

Integration of traditional, complementary, and alternative medicine with modern biomedicine: the scientization, evidence, and challenges for integration of traditional Chinese medicine

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Abstract

Traditional medicine has garnered significant global recognition, with an estimated 80% of the global population using it. Therefore, it is essential to fully understand the integration of traditional medicines into current healthcare systems. This review aims to provide a comprehensive overview of the standard process to modernize traditional medicine scientifically in the context of modern biomedicine, further termed here as “scientization”. Specifically, we aim to summarize the advancements made in understanding the efficacy, effectiveness, and underlying mechanisms of herbal medicine. We also examined the transition from experience- to evidence-based medicine during acupuncture. Furthermore, we explore the development of universal safety and quality control standards. Finally, we discuss international trade and export markets for Chinese medical products. The development and integration of traditional medicine have allowed it to further improve human health, resulting in a more comprehensive health solution for the global population.

Keywords: Acupuncture, Conventional medicine, Herbal medicine, Modernization, Scientization, Traditional Chinese medicine

Graphical abstract: <http://links.lww.com/AHM/A84>.

Introduction

A significant proportion of the global population uses traditional indigenous medicinal practices to meet their primary healthcare needs. They are collectively referred to as “complementary and alternative medicines (CAM)” when commonly used outside their traditional context, alongside other medical systems, including Western biomedicine. In recent decades, growing interest in non-Western biomedicine has led to the recognition of CAMs as an important part of healthcare. The most widely practiced traditional systems globally are Chinese, Indian, and African^[1]. The terms “complementary medicine” and “alternative medicine” inherently indicate an underlying collective and general intention to integrate more closely with Western biomedicine^[2].

First, the scientization of CAM was examined using biomedical system-level quantification methodologies to study fundamental ideas that surpass traditional

reductionism by focusing on the most prevalent CAM, traditional Chinese medicine (TCM). Evidence of progress through scientization was then reviewed. Finally, the remaining challenges for integration with modern biomedicine through the scientization route were discussed. Similar to other CAM, TCM theoretically frames the human body as a multifaceted, dynamic system that emphasizes the reestablishment of homeostatic equilibrium of the human body, both internally and externally. Scientization of TCM from a biomedical perspective can quantify dynamic complex systems and generate novel insights that can enhance our understanding of TCM^[3,4]. Evidence of Chinese herbal medicine as a source of new pharmaceutical compounds has progressed to an increasingly well-mined and problematic drug development pipeline, given the numerous contemporary biomedical drugs derived from herbal remedies and natural ingredients^[5–8]. The 2015 Nobel Prize in Physiology or Medicine was awarded to Tu Youyou for the identification and

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development of artemisinin, a highly effective antimalarial compound produced from the botanical source *Artemisia annua*, which serves as an indication of the value of herbal medicine^[9]. The challenges of integrating CAM with biomedicine are presented along with progress in understanding TCM-derived herbs and formulations through evidence-based medicine (EBM) research^[10]. However, together with the challenges, investigating the complex formulations of TCM herbal treatments using EBM techniques also provides novel and valuable insights into drug mechanisms, enhancing our understanding of TCM principles and theory. Further development and integration of TCM through evidence-based scientization are likely to contribute significantly to the progress of modern biomedicine and global human health^[11].

Examining the influence of scientization on the identity and quality of CAM, particularly TCM, as it integrated with modern biomedicine

TCM primarily emphasizes individualized assessment of patients and personalized treatment. Its subjective nature presents a challenge in addressing issues related to large populations in an EBM-standardized manner that is informed and applied according to population statistics *en masse*^[12]. Scientization presents an opportunity to redefine and integrate CAM into biomedicine. In Germany, midwives frequently provide acupuncture treatment to aid childbirth without requiring an in-depth understanding of personalized TCM philosophy and diagnosis, using basic techniques that are often considered overly simplistic and general by TCM practitioners, such as standardized point localization and needling methods. Critical traditional point locations and methods for needling have been identified through scientization using consensus techniques, such as the Delphi process, the use of focus groups, and the creation of questionnaire-based assessments and EBM methodologies central to modern clinical research philosophy. These techniques, originally from the fields of commerce and industry, have enabled the close integration of CAM with modern biomedicine. Following the transition from 2,000 years of emperor rule in China, which almost exclusively supported traditional Chinese medical systems. American, German, and British pharmacopeias were integrated into the Chinese national health system to identify and control the quality of both synthetic and naturally sourced medicines during a period of population growth, displacement, and worldwide conflict in the early 1900s. It significantly influenced the production of the first Chinese pharmacopeia (ChP) in 1977, which remains the foundation on which the current 10 successive editions were based, integrating a blend of millennia-old antecedent traditional and cutting-edge biomedical knowledge. In 2008, the European TCM Working Group collaborated with the Chinese State Administration of TCM (SATCM) to establish monographs for the European pharmacopeia. This collaboration highlights the countercurrent influence, as Chinese medicine is now impacting Western medicine^[13]. Further scientization is apparent from the shift in the ChP commission plan to adopt International Conference on Harmonization (ICH) guidelines to strictly inform the

choice, development, and validation of analytical biomedical methods to identify and define “acceptable quality” of Chinese herbal medicine. To further harmonize the definition of quality, use, and evidence in TCM, the basis for selecting herbal materials for clinical trials, data collection, and evidence of outcomes was evaluated^[14]. The adoption of analytical techniques, including physical and chromatography, previously used for pharmaceutical and environmental analyses shifted the characterization and, therefore, the definition of CAM herbal medicines^[15], which contains a minimum amount of active ingredients, defined chemical markers, and “fingerprints”^[16].

The three major CAM systems in the world

Africa, India, and China possess abundant natural resources that support diverse medicinal plant populations and contribute to their respective traditional medicine systems. The use of traditional medicinal practices has increased worldwide and has garnered significant attention and acceptance over the past few decades. Traditional medicine has demonstrated use together with modern medicine, partly because of its role in meeting the basic and essential healthcare needs of populations in developing countries.

African traditional medicine is a broad and inclusive system that incorporates elements of indigenous medicinal plants and spirituality. Traditional healers and plant-based treatments have long played vital roles in promoting the well-being of the large African population, with each community’s social context playing a significant role and with distinct regional variations. Africa’s diverse culture and ethnicity amalgamate global and local aspects with its traditional medical knowledge^[17]. The concepts of care and healing are referenced within the framework of “Ubuntu” or “Botho,” as referred to in Botswana. These phrases emphasize the interrelationships among humans, society, the environment, and spirituality. The concept of “Ubuntu” is based on principles of generosity, hospitality, loyalty, honesty, and reverence for elders, ancestors, nature, and the divine, due to their inherent interconnection. The idea of “Ubuntu” in healing emphasizes the need for a holistic approach to human well-being and recovery, which includes identifying root causes and implementing preventive measures that embody both pathogenic and social factors^[18,19].

Antecedent Indian knowledge inherently recognizes the health-promoting, preventative, and curative attributes of medicinal herbs, which serve as the theoretical basis of the Indian system of medicine. The accompanying table contains a concise summary of the prevalent Ayurvedic medications [Supplementary Table S1, <http://links.lww.com/AHM/A81>]. Indian medicine systems can be broadly divided into two distinct categories: classical and traditional. The “classical” Indian system includes Ayurveda, Siddha, Amchi, Unani, Yoga, and Naturopathy. Ayurveda is a comprehensive and preventive science of natural treatment that originated in India under the guidance of esteemed researchers. The prefix “Ayur” denotes the concept of “life” while “Veda” signifies “science” resulting in the translation of Ayurveda as the “science of life.” Ayurveda treatment objectives address ailments and symptoms while harmonizing

body, mind, and “soul” through vegetarian dietary practice, medicinal herbs, physical activity, and meditation. The precise roots of this discipline have been attributed to a period of around 6,000 BCE, and later treatises were derived based on interpretations by Ayurvedic scholars and practitioners^[20].

However, the increasing global use of traditional medicines has raised significant concerns over their safety, efficacy, and quality control, particularly because of the lack of biomedical understanding of these medicines.

Exploration of the evidence, efficacy, effectiveness, and defined mechanisms of herbal medicines

Chinese medicine, the most widely used and researched traditional medicine system worldwide, exemplifies progress in the modern biomedical understanding of the safety, efficacy, and quality control of medical systems. Research on TCM resources has identified more than 12,000 herb species, providing a promising foundation for the continued development of modern pharmaceutical compounds. The fields of “ecopharmacognosy” and “ethnopharmacology” have emerged to establish biologically active components of natural products from environmentally sustainable plant sources^[21]. In this study, we compiled a selection of herbal remedies that are currently undergoing clinical trials at ClinicalTrials.gov. In summary, between 2010 and 2020, 136 naturally derived substances were evaluated in clinical trials [Supplementary Table S2, <http://links.lww.com/AHM/A82>].

Modern pharmaceuticals can be traced back to the use of quinine and aspirin. Quinine was first isolated from the bark of various Cinchona species in 1820. Indigenous Peruvian people use these plants to stop shivering. Quinine has been used to treat malarial fever since the 17th century^[22]. Salicylic acid, which is found in the bark of willow trees, has been used for thousands of years to reduce fever and inflammation. Aspirin was synthesized from it^[23]. The success of the first two “blockbuster” pharmaceuticals laid the groundwork for ongoing efforts in drug discovery in traditional medicine. Although chemical synthesis can produce many compounds, those derived from medicinal extracts hold great potential^[24]. Herbal and natural medicines have long been used because of their diuretic and renoprotective properties. They can be added to current treatment protocols as a preventive measure against chronic kidney disease or as a complementary approach to existing treatments^[25]. These substances often have complex stereochemistry and multi- or macrocyclic structures, which make their chemical synthesis challenging. Additionally, they often possess unique and variable biological properties. Notably, the parent extracts of these substances have undergone extensive clinical testing within their traditional context, spanning several millennia in some cases^[26].

Transformation from experience-based to evidence-based medicine in acupuncture

Acupuncture research is characterized by two primary methodologies for scientific validation: randomized

clinical trials (RCTs) and mechanistic exploration (Figure 1). Acupuncture patients undergoing RCT with articles published in impact factor (IF) >10 journals and 56 papers were compiled^[27–82] (Table 1). The effects of acupuncture and moxibustion in treating diseases occur through stimulation of specific acupoints that regulate bodily functions. These acupoints are connected by a network of meridians that play a crucial role in facilitating therapeutic effects. Although the anatomical foundation of these meridians remains unclear, acupuncture point stimulation can activate somatosensory-autonomic reflexes that widely influence bodily functions. This process starts with the activation of sensory nerve fibers located in the dorsal root ganglion (DRG) or trigeminal ganglion, followed by the transmission of sensory information to the spinal cord and brain, and ultimately, the activation of peripheral autonomic nerves that regulate bodily functions. Research conducted since the 1970s has shown a correlation between these reflexes and distinct anatomical parts of the body^[83].

There is a wide variation in the effects of acupuncture. The application of low-intensity acupuncture stimulation on specific acupoints in the hind limbs of mice, such as Zusanli ST36, results in the activation of the vagus nerve-adrenal anti-inflammatory pathway. However, acupuncture stimulation of abdominal acupoints, such as Tianshu ST25, does not elicit the same anti-inflammatory response. This demonstrates that PROKR2-Cre-labeled DRG sensory neurons initiated the vagus-adrenal anti-inflammatory pathway with the application of low-intensity acupuncture stimulation^[84]. Electroacupuncture stimulates acupoints to activate specific regions and modulates the physiological processes that generate therapeutic effects. This falls under the remission of the growing field of “bioelectronic medicine.” Activation of a cluster of sensory neurons expressing the Prokr2 protein occurring at the acupoint “Zusanli” location has been linked with the activation of distinct neuronal pathways^[84]. The identification of new and effective targets has been made possible by the elucidation of protein reactions in the body and the discovery of small active molecules that mimic the effects of acupuncture^[84,85]. These findings hold great potential for the development of “acupuncture drugs” with a wide range of applications. Metallothionein-2 (MT-2) was subjected to experimental manipulation in a mouse model of asthma, and protein upregulation was later confirmed, thereby establishing its pivotal role in mitigating asthma initiation^[86]. One study demonstrated a substantial correlation between acupuncture and decreased pain intensity among patients with cancer compared with a control group that underwent sham operations. Acupuncture has an established efficacy in alleviating cancer-related pain and diminishing the reliance on opioid analgesics^[87]. Stimulation of the Shenmen acupoint has been shown to have positive effects in assisting patients with alcohol addiction^[88]. According to a recent study, acupuncture effectively reduces the frequency and severity of angina pectoris. This study provides evidence that acupuncture is a safe and effective complementary treatment to conventional anti-angina pectoris medications^[89]. Another study reported that acupuncture-moxibustion treatment

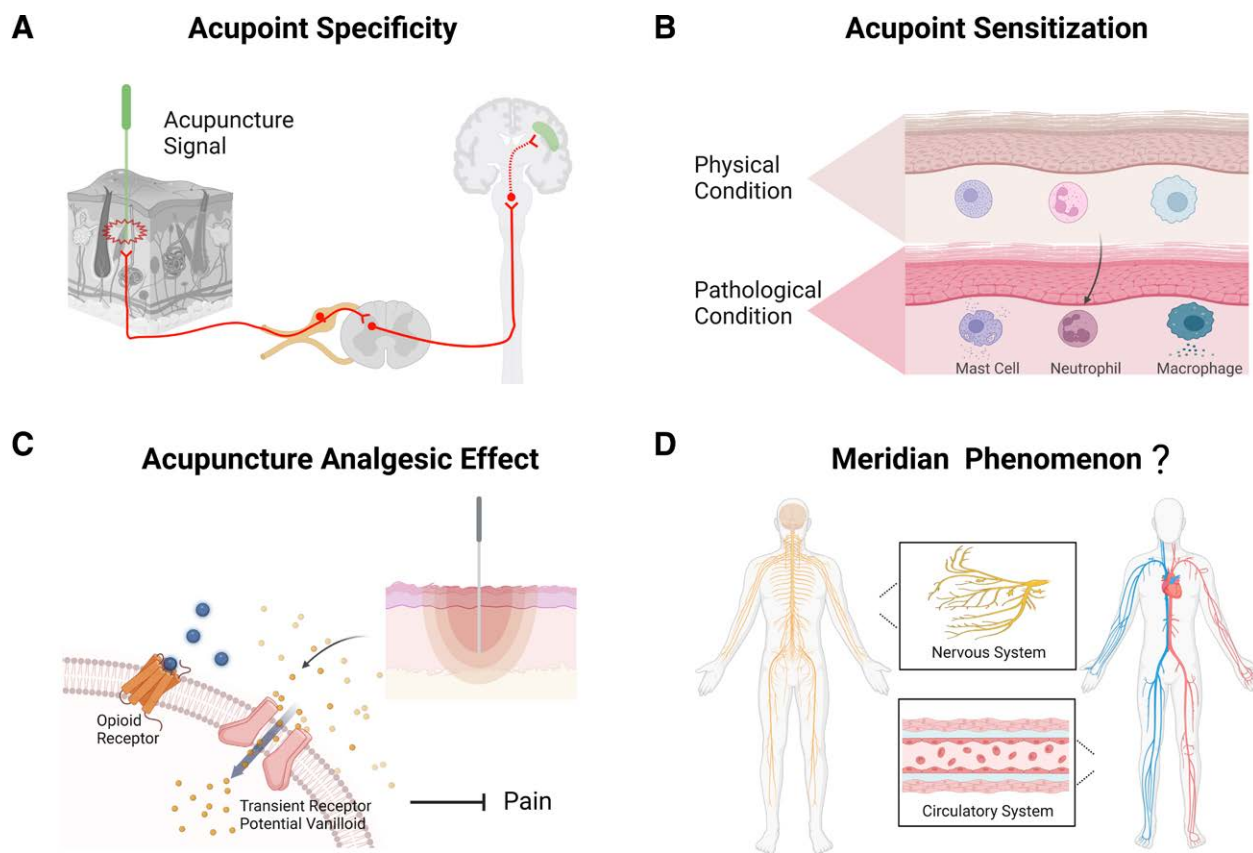


Figure 1. Mechanism study on the acupoint specificity, analgesic effect, and meridian phenomenon of acupuncture. (A) Specificity of acupoints: the difference in the central function areas of the cerebrum may be the key to the specificity of acupoints; (B) sensitization of acupoints: the change of chemical substances in the sensitized acupoints may be the material basis for the therapeutic effects; (C) acupuncture analgesic effect: various substances in the periphery nerve system play an important role in the mechanism of acupuncture inhibiting pain signal afferent and reducing peripheral sensitization; (D) meridian phenomenon: the meridian phenomenon of the nervous system and circulatory system.

for migraines in a 16-week RCT showed a lasting effect for at least 24 weeks, with no significant negative reactions reported^[90].

Construction of universal standards for safety and quality control

The acceptance of improved traditional medicines depends on scientific evidence, proving their safety and effectiveness, standardizing their dosage forms, and implementing strict quality control measures. Before a medicinal product can be marketed, a detailed dossier containing information on its safety and effectiveness must be submitted to the Commission Nationale d'Autorization de Mise sur le Marché, which is overseen by the Ministry of Health. The requirements for submitting a dossier for regulatory approval vary depending on the classification of the traditional medicines. Currently, seven enhanced traditional medicinal practices have been added to both the Malian Essential Drugs List and Malian National Formulary in addition to their conventional counterparts. These traditional medicines are readily available in pharmacies^[91].

In line with this rationale, the World Health Organization (WHO) has formulated global standards and technical recommendations, such as those pertaining to the evaluation of the safety and efficacy of herbal medicines and the conduct of clinical acupuncture research. These guidelines were established in accordance with

various resolutions of the World Health Assembly and Executive Board, indicating substantial support from global authoritative bodies^[92].

The WHO created draft “Methodology on Research and Evaluation of Traditional Medicine” guidelines in 1997, which was later adopted in April 2000. Its objective was to advocate for the appropriate advancement, registration, and utilization of traditional medicines, while also providing a unified approach toward using specific terminology across traditional medicine traditions^[93]. In 2006, the WHO established a global network called the International Regulatory Cooperation for Herbal Medicines. This network facilitates communication and collaboration among the regulatory agencies in various countries responsible for overseeing herbal medicines regulation^[94]. The establishment of Technical Committee TC249 within the International Organization for Standardization (ISO) serves as a crucial venue for the development of international standards pertaining to TCM. ISO/TC249 has produced 22 international standards for TCM, with six ISO standards that have already been formally released, including those for acupuncture needles and ginseng seedlings. Numerous ISO standards are currently being developed^[95]. The ISO related to traditional medicine are summarized in Supplementary Table S3, <http://links.lww.com/AHM/A83>. (ISO. <https://www.iso.org/search.html?q=traditional%20medicine> (accessed June 27, 2023).)

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Table 1
Researches published on IF (2022) >10 journals on RCT of acupuncture^[27-42]

Disease	Treatment group	Control group	P	Journal	IF
Joint pain	Acupuncture	Sham acupuncture	0.01	<i>Journal of the American Medical Association (JAMA)</i>	120.7
Polycystic ovary syndrome	Acupuncture and clomiphene	The control acupuncture group received superficial needle insertion, no manual stimulation, and mock electricity	>0.05	<i>Journal of the American Medical Association (JAMA)</i>	120.7
Carpal tunnel syndrome	Electroacupuncture	Sham electroacupuncture	Not shown	<i>Brain</i>	18.5
Migraine	Acupuncture	Sham acupuncture/waiting list	>0.05	<i>Journal of the American Medical Association (JAMA)</i>	120.7
Episodic migraine without aura	Manual acupuncture at true acupuncture points plus usual care	Non-penetrating sham acupuncture at heterosegmental non-acupuncture points plus usual care, or usual care alone over 8 weeks	<0.01	<i>British Medical Journal (BMJ)</i>	105.7
Osteoarthritis of the knee	Acupuncture	Minimal acupuncture (superficial needling at non-acupuncture points; n = 76), or a waiting list control	<0.01	<i>Lancet</i>	168.9
CRF	Treatment delivered by therapists or self-acupuncture/self-needling	No acupuncture	P > 0.05 (0.07)	<i>Annals of Oncology</i>	50.5
Fibromyalgia	Acupuncture	Sham acupuncture	P > 0.05	<i>Annals of Internal Medicine</i>	39.2
Tension-type headache	Acupuncture	Minimal acupuncture or no acupuncture	<0.01 versus no acupuncture, but >0.05 versus sham	<i>British Medical Journal (BMJ)</i>	105.7
Functional dyspepsia	Acupuncture	Sham acupuncture	P < 0.05	<i>The American Journal of Gastroenterology</i>	12.045
Osteoarthritis of the knee	Acupuncture	Sham acupuncture/conservative therapy	Not shown	<i>Annals of Internal Medicine</i>	39.2
PE	Acupuncture	Paroxetine/placebo	<0.01 versus placebo, but <0.01 versus paroxetine (less effective than medicine)	<i>European Urology</i>	23.4
Hot flash frequency in women with breast cancer	Acupuncture	Sham acupuncture	Not shown	<i>Journal of Clinical Oncology</i>	45.3
Exercise-induced asthma	Acupuncture	Sham acupuncture	P < 0.05	<i>Lancet</i>	168.9
Sham feeding stimulated gastric acid secretion	Electroacupuncture	Classic needle acupuncture, laser acupuncture	P < 0.05	<i>Gut</i>	24.5
Menopausal hot flashes	Acupuncture	Sham acupuncture	>0.05	<i>Annals of Internal Medicine</i>	39.2
Migraine	Acupuncture	Sham acupuncture/waiting list		<i>JAMA Internal Medicine</i>	44.46
Osteoarthritis of the knee	Acupuncture + exercise	Exercise, exercise + sham	Not shown, but no improvement	<i>British Medical Journal (BMJ)</i>	105.7

(Continued)

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Table 1
Continued

Disease	Treatment group	Control group	P	Journal	IF
IBS	Acupuncture	Sham acupuncture/waiting list	<0.01 versus no acupuncture, but >0.05 versus sham	American Journal of Gastroenterology	12.045
Chronic obstructive pulmonary disease	Acupuncture	Placebo acupuncture	Not shown but significantly	Lancet	202.731
Antiemetic effect	Acupuncture	Placebo acupuncture	>0.05	Clinical Cancer Research	11.5
Pain and dysfunction in patients with cancer with a history of neck dissection	Acupuncture	Usual care (eg, physical therapy, analgesia, and/or anti-inflammatory drugs, per patient preference or physician recommendation)	<0.05	Journal of Clinical Oncology	45.3
Live births of IVF	Acupuncture	Sham acupuncture	>0.05	Journal of the American Medical Association (JAMA)	120.7
Nausea and vomiting (emesis) during radiotherapy	Acupuncture	Placebo acupuncture	Not shown, effective but no difference to sham	Annals of Oncology	50.5
Seasonal allergic rhinitis	Acupuncture plus RM	Sham acupuncture plus RM (n = 102), or RM alone	<0.05	Annals of Internal Medicine	39.2
Vasomotor symptoms of breast cancer patients	Acupuncture	Venlafaxine	>0.05, as effective as the medicine	Journal of Clinical Oncology	45.3
Chronic headache	Acupuncture	Usual care	<0.05	British Medical Journal (BMJ)	105.7
Chronic mechanical neck pain	Electroacupuncture	Electricity on points	<0.05 both effective, but no difference in the effect	Annals of Internal Medicine	39.2
CRF	Acupuncture + usual care	Usual care	<0.05	Journal of Clinical Oncology	45.3
Migraine	Acupuncture	Sham acupuncture/standard therapy	<0.01 after treatment, but >0.05 versus sham or standard treatment	Lancet Neurology	48.0
Angina pectoris	Acupuncture	Placebo tablet treatment	<0.05	European Heart Journal	39.3
Osteoarthritis of the knee	Acupuncture	Sham acupuncture or education	<0.05	Annals of Internal Medicine	39.2
Chronic neck pain	Acupuncture	Massage or laser acupuncture	<0.05 versus massage but >0.05 versus laser acupuncture	British Medical Journal (BMJ)	105.7
Hot flashes in women with breast cancer	Acupuncture + self-care	Self-care	<0.01	Journal of Clinical Oncology	45.3
Insomnia in cancer survivors	Acupuncture	CBT-I	Acupuncture: -8.31 points, 95% confidence interval = -9.36 to -7.26; CBT-I: -10.91 points, 95% confidence interval = -11.97 to -9.85) CBT-I was more effective for those who were male (P < 0.001), White (P = 0.003), highly educated (P < 0.001), and had no pain at baseline (P < 0.001)	Journal of the National Cancer Institute	10.4
Cancer pain	Auricular acupuncture	Two placebo groups received auricular acupuncture at points with no electrodermal signal (placebo points) and one with auricular seeds fixed at placebo points	<0.01	Journal of Clinical Oncology	45.3

(Continued)

Increasing international trade and export market of Chinese medical products

Significant advancements have been made since the integration of TCM into the International Classification of Diseases (ICD-11) in 2019. This integration has led to the development of a classification system framework focusing primarily on TCM and other traditional medicinal practices^[96]. Significant progress has been made in the scientific and technical innovations in TCM. Considerable improvements have been made in the assessment of resources related to Chinese medicinal materials, resulting in the development of extensive cultivation practices for over 200 frequently used materials. These cultivation efforts cover an impressive land area of over 30 million acres and have established a fundamental production system for commonly used Chinese medicinal materials. The field of TCM is experiencing a surge in innovation, as indicated by the growing number of TCM variations valued at over 100 million RMB. This number increased from a few dozen to 500, with 50 TCM varieties now valued at over 1 billion RMB. Certain Chinese herbal medicine standards have been adopted by the United States Pharmacopoeia and European Union Pharmacopoeia. Seven different types of Chinese medicines have successfully completed phase II/III clinical studies in the United States, thereby allowing Chinese medicines to gain momentum in the global market. Several contemporary Chinese medicine firms have been established, and 25 industrial bases dedicated to modern Chinese medicine research and technology have been developed. The TCM and health industries have seen increased activity focusing on integrating TCM with the pension and tourism sectors. The overall output value of the TCM industry has grown significantly from 23.4 billion RMB in 1996 to 786.7 billion RMB in 2015, largely due to advancements in scientific and technological innovation. This increase accounts for approximately one-fifth to one-third of the pharmaceutical industry's total output. Despite the influence of the pandemic, the export market statistics of Chinese pharmaceuticals in 2020 revealed a rising global demand for herbal products, particularly in the USA, Japan, and China (Figure 2).

Discussion and conclusion

Over the years, traditional medicines have been extensively developed as representative examples of naturally derived drugs. A wealth of human pharmacological knowledge and experience has been accumulated, forming a comprehensive theoretical framework. The active components, specifically the material basis for compound prescriptions and their pharmacodynamic mechanisms, are central to this framework. The utilization of various technological advancements in analytical chemistry, such as high-performance liquid chromatography, high-performance capillary electrophoresis, and high-speed countercurrent chromatography, together with molecular biology techniques, including patch clamp, gene clamp, gene chip, fluorescent probes, DNA TUNEL assay, and *in situ* hybridization, has played a crucial role in the modernization of TCM. Adherence to international standards, such as the CONSORT and TREND declarations, is vital for advancing and accepting TCM. Enhancing

the quality of clinical data is a crucial undertaking in the pursuit of TCM research progress^[97]. Advancements in “omics” and high-throughput investigative methods, such as proteomics and genomics, have greatly contributed to drug target discovery and understanding of pharmacological mechanisms, making them crucial for modern drug design^[98–100]. In conjunction with advancements in computer technology, conventional medical devices are expected to undergo digitization and standardization. Consequently, this modern approach provides valuable reference data for traditional medications, thus benefiting the global community^[101,102].

Challenges to the scientization of traditional medicine

The reductive philosophy and terminology of current biomedicine describe complex, multivariate, and multisystem holistic concepts. The multidisciplinary, cultural, and generational terminology of TCM cannot be readily reduced to simple biomedical descriptions. EBM relies on observing statistically significant effects as positive experimental outcomes, whereas traditional medicine systems focus on restoring homeostasis, which reduces the significant observed biochemical effects. Biomedicine aims to develop well-defined, measurable, and reproducible therapeutics that produce perceivable effects in large populations, whereas traditional medicine emphasizes personalized medicine, in which even identical twins presenting with identical symptoms are treated differently depending on, for example, pulse and tongue diagnosis. Furthermore, the same patient with the same condition presenting at a different time of day or season could be treated differently using traditional medicine. The economic advantage of biomedical therapeutics is the efficiency of scale with non-personalized medicines versus, sometimes, unpatentable and economically unfavorable natural medicines, even though they may be effective. The cost of registering one herbal medicine in the European Union (EU) would typically be more than 1 million euros, and for mixtures of multiple millions of herbs, the relative concentrations may not be significantly altered or reregistration would be required. Chinese medicine commonly uses four to 12 herbs in a single prescription that are regularly modified, rendering the current registration system unsuitable and unviable. The standard of traditional medicine training is variable and generally insufficient compared with biomedical training courses. The availability of traditional medicine courses is limited, and they are difficult to test and standardize. Therefore, the predominant bias in evaluating clinical research data is through a biomedical lens, which is yet to develop into a fully modern and compatible conceptual framework to incorporate more holistic considerations.

Conflict of interest statement

The authors declare no conflict of interest.

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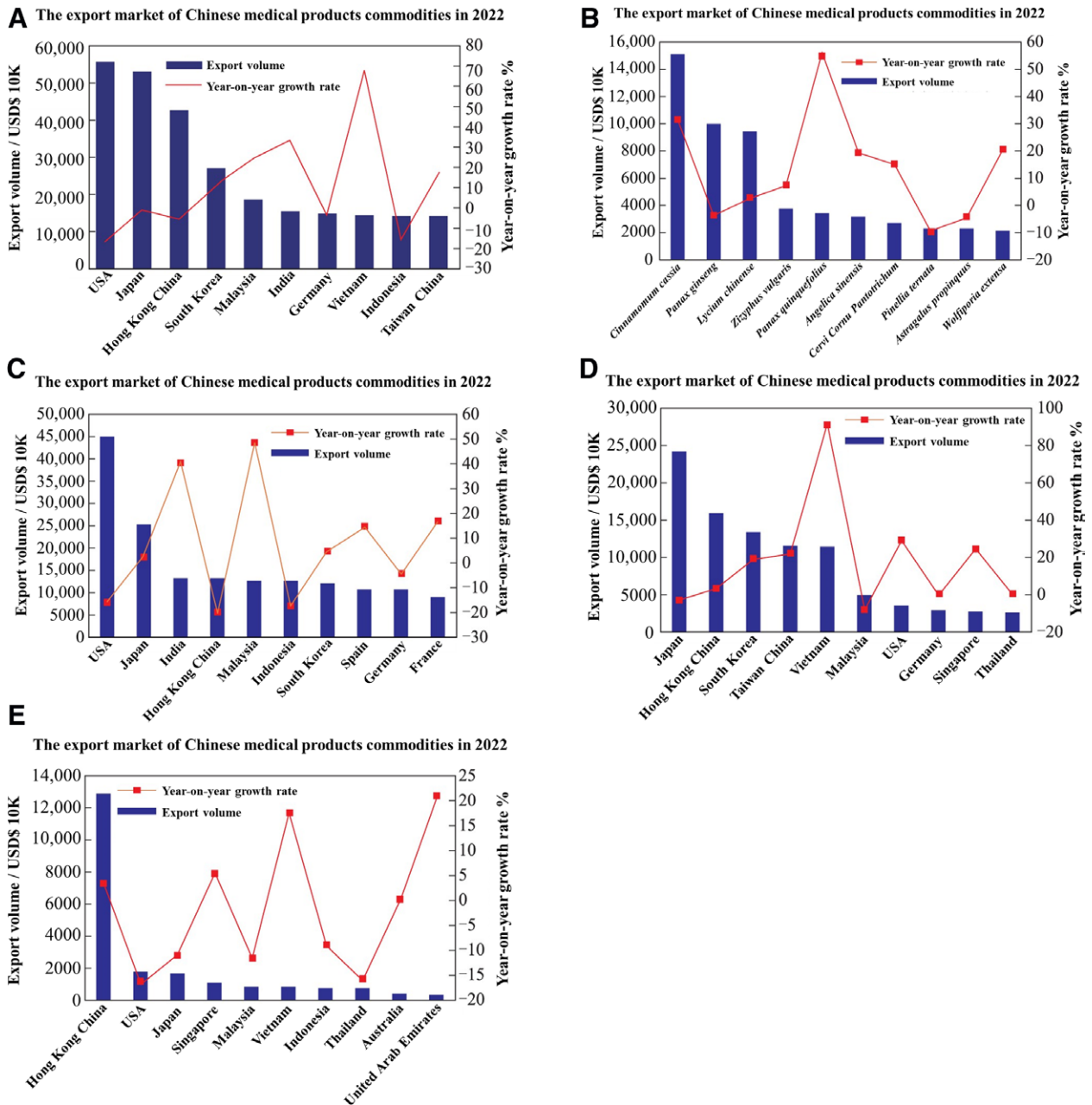


Figure 2. Exportation of Chinese medicinal products in 2022. (A) The export market of Chinese medical product commodities in 2022; (B) Top 10 export brands of Chinese medicinal materials in 2022; (C) The major export market for plant extracts in 2022; (D) The major export markets for raw and refined Chinese medicinal materials in 2022; (E) The major export markets for Chinese herbal patents in 2022 [data from Import and export data of Chinese medicine and health products. Chamber of Commerce for Import and Export of Chinese Medicines. <https://www.ccmhpie.org.cn> (accessed March 20, 2023)].

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Author contributions

Lu Luo: Writing - original draft, writing - review & Editing, funding acquisition, supervision; Zihao Zhang: formal analysis, writing - original draft, writing - review & editing; Raorao Li: formal analysis, writing - original draft, writing - review & editing; Yu Chen: formal analysis; Hui Yang: formal analysis; Martin Fitzgerald: formal analysis; Qiaochu Wang: writing - review & editing; Ziwen Xu: investigation, data analysis, writing - review

& editing; Nanxi Huang: writing - original draft, writing - review & editing; Dajun Lu: formal analysis;

Ethical approval of studies and informed consent

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Data availability

All data generated or analyzed during this study are included in this published article.

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