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The Necessity and Importance of Research Training for Residents in Standardized Residency Programs

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Abstract: Standardized residency training programs primarily focus on developing clinical diagnostic and treatment skills, often allocating limited time to research activities. However, enhancing research skills is of paramount importance for residents, as it fosters critical thinking, problem-solving abilities, and a deeper understanding of applying scientific principles to clinical practice. This paper explores the necessity and significance of integrating research training into residency programs, emphasizing its role in cultivating well-rounded physicians capable of advancing medical knowledge. This study proposes a competency-based research training model that encompasses research literacy, study design, biostatistics, and scientific writing. Additionally, online asynchronous training modules, robust mentorship, and balanced time management strategies are recommended to enhance residents' research engagement without compromising clinical training. By implementing these measures, residency programs can improve residents' research capabilities, contributing to both individual professional growth and the broader advancement of medical science.

Keywords: Residency training; Research skills; Competency-based training; Mentorship; Online learning

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1. Introduction

Standardized residency training is a cornerstone of medical education, aiming to equip physicians with essential clinical skills for patient care. In many countries, including China, these programs emphasize clinical competencies such as diagnosis, treatment, and patient management, often at the expense of research training. While clinical expertise is crucial, the ability to engage in research is equally vital for promoting evidence-based practice, advancing medical knowledge, and addressing complex healthcare challenges. Research training during residency not only enhances critical thinking and problem-solving skills but also enables residents to translate scientific advancements into clinical applications, thereby improving patient outcomes. The current

landscape of medical education reveals a gap in residents' research training. Studies indicate that only 10–20% of residents in standardized training programs participate in research activities, with an even lower proportion publishing peer-reviewed articles. This disconnect is particularly evident in fields such as traditional Chinese medicine (TCM), where the integration of traditional theories with modern scientific methods necessitates a solid foundation in research capabilities. The lack of structured research training limits residents' ability to contribute to medical innovation and adapt to the rapidly evolving healthcare environment. This paper argues that research training is a critical component of residency education, with benefits extending beyond individual career development to the broader medical field. By analyzing the necessity and importance of research training, we propose strategies such as competency-based training models, online asynchronous modules, and mentorship programs to enhance residents' research capabilities. These approaches aim to bridge the gap between clinical and research skills, fostering a new generation of physician-scientists capable of driving medical practice forward.

2. Importance of research training for residents

2.1. Enhancing critical thinking and problem-solving abilities

Research training plays a crucial role in fostering critical thinking among residents. By requiring residents to formulate hypotheses, evaluate evidence, and interpret data, these trainings not only enhance their research capabilities but also directly impact their performance in clinical practice. In clinical settings, physicians often face complex cases, making it essential to effectively analyze these cases and make evidence-based decisions. Critical thinking has broad applications in healthcare and research. It is not merely the process of acquiring and evaluating evidence but also requires integrating this evidence with clinicians' expertise, patients' individual circumstances (including values and preferences), and the clinical context and setting. Critical thinking and decision-making are the tools to achieve this integration [1]. In medical research and writing, critical thinking is equally indispensable, especially when preset methodologies are insufficient to address complex problems [1]. Furthermore, teaching critical thinking is significant for reducing diagnostic errors and improving patient safety. Diagnostic errors are a major component of medical errors, and preventing them relies not only on establishing safety checks within the healthcare system but also on a deep understanding of critical thinking, clinical reasoning, and cognitive processes in diagnosis. By understanding how physicians make clinical decisions and studying errors caused by cognitive biases, awareness training for cognitive biases and debiasing strategies can be developed, thereby reducing diagnostic errors and patient harm [2]. In resident education, curricular innovations that integrate case-based learning with seminars and journal clubs can effectively enhance critical thinking skills. Through systematically planned seminars, journal presentations, and in-depth case presentations, residents can bridge the gap between theoretical knowledge and clinical practice, improving critical thinking, diagnostic skills, and teamwork [3]. This educational approach not only enhances residents' knowledge acquisition and retention but also significantly improves their critical thinking abilities in clinical assessment [3].

2.2. Bridging the gap between theory and practice

Research training plays a vital role in residents' education, not only helping them bridge the gap between theoretical knowledge and clinical application but also promoting their growth in the field of medical research. By engaging in research, residents can apply scientific principles to real-world clinical problems, such as evaluating the efficacy of new therapies or understanding the pathological mechanisms of diseases. This training not only enhances their clinical judgment but also provides them with a foundation for conducting independent

research in their future careers.

In residents' research training, interdisciplinary research methods are particularly important. As a study on translational medicine indicates, interdisciplinary research training can provide researchers with the multidisciplinary background needed for medical research in the post-genomic era [4]. This training approach not only helps cultivate a new generation of researchers but also promotes effective translation between basic science and clinical practice. Furthermore, the challenges faced by residents in research training should not be overlooked. Studies show that residents often face issues such as insufficient time, inadequate technical support, and a lack of mentorship during the research process [4]. To overcome these obstacles, some healthcare institutions have significantly improved residents' research output and academic performance by implementing comprehensive research programs that provide structured research time, technical support, and mentorship. Finally, research training benefits not only the personal development of residents but also contributes to the progress of the entire medical community. By integrating research into residents' education, future physicians can be ensured to possess not only clinical skills but also the ability to conduct scientific research, thereby promoting the continuous advancement of medical science [5]. This educational model, combining scientific research with clinical practice, helps cultivate excellent clinicians and promotes the innovation and application of medical knowledge. For example, in the field of Traditional Chinese Medicine (TCM), research training allows residents to explore the scientific basis of traditional practices (such as acupuncture) through modern methods like Randomized Controlled Trials (RCTs). This integration is crucial for validating the effectiveness and safety of TCM in the context of evidence-based medicine. In recent years, with the development of bioinformatics and artificial intelligence technologies, TCM research methods have significantly improved. These technologies have not only helped reveal the potential mechanisms of TCM but also promoted the interaction and integration of Chinese and Western medicine [6]. For instance, AI's application in acupuncture has made significant progress, using data mining methods to identify key acupoint combinations for treating various diseases, providing a scientific basis for clinical practice. The introduction of this modern technology has greatly improved the quantification, objectification, and standardization of acupuncture [7]. Additionally, modern bioinformatics techniques are also used to analyze TCM-related omics data, providing biological evidence for TCM mechanisms, thereby promoting the modernization and internationalization of TCM [6]. Concurrently, in the modernization process of traditional Chinese medicine, the combination of nanotechnology also brings new possibilities for TCM drug delivery systems. Through the meticulous design of nanotechnology, traditional Chinese medicines can be developed as nano-drug delivery systems, thereby enhancing their medicinal value for the treatment and prevention of diseases [4]. The application of this technology not only broadens the scope of TCM application but also provides new research ideas for the modernization of TCM. In summary, the modernization and internationalization of TCM require multidisciplinary collaboration and innovation; by integrating modern scientific technologies, TCM's influence and application potential in global health will be further enhanced.

2.3. Promoting medical innovation

Residents who receive research training play a significant role in medical innovation, especially with the rapid advancements in artificial intelligence (AI) and precision medicine. The progress in AI technology enables physicians to better interpret and apply research findings, thereby improving the quality and efficiency of healthcare services. In recent years, AI's application in medicine has continuously expanded, from image analysis to genomics and the integration of electronic health records, AI is transforming how physicians work

and patients experience treatment [8].

In the realm of precision medicine, AI's application is particularly noteworthy. By integrating health records, genomics, and immunology data, AI can provide personalized treatment plans for patients. This approach not only enhances diagnostic accuracy but also optimizes treatment strategies, allowing physicians to better predict disease activity and identify high-risk patients [9]. However, AI's application in precision medicine also faces challenges such as data quality, privacy concerns, and clinician trust, which need to be addressed during implementation. Furthermore, AI's role in medical education cannot be overlooked. As medical practice gradually transitions from the information age to the AI era, medical education needs corresponding reforms to cultivate physicians who can effectively work in this new environment. Future physicians will not only need traditional medical knowledge but also proficiency in using AI tools to provide high-quality healthcare services supported by multi-source data and AI applications [10]. This educational reform will help cultivate more innovative and adaptable medical talents, supporting the continuous development of the medical field. A survey by Smith et al. showed that residents involved in research are more likely to propose innovative solutions to clinical problems, such as developing new diagnostic tools or treatment protocols. This innovative ability is also reflected in the field of traditional Chinese medicine (TCM). Modern medicine has made significant achievements in safeguarding human health, but when facing complex diseases, single-target selective treatments often struggle to produce comprehensive recovery effects and can easily induce drug resistance and side effects. Traditional Chinese medicine (TCM) has distinct advantages in treating complex diseases, and its clinical value has been proven [11].

Additionally, the integration of artificial intelligence (AI) and Traditional Chinese Medicine (TCM) also marks a new frontier, demonstrating the potential to combine ancient therapies with modern technologies. AI's application in TCM, particularly in diagnosis, enhances the precision of treatment through complex pattern recognition. For example, AI analysis of tongue images can improve the accuracy of TCM syndrome differentiation. However, integrating AI into TCM also faces multifaceted challenges, such as data quality and ethical issues, thus requiring unified strategies to improve AI's understanding and application of TCM principles [12].

In terms of TCM pattern diagnosis, CM pattern diagnosis (Bian Zheng), as another patient classification method, has been combined with biomedical diagnosis in clinical practice in China. Clinical experience has shown that the combination of biomedicine and TCM is more effective in treating many diseases. CM pattern diagnosis has played an active role in the innovation of basic research, clinical research, and new drug discovery, promoting the innovation of medical science [13]. This research and innovations not only promote the development of TCM but also provide new perspectives and methods for modern medicine.

2.4. Career development and professional growth

Research training plays a crucial role in residents' career development. By participating in research activities, residents can not only enhance their academic abilities but also gain a competitive advantage when applying for specialized training and academic positions. Studies show that residents' research output during training is closely related to their future academic achievements. The quantity and quality of publications can predict their performance in an academic career [14].

Furthermore, gender differences also play an important role in residents' academic productivity and career choices. Research finds that although female residents may have lower research output than males, they are equally likely to choose academic careers and succeed in academia [15]. However, women still face challenges in advancing to higher academic positions, especially in the process of promotion to associate or full professor,

where this gender disparity is particularly evident [16].

To increase the retention rate of residents in academic medicine, it is recommended to strengthen the focus on research, mentorship, and career development during training. By providing more guidance and support, residents can better balance research and clinical responsibilities, thereby achieving greater success in academic medicine [17]. This support contributes not only to individual career development but also to the progress of the entire medical field. In China's Traditional Chinese Medicine (TCM) education, the cultivation of research capabilities is particularly important. By improving the quality of TCM research education, students can better grasp the practice of evidence-based medicine, thereby enhancing their clinical decision-making abilities and scientific understanding [18]. Furthermore, participation in research activities can not only improve students' academic performance but also stimulate their interest in future research [19]. In medical education, research experience is considered an important pathway for cultivating the next generation of academic physicians, and formal research training can help students build research skills, including hypothesis generation, problem formulation, and addressing knowledge gaps [20].

In China, the government and educational institutions are striving to strengthen support for clinical research to correct the misconception that graduate students only focus on basic biomedical research. By increasing support for clinical research, graduate students' research capabilities and career development potential can be enhanced [21]. Additionally, lifelong learning plays an important role in career sustainability, especially in the context of digital transformation, where lifelong learning can help practitioners maintain competitiveness and career sustainability [22].

3. Challenges of integrating research training into residency programs

3.1. Time constraints

The rigorous nature of residency training programs, characterized by long clinical hours and heavy patient loads, leaves little time for research. Studies show that residents spend an average of 60-80 hours per week on clinical work, limiting the time and energy available for research activities. This situation is evident across various medical fields. For example, in internal medicine residency training, despite work hour restrictions, there is still an issue of insufficient surgical experience [23]. Similarly, in orthopedic residency training, although the implementation of work hour restriction policies did not significantly reduce surgical volume, it still affected residents' overall operative experience [24].

Furthermore, residents' work hour limitations also impact their education and quality of life. Research indicates that while some residents support further reducing work hours to improve education and quality of life, most are unwilling to extend training time to achieve this goal [25]. This contradiction reflects the challenge residents face in balancing work hours, educational quality, and personal life.

To address these challenges, some training programs are beginning to explore new training models. For example, certain programs integrate research and clinical training, providing residents with opportunities to engage in research during their training. This model not only helps residents find time for research amidst busy clinical work but also promotes their career development [26]. Through these efforts, residents can gain more research experience and opportunities without compromising the quality of their clinical training. In Traditional Chinese Medicine (TCM) residency training programs, this challenge is particularly prominent because clinical training often involves mastering complex diagnostic techniques, such as pulse diagnosis, as well as modern medical practices. This complexity is also reflected in residency training in other medical fields. For example,

in the American Otolaryngology-Head and Neck Surgery (OTO-HNS) residency training program, the use of tracheotomy is controversial. Although this procedure is routinely used in multiple surgical fields, it is not widespread in OTO-HNS. Research shows that only 29% of OTO-HNS residency training programs regularly perform percutaneous tracheotomy (PT), indicating a significant divergence in attitudes towards this technique within the field [27].

Similarly, in American urology residency training, the structure of the clinical learning environment is also highly diverse. According to a national survey, urology residents participate in clinical work in various types of hospitals, including children's hospitals, county hospitals, private hospitals, university hospitals, and Veterans Administration hospitals. Although some programs offer dedicated outpatient rotations, time constraints and scheduling are considered the biggest barriers to teaching. Only 40% of program directors believe that residents view outpatient clinics as an important part of training, while 30% believe that outpatient clinics are merely necessary practice with limited learning opportunities [28].

3.2. Limited research infrastructure

Many residency training programs lack sufficient infrastructure to support research, including access to research mentors, funding, and statistical resources. In Traditional Chinese Medicine (TCM) institutions, the shortage of clinical teaching resources (such as hospital beds and experienced faculty) further exacerbates this issue. According to a study on American urology residency programs, the vast majority of programs require residents to participate in academic activities as a graduation requirement. However, major barriers to engaging in original research include a lack of experienced faculty, statistical and ethics committee support, and insufficient funding [1]. These factors not only affect residents' participation in research activities but also limit their ability to publish academic achievements in peer-reviewed journals.

Furthermore, research indicates that residents' experiences and opportunities in research training vary greatly. Some radiology residency training programs may offer specialized research pathways, while others may have no exposure to hypothesis-driven projects at all. To standardize research training for radiology residents, it is suggested to develop a resident-led standardized program, with the American Association of Academic Chief Residents in Radiology (A3CR2) collaborating with other national organizations to compile resources to improve residents' research experience [29]. To enhance residents' research productivity, programs need to identify and overcome key barriers affecting the success of academic activities, and may need to implement changes to improve research productivity within the program [30]. For example, a study by Han et al. found that only 30% of Traditional Chinese Medicine (TCM) residency training programs in China have dedicated research facilities. This finding highlights a significant issue in current TCM residency training, namely that the cultivation of research capabilities has not received sufficient attention. In contrast, China officially established a unified national medical residency standardization training system in 2014, a system that impacts the health of 1.4 billion people [31]. Under this system, new guidelines and standards for internal medicine residency training were introduced. However, most standards primarily focus on process measures, such as minimum case requirements for diseases and operative skills, rather than describing broader domains of physician competency, such as professionalism, patient care, communication, teamwork, quality improvement, and scholarly inquiry [31].

Although China has achieved standardization in some aspects of internal medicine residency training, the next step should focus on outcome measures and creating a competency-based system [31]. This means not only improving residents' clinical skills but also strengthening the cultivation of research capabilities so that they can innovate and improve in medical practice. This competency-oriented training model will help cultivate more

well-rounded medical professionals to meet the needs of modern healthcare systems.

3.3. Insufficient research training

In medical education, the cultivation of research skills is crucial for the professional development of medical students and residents. However, due to limited exposure during medical school, residents often lack foundational research skills such as research design, data analysis, and scientific writing. In Traditional Chinese Medicine (TCM) programs, this gap is more severe because the curriculum prioritizes classical theories over modern research methods.

Firstly, research indicates that the cultivation of research skills in medical education can be improved in various ways. For example, some medical schools have begun to introduce academic programs into their curricula to foster students' critical thinking and analytical abilities, and to encourage self-directed learning. This approach not only helps students understand the relationship between clinical care and research but also increases their research output [32].

Secondly, specialized research training programs have also proven effective. The summer internship program at the American Society for Reproductive Medicine is a successful example. Through intensive training, this program helps medical students master the basic principles of basic research and scientific writing, achieving significant research results in just a few years. This program not only enhances students' research capabilities but also strengthens their soft skills, such as time management and communication [33].

Furthermore, online research training courses also offer new possibilities for medical training. Research shows that online courses can significantly improve participants' knowledge and confidence in research concepts. This course is designed in an expert interview format, aiming to create a relaxed learning environment that promotes experience sharing, rather than merely transmitting factual information about research. This method is particularly suitable for remote learning during pandemics or other restrictive conditions [34].

In summary, the cultivation of research skills in medical education requires multi-faceted efforts, including improvements in curriculum design, implementation of specialized training programs, and utilization of online learning platforms. These measures can help medical students and residents better adapt to the demands of modern medical research and achieve greater success in their careers. Without structured training, residents may feel incompetent to conduct research, leading to low participation. This situation has been confirmed in multiple studies. For example, a survey on resident research education found that only 32% of programs offer structured research education plans, and these plans are more likely to be curriculum-based, require residents to participate in research projects, and provide specific lecture and writing skills training. In contrast, residents in unstructured programs had significantly lower publication rates [35].

Moreover, a nationwide survey in Japan found that residents participating in academic activities reported significantly higher overall satisfaction with their training programs. Despite barriers such as insufficient time, lack of mentors, and residents' lack of interest, most respondents still considered research activities worthwhile, and participation in research activities was positively correlated with resident training satisfaction [36].

In a study conducted in the United States, research participation was considered to have a positive impact on residents' careers. The study found that residents who had published peer-reviewed research during residency were more likely to continue publishing research throughout their careers. This suggests that research participation not only helps with academic productivity during residency but may also have a positive impact on future career development [37].

4. Strategies for enhancing research training in residency programs

4.1. Competency-based research training model

To address the research gap, many researchers and educational institutions are exploring how to effectively integrate research training into educational curricula. First, research literacy is one of the core components of research training. Research literacy includes not only an understanding of research methods but also critical evaluation of literature and ethical considerations. The cultivation of this literacy is crucial for students and professionals to effectively conduct research activities throughout their careers.

In higher education, the cultivation of data ethics and critical data literacy is also considered an important part of research training. By introducing ethical frameworks into research methods courses, educators can help students understand power structures in technological environments and promote a critical understanding of data collection and use [38]. This approach is not limited to medical education but can be applied to other disciplines to ensure students can apply these principles in various research environments.

Furthermore, the teaching of research methods and the cultivation of research skills have received widespread attention in medical education. By integrating research skills into undergraduate medical curricula, students can gradually develop these skills throughout their studies. This integration can be achieved by designing elective modules or courses that focus on aspects such as research design, data management, and academic communication [39]. In this way, students can not only understand the basic principles of research but also apply these skills in practice.

Finally, the effectiveness of research training can also be improved through evaluation and feedback mechanisms. For example, using the Kirkpatrick model to evaluate research methods workshops can help educators understand participants' satisfaction, improvement in knowledge and skills, and impact on practice [40]. This evaluation method can provide valuable feedback for curriculum design, further optimizing the effect of research training. In summary, by integrating research training into educational curricula, cultivating students' research literacy, and improving teaching methods through effective evaluation mechanisms, the research gap can be effectively narrowed, and students' and professionals' research capabilities can be enhanced.

In medical training, residents should focus on learning how to use the CONSORT (Consolidated Standards of Reporting Trials) checklist to evaluate scientific evidence from Randomized Controlled Trials (RCTs). The CONSORT checklist is a validated tool designed to improve the transparency and quality of RCT reporting. By learning the CONSORT checklist, residents can better understand and evaluate the design, conduct, and reporting of clinical trials, thereby improving their ability to apply scientific evidence in clinical practice.

Firstly, understanding the history and development of the CONSORT checklist is necessary. The CONSORT checklist was initially published in 1996, with subsequent updates in 2001 and 2010, and the most recent update in 2025 [41]. Each update aims to reflect the latest methodological advancements and user feedback. Through these updates, the CONSORT checklist continues to improve to ensure its applicability in different types of RCTs.

Secondly, residents should be familiar with the specific content and application methods of the CONSORT checklist. The CONSORT checklist includes a series of key items covering various aspects such as trial design, participant flow, and outcome reporting. By thoroughly studying these items, residents can better understand how to evaluate the credibility and validity of trials. For example, the TRACT checklist is a tool specifically designed to detect credibility issues in RCTs, comprising 19 items divided into seven domains [42]. Learning these domains can help physicians identify potential reporting problems.

Finally, residents should also understand the application of the CONSORT checklist in different medical

fields. For instance, in the field of medical informatics, the quality of RCT reporting is generally low, emphasizing the need to develop reporting standards applicable to this field [43]. By understanding reporting standards in different fields, physicians can more comprehensively grasp how to apply the CONSORT checklist in their respective specialties.

In summary, by learning and applying the CONSORT checklist, residents can improve their ability to evaluate and apply scientific evidence from RCTs, thereby making more informed decisions in clinical practice. When studying research design and methods, understanding different types of research designs and their applications is crucial. Observational studies, randomized controlled trials (RCTs), and meta-analyses are commonly used research design types, each with its unique advantages and applicable scenarios. Firstly, an observational study is a non-interventional research design where researchers collect data by observing and recording naturally occurring phenomena. This design is often used to study causal relationships and evaluate the real-world effects of interventions. Observational studies can be divided into prospective and retrospective types; prospective studies collect data at the beginning of the study, while retrospective studies analyze existing data [44].

Secondly, randomized controlled trials are considered the "gold standard" for evaluating the effectiveness of interventions. In an RCT, participants are randomly assigned to either an intervention group or a control group to ensure that differences between the two groups are caused solely by the intervention. This design effectively controls confounding factors and improves the internal validity of research results [45]. However, RCTs may face some challenges in practical application, such as ethical issues and high costs [46]. Finally, meta-analysis is a method that synthesizes and analyzes results from multiple independent studies. By statistically analyzing the results of multiple studies, meta-analysis can provide more comprehensive and reliable evidence. This method is particularly suitable for situations where research results are inconsistent or individual study sample sizes are small [47].

By participating in practical workshops on research design, residents can improve their ability to formulate research questions and hypotheses. These workshops typically include detailed introductions to different research designs and analyses of practical application cases, helping participants better understand how to select appropriate research designs to answer specific research questions. Additionally, workshops may also involve how to consider ethical issues and resource limitations in research design to ensure the feasibility and scientific rigor of the research. Biostatistics plays an important role in clinical data analysis, and mastering basic statistical techniques such as hypothesis testing and regression analysis is fundamental for effective data analysis. In this process, choosing appropriate statistical software tools is crucial. SPSS and R are two commonly used statistical software programs, each with unique advantages and application scenarios.

Firstly, SPSS is a statistical software widely used in social sciences and medical research, with a user-friendly interface suitable for beginners and non-statisticians. SPSS provides a rich set of statistical analysis functions, including hypothesis testing, regression analysis, ANOVA, etc., which can meet the needs of most clinical research [48]. In addition, SPSS also supports data analysis for single-case experimental designs, which is very useful for evaluating the progress of individual patients in clinical research [49].

On the other hand, R is a powerful programming language and software environment widely used in biostatistics and data science. The advantage of R lies in its flexibility and scalability, allowing users to perform complex data analysis tasks by writing scripts. R's open-source nature gives it a large user community and rich package resources, suitable for researchers who need advanced statistical analysis and data visualization [50]. For example, R can be used for comprehensive analysis of metabolomics data, supporting the entire process from

data preprocessing to association analysis [51].

In the teaching of biostatistics, integrating tools like SPSS and R into training can help students better understand and apply statistical techniques. By using these tools, students can practice on real datasets, thereby improving their data analysis skills and statistical thinking [52]. This practice-oriented teaching method not only helps students master theoretical knowledge but also enhances their application abilities in actual research.

Scientific writing and publishing play a crucial role in academia. It is not only the primary means of disseminating research findings but also an important component of researchers' career development. To improve the quality and efficiency of scientific writing, many scholars and institutions are exploring various methods to support and cultivate researchers' writing skills.

Firstly, the foundation of scientific writing lies in mastering multi-dimensional techniques for writing high-quality articles. According to a study, writing scientific manuscripts requires an international and interdisciplinary perspective, covering writing advice for major sections such as the title, abstract, introduction, methods, results, and discussion. These suggestions not only help improve the quality of the manuscript but also help authors better understand the peer review process and the impact of the article after publication [53].

Secondly, peer review, as the gatekeeper in the scientific process, plays a decisive role in the quality of academic articles. Although peer review is significant in supporting authors to improve their papers, training for early career researchers is relatively scarce. Standardized training and guidance can help reviewers improve feedback quality, thereby enhancing the overall level of scientific writing [54].

Furthermore, interventions supporting writing productivity have also proven effective. For example, a comprehensive structured writing intervention program for biomedical graduate students, through writing workshops, publishing workshops, and one-on-one writing coaching, significantly improved students' writing confidence and productivity. This intervention not only helped students overcome writing anxiety but also promoted their development in scientific careers [55].

This model can be implemented through modular courses, with each module lasting 4-6 weeks and culminating in a practical research project. For example, residents could design a research project on a Traditional Chinese Medicine intervention (such as acupuncture for chronic pain). During this process, participants would learn skills such as teamwork, project design, and data analysis. The design of this modular course is similar to the "Realizing Improvement through Team Empowerment (RITE)" project, which successfully achieved performance improvements in complex healthcare environments through a team and project-based model [56].

4.2. Mentorship system and support system

The mentorship system plays an important role in medical education, especially in cultivating residents' research capabilities. Experienced mentors can not only provide guidance during the research design phase but also offer support during research implementation and publication. This mentoring relationship is similar to the TCM apprenticeship system, which gradually improves residents' research capabilities through graded guidance.

Firstly, the mentorship system can help residents overcome various challenges in the research process by providing personalized guidance and feedback. Research indicates that mentors are crucial in research training, as they can help residents better understand research design and methodology by providing expertise and experience [57]. Additionally, mentors can help residents improve their research skills and confidence through regular communication and discussions [58].

Secondly, the mentorship system can foster residents' research independence by creating a supportive

learning environment. Studies show that with mentor guidance, residents can transition to research independence more quickly and achieve research results in a shorter time [59]. This support is reflected not only in the improvement of research skills but also in guidance on research project management and paper publication.

In summary, the mentorship system plays an important role in cultivating residents' research capabilities. Through personalized guidance, a supportive learning environment, and interdisciplinary collaboration, mentors can help residents improve their research skills, boost their research confidence, and promote their research independence. For example, Zhuang et al. proposed the "Master+" model, which pairs residents with national and provincial Traditional Chinese Medicine (TCM) experts to enhance research output. This model is similar to introducing innovation and research societies in residency training. According to a study, the Society for Innovation and Research (SIR) is a resident-led organization aimed at promoting and supporting residents' achievements in research and innovation. SIR provides key guidance and feedback through only 1 hour of protected teaching time per month to ensure residents' research success and educates residents on various topics of interest. Research indicates that since SIR's establishment, residents' research output has significantly increased, with both the number of published articles and the number of residents participating in research improving [60].

4.3. Balancing clinical and research responsibilities

For example, Zhuang *et al.* proposed the "Master+" model, which pairs residents with national and provincial Traditional Chinese Medicine (TCM) experts to enhance research output. This model is similar to introducing innovation and research societies in residency training. According to a study, the Society for Innovation and Research (SIR) is a resident-led organization aimed at promoting and supporting residents' achievements in research and innovation. SIR provides key guidance and feedback through only 1 hour of protected teaching time per month to ensure residents' research success and educates residents on various topics of interest. Research indicates that since SIR's establishment, residents' research output has significantly increased, with both the number of published articles and the number of residents participating in research improving [60].

Additionally, in research universities in China, an experimental teaching model is being explored where graduate students serve as teaching assistants for human anatomy courses. This model provides graduate students with more teaching opportunities, thereby expanding their knowledge base and improving their competitiveness for future employment. This model is more common in Western countries but is a new attempt in China [61]. These innovative teaching and research models not only enhance the research capabilities of residents and graduate students but also provide new ideas for medical education reform. In the field of Traditional Chinese Medicine (TCM), establishing partnerships with hospitals is crucial for residents' training and research development. Through such cooperation, residents can gain support for clinical data and research facilities, thereby better understanding and analyzing the actual effects of TCM treatments. This collaborative model not only helps improve residents' clinical skills but also promotes the modernization and internationalization of TCM.

Firstly, establishing research and education partnerships between China and the United States is a successful case. Taking the collaboration between the University of Pittsburgh School of Medicine and Tsinghua University as an example, Tsinghua medical students undergo two years of research training at the University of Pittsburgh, allowing them to engage in in-depth research in an international environment [62]. This collaborative model provides a valuable reference for residents in the TCM field; by cooperating with internationally

renowned institutions, the research level and international influence of TCM can be enhanced. Secondly, the application of artificial intelligence in the field of Traditional Chinese Medicine (TCM) also offers new research directions for residents. Through cooperation with hospitals, residents can utilize AI technology to analyze data and recognize patterns related to the therapeutic effects of TCM, thereby improving the accuracy of diagnosis and treatment [63]. This technological application not only enhances the efficiency of TCM research but also provides residents with an opportunity for interdisciplinary collaboration.

5. Case studies and evidence of success

Some residency training programs have successfully integrated research training. For example, the Mayo Clinic's physician-scientist training program combines clinical and research training, resulting in a 50% increase in resident publications within five years. This integration not only enhances residents' research capabilities but also promotes the overall development of medical research. The Mayo Clinic's success story can be further supported and expanded through multiple studies.

Firstly, the success of the Mayo Clinic's researcher training program is inseparable from its long-standing educational tradition. Since its establishment in 1915, the Mayo Clinic has been committed to raising the training standards of medical professionals and collaborated with the University of Minnesota to create graduate medical education programs that allow residents to earn master's and doctoral degrees in clinical medicine and surgery [64]. This non-pyramidal training structure provides residents with more research opportunities, enabling them to progress simultaneously in clinical and research fields.

Furthermore, research from other institutions also indicates that residency programs integrating research training can effectively bridge the gap between clinical training and research. For example, the psychiatry resident research track program created by Columbia University Medical Center in collaboration with the New York State Psychiatric Institute provides residents with protected research time and clear developmental milestones through a combination of core clinical rotations and research units [26]. This model not only increased residents' research interest but also promoted their career development in translational research through continuous mentorship and financial support.

Finally, the implementation of internal medicine resident research pathways has also shown significant results. According to a survey, 91% of residents who completed research pathway training dedicated some research effort to their careers, with 72% working in academic medicine [65]. This integrated training pathway not only increased residents' research participation but also laid a solid foundation for their career development in academia and the biomedical industry.

6. Conclusion

Research training is an important component of standardized residency training programs , with benefits including enhanced critical thinking, bridging the gap between theory and practice, promoting innovation, and supporting career development. Despite challenges such as time constraints and insufficient infrastructure, strategies like competency-based training, online modules, mentorship systems, and balanced scheduling can effectively integrate research into residency training programs. In the context of Traditional Chinese Medicine, these methods are particularly crucial for validating traditional practices through modern research methods. By fostering a research culture, residency training programs can cultivate physician-scientists, there by advancing medical knowledge and improving patient care.

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Disclosure statement

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