, senior researchers, professors.

Organizational environment and teamwork

Scientific research institutions should be committed to creating an Organizational environment that values research integrity. Through leadership demonstration and system construction, the awareness and responsibility of scientific research integrity of all staff are enhanced. This kind of cultural construction needs long-term efforts and sustained attention. The role of team in scientific research integrity cannot be ignored. Future intervention strategies should emphasize teamwork and internal supervision. Through mutual supervision and feedback within the team, reduce the possible misconduct of individuals under pressure.

Application and development of technology

The use of modern technologies, such as data management platforms, duplicate checking software and research tracking systems, can improve the transparency and traceability of the scientific research process. Future research should continue to develop and promote these technical tools to help researchers better comply with the norms of scientific integrity. Not only to develop technical tools, but also to ensure that researchers are proficient in using these tools. Therefore, technical training should be an important part of scientific research integrity education, and the technical application ability of researchers should be improved through training.

The intervention strategies of medical research integrity have important implications for future research and practice. Strict implementation of policies and regulations, systematic and continuous education, organizational environment and teamwork, and the application of technical tools are all important ways to improve the level of scientific research integrity. Through the comprehensive implementation of these strategies, we can effectively reduce scientific misconduct, improve the quality and credibility of scientific research, and provide a solid ethical foundation for scientific progress.

Limitations

There are some limitations in this study. First of all, although a variety of research integrity interventions have been systematically reviewed, since the initial screening only reviews the topics and abstracts, it may not cover all intervention strategies. Secondly, the scope review does not require the quality of the article, so the quality of the included studies may be uneven. Moreover, the evaluation of the effectiveness of interventions mostly relies on short-term observations, and the lack of long-term tracking data makes it difficult to fully understand the long-term impact of these interventions on the career of researchers. In addition, the research mainly focuses on educational intervention and policy intervention, and there are relatively few discussions on environmental

intervention and technical intervention, which fails to fully demonstrate the potential effects of these methods in different scientific research environments. Others, the research integrity policies and cultural differences of different countries and institutions are relatively large. The results of this study may have certain geographical and cultural limitations and fail to fully reflect the status quo and intervention effects of research integrity worldwide. Finally, this study mainly relies on the data of the existing literature for analysis, lacking the support of actual research data. Future research should consider combining field research and experimental data to provide more comprehensive and reliable evidence. Importantly, we included several terms related to research integrity (ethics, academic integrity and plagiarism) throughout the study. Although these terms are conceptually different, there is considerable overlap.

Conclusion

This review highlights the importance of medical research integrity, its global attention, and the practical challenges it faces. Despite a consensus on its core principles, integrity violations remain frequent, indicating the insufficiency of current interventions. Existing measures, primarily policy and educational interventions, each have distinct advantages in promoting research integrity. Additionally, the impact of organizational environments on integrity has been explored, though uniform standards and long-term evaluation mechanisms are still lacking. Future strategies should focus on top-level policy interventions, foster an integrity-driven external environment, and ultimately influence individual researchers' integrity cognition.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

L.S.H. and Y.Y. wrote the main manuscript text and L.M.Q. prepared Table 1. All authors reviewed the manuscript.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

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Consent for publication

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Competing interests

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