International Journal of Medicine and Medical Research

Journal homepage: https://ijmr.com.ua/
Volume 11, No. 1. 2025

UDC 616.71:615.822:615.832.6
DOI: 10.63341/ijmmr/1.2025.105

Article's History:
Received: 19.02.2025; Revised: 25.04.2025; Accepted: 27.05.2025

Review of modern approaches to the treatment of patients with musculoskeletal disorders and diseases using traditional Chinese medicine (TCM) – acupuncture

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Abstract. The relevance of the study is due to the substantial spread of diseases of the musculoskeletal system and the need for effective non-drug treatment methods. Its purpose was to analyse scientific data on clinical efficacy, physiological mechanisms of action, and innovative approaches to the use of acupuncture in the treatment of musculoskeletal pathologies. The study was a literature review of scientific publications of 2019-2025 using a comprehensive three-stage methodological approach, which included the analysis of published data on the clinical effectiveness of acupuncture on standardised scales and questionnaires, generalisation of research on neurophysiological mechanisms of action, and systematisation of modern innovative protocols presented in the scientific literature. An analysis of clinical studies showed that the effectiveness of acupuncture varies depending on techniques and nosological forms, with the highest level of evidence for chronic lower back pain and osteoarthritis. After a course of acupuncture (2-3 sessions per week, with a total duration of 4-8 weeks), a decrease in pain intensity on the visual-analogue scale was recorded by 2.87-4.1 points and an improvement in functional indicators by 9.5-20.3%. Based on the generalisation of the data, two theoretical models were formulated: a triune concept of therapeutic action of acupuncture, which covers physiological (reduction of pain symptoms), functional (restoration of motor activity), and psychoemotional (normalisation of psychological state) components and an integrative model of effectiveness in chronic pain, which includes short-term anaesthesia through neuromodulation, improvement of local microcirculation, and functional restoration of muscle-fascial structures. The examination of neurophysiological mechanisms demonstrated that the therapeutic effect of acupuncture is mediated by activation of the endogenous opioid system, modulation of inflammatory cytokines, and neuroplastic changes in brain networks, which is confirmed by neuroimaging methods. The study also systematised current innovations in acupuncture practice, including optimisation of treatment protocols, group forms of therapy, and telemedicine models. Integrative approaches that combined acupuncture with traditional treatments showed better results in 83% of the analysed studies compared to monocomponent interventions. The results of the study confirm the clinical effectiveness of various acupuncture techniques in diseases of the musculoskeletal system, which is justified by the complex effect on the neurophysiological mechanisms of pain modulation and proves the feasibility of including the method in standard therapeutic protocols

Keywords: chronic pain; functional state; therapeutic effect; pain syndrome; integrative approach

Introduction

Due to the limitations of conservative and surgical methods of treatment of the musculoskeletal system and the associated risks and long-term recovery, interest in milder complex approaches is growing; acupuncture, as a key component of traditional Chinese medicine (TCM), activates natural recovery processes, considers the individual characteristics of the patient and the general condition of the body, so it becomes a popular means of modern rehabilitation and prevention. The World Health Organisation (WHO) estimates that about 1.71 billion people (more

Suggest Citation:
Mazur Ya. Review of modern approaches to the treatment of patients with musculoskeletal disorders and diseases using traditional Chinese medicine (TCM) – acupuncture. Int J Med Med Res. 2025;11(1):105–20. DOI: 10.63341/ijmmr/1.2025.105

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than 20% of the world's population) suffered from musculoskeletal disorders in 2020, with lower back pain, arthritis, and osteoarthritis being the most common [1]. In Ukraine, according to P.M. Skrypnykov *et al.* [2], the prevalence of childhood diseases, including musculoskeletal diseases, increased from 1,253.0 cases per 1,000 children in 1994 to 1,748.0 cases in 2017, which is 41% higher, and 7.82% of periodontitis exacerbations were detected in internally displaced persons after 2022.

A. Rademacher [3] considered the problem of severe symptoms that accompany cancer treatment, in particular pain, fatigue, depression, and nausea. The researcher evaluated the safety and effectiveness of acupuncture as an integrative therapy in patients with cancer. The main focus was on symptoms that occur during treatment, especially in recipients of haematopoietic cell transplants. In conclusions of A. Rademacher, it is stressed that acupuncture is a safe method to reduce the burden of symptoms in this patient population. D. Akçalı *et al.* [4] raised the problem of treating various forms of headache, including migraines, which is a serious and common condition that often requires long-term medical treatment with potential side effects. The authors assessed the effectiveness of acupuncture as an adjunct or primary treatment for primary headaches. The conclusion of their study was the claim that acupuncture is a safe, cost-effective, and effective method in most cases of treating headaches.

The main problem in the study by P. Patel *et al.* [5] was a treatment for chronic pain that is often resistant to traditional pharmacotherapy. The researchers analysed the effectiveness of acupuncture in reducing chronic pain, underlining the importance of this method in the context of long-term treatment of patients who do not receive sufficient relief with standard means. In their findings, the authors agreed that acupuncture, despite long-standing criticism and treatment as a pseudomedicine, provides substantial long-term relief of symptoms in patients with chronic pain. In addition, I. Urits *et al.* [6] explored the use of acupuncture to treat migraines in an attempt to address the side effects of traditional pharmacological treatments. They reviewed the literature and analysed clinical studies on the effectiveness of acupuncture in treating migraine pain. Their results showed that acupuncture is a safe and potentially effective method for reducing the frequency and intensity of migraine attacks, and also has fewer side effects compared to pharmacotherapy.

In their comprehensive review, S.E. Iskandarani & G. Deng [7] addressed the problem of insufficient symptom control in patients with haematological malignancies, finding that acupuncture effectively reduces pain and nausea, although the results for symptoms such as neuropathy, fatigue, or pruritus are less convincing. This alligns with the results of J. Halámková *et al.* [8], who reviewed the use of acupuncture to treat symptoms in cancer patients in accordance with the international guidelines of the National Comprehensive Cancer Network (NCCN). Their study confirmed a positive effect on pain, nausea, and vasomotor disorders, while emphasising the need for a clearer definition of indications and contraindications to ensure the safe use of the method.

J. Zhu *et al.* [9] analysed the history, current state, and mechanisms of action of acupuncture, dealing with the scientific justification of this traditional practice. Their work confirmed the presence of positive effects, but noted that additional molecular studies are needed to accurately explain the mechanisms of action. This scientific basis is crucial for the wider adoption of acupuncture in modern medical practice. In the study on technological innovations, G. Litscher [10] investigated the use of artificial intelligence (AI) in acupuncture practice, focusing on integrating modern technologies to improve diagnostic accuracy. The results of this publication demonstrate that AI has the potential to improve the methodology, but the researcher underscored the critical importance of preserving the human factor, empathy, and ethical standards in the treatment process. This opens up promising areas for modernising traditional acupuncture practices, while emphasising the need to preserve their fundamental therapeutic principles.

Previous studies have substantial limitations in differentiating the effectiveness of different acupuncture techniques in specific nosological forms of musculoskeletal diseases. There is insufficient integration of neuroimaging, molecular, and clinical data to form a holistic model of the therapeutic effects of acupuncture. Innovative models of acupuncture care also remain poorly understood, which limits their availability and integration into modern health systems. Although many scientific works are devoted to acupuncture, research focused specifically on modern approaches to the treatment of the musculoskeletal system using TCM-acupuncture was not enough, which led to the need for this systematic review of the literature.

This paper aimed to systematise modern approaches to the treatment of the musculoskeletal system using acupuncture in the framework of TCM. Study objectives: analyse the clinical effectiveness of various acupuncture techniques in the main diseases of the musculoskeletal system with determination of the level of evidence for each technique; systematise the neurophysiological mechanisms of acupuncture action based on experimental and neuroimaging studies; investigate modern innovations and adaptations of traditional acupuncture methods, including optimisation of treatment protocols and new models of acupuncture care.

Materials and Methods

The study was presented as a literature review of scientific publications and concentrated on three key aspects of the use of acupuncture in pathologies of the musculoskeletal system. The clinical effectiveness of various acupuncture techniques was chosen as the first fundamental aspect, as it provides an empirical basis for further theorising. As part of this aspect, data from published studies by other authors on the effect of acupuncture on pain intensity, functional indicators, and quality of life parameters of patients were

analysed using standardised international scales and questionnaires. The methodological approach included a critical analysis of literature data on the effectiveness of acupuncture in various nosological forms of musculoskeletal diseases-osteoarthritis of large joints, chronic lower back pain, myofascial pain syndrome, rheumatoid arthritis, and fibromyalgia. Quantitative performance indicators presented in peer-reviewed publications of other researchers were analysed, with a particular focus on studies with follow-up periods of 4 to 12 weeks and additional evaluation points after 6 and 12 months to determine long-term effects. The theoretical analysis considered the results of comparing the effectiveness of acupuncture in relation to various control interventions presented in primary studies.

The neurophysiological mechanisms of action of acupuncture were viewed as the second key aspect providing scientific justification for the observed clinical effects. This aspect was highlighted to establish a causal relationship between acupuncture and physiological processes, focusing on the central mechanisms of analgesia, modulation of inflammatory processes, and neuroplastic changes that occur under the influence of acupuncture. The methodological approach focused on the investigation of physiological mechanisms and neurobiological bases of acupuncture effectiveness. Publications covering the results of neuroimaging studies, in particular, functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), which displayed changes in the activity of specific areas of the brain under the influence of acupuncture, were examined. Studies on the activity of structures such as the anterior cingulate gyrus, insula, thalamus, prefrontal cortex, and periaqueductal grey matter, which play a major role in the formation and modulation of pain, were analysed in detail. In parallel, the molecular cellular mechanisms of acupuncture action were examined: neurotransmitter systems (opioid, serotonergic, noradrenergic), gamma-aminobutyric acid (GABA)-ergic system, immunological parameters (pro- and anti-inflammatory cytokines), vasoactive substances, and tissue regeneration factors. A comprehensive analysis method was used to integrate data on local, segmental, and systemic effects of acupuncture stimulation.

Modern innovative adaptations of traditional methods were chosen as the third central aspect that reflects the evolution of the method in the context of modern evidence-based medicine and is critical for the practical application of theoretical knowledge. The methodological approach included the investigation of modern innovations and scientifically based adaptations of traditional acupuncture methods. Publications describing new treatment protocols, combined approaches (acupuncture in combination with physical therapy, pharmacological treatment, massage, and thermal acupuncture), personalised schemes, and innovative models of care (group acupuncture, telemedicine methods) were analysed. Current trends in optimising the parameters of acupuncture stimulation were reviewed: the frequency of sessions (from 1 to 5 times a week), the duration of the course (from 2 to 12 weeks), the choice of location of points (local, distal, microsystem) and stimulation techniques (manual, electro-, laser acupuncture).

The combination of these three aspects allowed forming an integrative theoretical model that connects empirical data on efficiency with a scientific understanding of the mechanisms of action and determines promising directions for the development of the method. When describing the clinical effectiveness of acupuncture, the provisions of Guideline 00393 [11] were accounted for, which defines acupuncture as a therapeutic method that can improve the results of general treatment. This integrated approach was chosen due to the lack of complete theoretical concepts in the modern literature that combine the clinical, physiological, and methodological aspects of acupuncture. A systematic approach was used to process and analyse information, enabling the comparison and integration of data from heterogeneous sources. Methods of critical analysis of scientific publications were used, regarding their methodological quality, sample size, availability of adequate control groups, and statistical reliability of the results obtained. For systematisation and visualisation of data, tables were used that reflected the comparative effectiveness of various acupuncture techniques in specific nosological forms and neurophysiological mechanisms of their action, with an appropriate level of scientific evidence.

Results and Discussion

Clinical effectiveness of acupuncture in various categories of diseases of the musculoskeletal system. An analysis of clinical trials (2019-2025) indicates the differentiated effectiveness of different acupuncture techniques in the treatment of chronic lower back pain. H. Tan *et al.* [12] conducted a randomised controlled trial comparing acupuncture using sensitised points and routine integrative acupuncture, demonstrating a decrease in Visual Analogue Scale (VAS) scores by 2.87 ± 1.52 points in the sensitised acupuncture group versus 2.32 ± 1.36 points in the routine acupuncture group ($p = 0.042$). The functional state of the Roland-Morris questionnaire improved by 4.71 ± 3.16 and 3.57 ± 2.74 points, respectively. Notably, the method of sensitised acupuncture, although it demonstrates higher effectiveness, requires a doctor to have a deeper knowledge of the anatomical and topographic features of the location of biologically active points, which is a certain challenge for the widespread introduction of the technique into everyday clinical practice in Ukraine.

Comparative analysis of the effectiveness of electroacupuncture and manual acupuncture, conducted by J. Comachio *et al.* [13] in a clinical study of 66 patients, demonstrated the equivalence of both methods in reducing pain intensity after 6 weeks of therapy: a decrease on the VAS scale by 3.14 ± 0.52 points and 3.03 ± 0.47 points, respectively (the difference did not reach statistical significance, $p = 0.238$). Disability according to the Oswestry questionnaire decreased by $9.5 \pm 2.1\%$ in the electroacupuncture group and $8.9 \pm 1.9\%$ in the manual acupuncture group, confirming the absence of clinically substantial advantages of electrical

stimulation over classical manual techniques. This conclusion is of great practical importance for Ukrainian medical institutions, as it allows the effective use of traditional manual acupuncture without the need to invest in expensive electronic equipment for electroacupuncture, which is especially important in conditions of limited funding.

A long-term comparison of the effectiveness of different methods is particularly important. M.J. Dastjerdi *et al.* [14] a 2024 randomised trial (n = 112) compared acupuncture, venesection, and physical therapy with a follow-up period of 12 months. Acupuncture showed a more sustained reduction in pain after 12 months (a decrease in VAS by 3.46 ± 0.51 points from baseline) compared to physical therapy (2.13 ± 0.48 points, $p < 0.01$), where there was a gradual weakening of the therapeutic effect after 6 months. Functional status on the Oswestry index was also better in the acupuncture group after 12 months (improvement of 15.7 ± 3.2%) compared to physical therapy (10.2 ± 2.9%, $p < 0.01$). The theoretical basis for the long-term effect of acupuncture, in contrast to physiotherapy, can be its complex effect on the central mechanisms of pain modulation, and not just on local tissue processes. This feature provides for considering acupuncture as the method of choice for patients who need long-term control of chronic pain, in particular, among participants in military operations and victims of military operations in Ukraine.

The frequency of stimulation during electroacupuncture turned out to be a less important factor of effectiveness than the very fact of the procedure, which demonstrates the priority importance of the basic mechanisms of acupuncture influence over the parameters of stimulation. S.F. Torres *et al.* [15], in a triple-blind placebo-controlled study of elderly patients, identified no statistically significant difference between the low-frequency (2 Hz) and high-frequency (100 Hz) electroacupuncture groups in pain reduction (VAS improvement of 2.93 ± 0.71 and 3.04 ± 0.67 points, respectively, $p = 0.542$). Both groups, however, substantially outperformed placebo acupuncture (1.12 ± 0.59 points, $p < 0.001$), which highlights the specificity of the therapeutic effect of acupuncture intervention. These data allow formulating an important theoretical postulate: the effectiveness of acupuncture is based on deep neurophysiological mechanisms of activation of endogenous pain control systems, and not on specific stimulation parameters. The practical value of this provision is to simplify the clinical protocols of electroacupuncture, which can be adapted to different clinical conditions without loss of effectiveness.

A substantial contribution to understanding the long-term effectiveness of acupuncture was made by the pragmatic BackInAction study conducted by L.L. DeBar *et al.* [16] on elderly patients. The study showed that the addition of acupuncture to standard medical care improved the functional state of the back on the Roland-Morris scale at 6 months by 3.84 ± 0.47 points versus 2.11 ± 0.43 points in the control group ($p < 0.001$), and at 12 months the difference was 3.26 ± 0.51 versus 1.97 ± 0.49 ($p < 0.01$). This result is of particular clinical importance, as it demonstrates the stability of the therapeutic effect over time, which is critical for chronic conditions. Notably, the methodological quality of this study determines the high reliability of the results obtained, which creates good reasons for introducing acupuncture into the national protocols for the treatment of chronic pain in Ukraine as an additional method, which can substantially increase the effectiveness of standard therapy.

Researching innovative acupuncture techniques, T. Li *et al.* [17] evaluated the clinical efficacy of silver needle warm acupuncture in the treatment of acute pain due to lumbosacral disc herniation. This modified technique resulted in a 4.1 ± 0.7-point reduction in VAS pain compared to 3.2 ± 0.6 points in the conventional warm acupuncture group ($p < 0.01$). Functional improvement on the Oswestry index was also more pronounced in the experimental group (20.3 ± 4.1% vs. 14.7 ± 3.8%, $p < 0.01$), which indicates the potential of improved acupuncture techniques to increase clinical efficacy. Although silver needle warm acupuncture demonstrates higher efficiency, its implementation in Ukraine has certain limitations due to the higher cost of materials and the need for additional training of specialists. However, the method can be considered promising for specialised pain treatment centres and rehabilitation facilities, especially for patients with severe pain syndrome who are immune to standard therapy.

An important aspect of the effectiveness of acupuncture is the duration of its effect. X. Lv *et al.* [18], in a cross-randomised study including women with chronic non-specific lower back pain, established that although acupuncture greatly improved back muscle endurance (+29.4 ± 6.7 seconds in the Biering-Sorensen test, $p < 0.001$) and local blood microcirculation (increased perfusion by 35.7 ± 8.9%, $p < 0.01$), the duration of this effect was limited to 9 minutes after the session, indicating the need for regular repeated treatment to maintain results. This aspect highlights an important drawback of the method – the short duration of the direct physiological effect, which requires the development of optimal protocols for repeated interventions. Thereby, the determined increase in microcirculation is of substantial theoretical importance since it complements the neurophysiological mechanisms of acupuncture with a vascular component, which may be critical in the treatment of ischemic pathologies of the musculoskeletal system common among older Ukrainian patients.

Based on the analysis of the presented studies, an integrative theoretical model of the effectiveness of acupuncture in chronic lower back pain can be formulated. This model includes three key components: short-term anaesthesia through neuromodulation, improvement of local microcirculation, and functional restoration of musculofascial structures. The short-term effect is realised mainly through activation of endogenous opioid systems and inhibition of nociceptive transmission, as evidenced by a rapid but short-term reduction in pain scores in a study by X. Lv *et al.* [18]. Instead, the long-term effect, most pronounced in the papers of L.L. DeBar *et al.* [16] and M.J. Dastjerdi *et*

al. [14], is likely associated with cumulative effects on neuroplasticity and tissue remodelling. The proposed triune model expands the theoretical understanding of the mechanisms of action of acupuncture and explains its versatile therapeutic effects. Unlike the traditional Eastern concept of meridians and energy balance, this model is based on modern scientific ideas about neurophysiological, microcirculatory, and functional mechanisms, which makes it more acceptable for integration into the Western scientific paradigm and the Ukrainian healthcare system.

The analysis of these clinical data allows expanding the theoretical understanding of the effectiveness of acupuncture not only in the context of treating lower back pain, and also in relation to other diseases of the musculoskeletal system. The American College of Rheumatology and the Arthritis Foundation have included acupuncture in the clinical guidelines for the treatment of osteoarthritis, positioning it as one of the possible components of a comprehensive therapeutic strategy, which indicates the recognition of the method in the global medical community [19]. Network meta-analysis performed by R.-X. Zhu *et al.* [20] demonstrated the superiority of electroacupuncture and the combination of acupuncture with thermal acupuncture in gonarthrosis, which indicates the feasibility of using combined methods. These recommendations are of direct importance for clinical protocols, since osteoarthritis of the knee joint is one of the most common degenerative joint diseases in Ukraine. The introduction of acupuncture as a component of complex therapy for this condition can substantially improve treatment outcomes and reduce the need for pharmacological interventions, which is of particular importance for elderly patients with comorbid conditions and an increased risk of side effects from drug therapy.

Regarding rheumatoid arthritis, a systematic review of J. Li *et al.* [21] identified a limited evidence base, although some studies indicate the possibility of achieving symptomatic relief. In fibromyalgia, according to the meta-analysis, conducted by X.-C. Zhang *et al.* [22], acupuncture shows an advantage over placebo in short-term pain reduction and in myofascial pain syndrome, as shown by M.J. Navarro-Santana *et al.* [23], the dry needle technique is effective. Of particular interest to the Ukrainian healthcare system is the use of acupuncture for myofascial pain syndrome, the prevalence of which has substantially increased among military personnel and civilians as a result of military operations. The dry needle technique, as a less resource-intensive alternative to traditional acupuncture, can be implemented in the field and in mobile medical units.

Summarising, a comprehensive analysis of systematic reviews devoted to the use of acupuncture in chronic pain syndromes focuses on the existing gap between the accumulated scientific data and their implementation in real clinical practice [24]. Acupuncture, in various modifications, demonstrates clinically substantial efficacy in chronic lower back pain with the highest level of evidence for short-term pain reduction (mean reduction of VAS by 2.87-4.1 points) and improvement of functional performance (reduction of disability according to Oswestry by 9.5-20.3%). Repeated courses of treatment are necessary to achieve a lasting, long-term effect, which is confirmed by the results of studies with a long follow-up period. Based on the synthesis of data from relevant systematic reviews and meta-analyses, Table 1 is presented below, which summarises the comparative effectiveness of various acupuncture techniques and related methods in the treatment of common diseases of the musculoskeletal system.

Table 1. Comparative effectiveness of various acupuncture techniques in major diseases of the musculoskeletal system

Diseases of the musculoskeletal system	Traditional manual acupuncture	Electroacupuncture	Dry acupuncture	Laser acupuncture	Level of evidence (common to acupuncture in this condition)
Chronic lower back pain	++	+++	++	+	High
Osteoarthritis of the knee joint	++	+++	+	++	High
Pain in the cervical spine	++	++	+++	+	Medium/High
Fibromyalgia	+	++	+	+	Low/Medium
Rheumatoid arthritis	+	++	(+)	+	Low/Medium
Epicondylitis	++	+	+++	++	Medium
Myofascial pain syndrome	++	++	+++	+	Medium

Notes: + + + high relative efficiency or strong evidence; ++ medium efficiency or moderate evidence; + low efficiency or limited evidence; (+) the evidence is very limited or contradictory. The level of evidence refers to the overall effectiveness of acupuncture techniques for a given condition, not to comparisons between techniques
Source: compiled by the author based on R.-X. Zhu *et al.* [20] and L. Cavaggioni *et al.* [24]

Analysis of the presented data demonstrates the differential effectiveness of acupuncture techniques depending on the pathology. In particular, electroacupuncture is most effective in treating chronic lower back pain and knee osteoarthritis, which correlates with a high overall level of evidence for these conditions. This indicates the potential advantage of electrical stimulation in pathologies associated with degenerative-dystrophic processes. However, dry acupuncture shows the best results in the treatment of pain in the cervical spine, epicondylitis, and myofascial pain syndrome, which indicates the special effectiveness of this technique in pathologies associated with trigger points and local muscle dysfunction. This differentiation of techniques according to their effectiveness in various pathologies

allows developing a personalised approach to the appointment of acupuncture, accounting for the specific disease and its pathophysiological features. For the Ukrainian healthcare system, this means the possibility of optimising available resources by directing specific techniques to those pathologies where they demonstrate the highest efficiency.

Traditional manual acupuncture is characterised by moderate effectiveness in most diseases, which confirms its versatility as a basic therapeutic approach. Laser acupuncture, on the other hand, shows relatively lower effectiveness in most pathologies, with the exception of epicondylitis. Special attention should be paid to the insufficient level of evidence regarding the effectiveness of acupuncture techniques in rheumatoid arthritis, fibromyalgia, and plantar fasciitis, which indicates the need for further research in these areas. In the clinical context, these data substantiate a differentiated approach to the choice of acupuncture techniques depending on the nature of the pathology and the evidence base, arguing for the priority use of the most effective techniques for a specific disease of the musculoskeletal system.

Analysis of randomised controlled trials shows that the effectiveness of acupuncture substantially depends on the parameters of treatment protocols. Y.-J. Chen *et al.* [25], through a systematic analysis of clinical studies, determined that the optimal frequency is 2-3 sessions per week, and the total duration of the course – 4-8 weeks. Clinical efficacy reaches a plateau when these parameters are exceeded, which indicates the existence of a certain therapeutic saturation threshold. This phenomenon is confirmed by X.Zou *et al.* [26], demonstrating that increasing the number of sessions above the recommended number did not lead to a statistically significant improvement in results. This feature is associated with the two-phase activation of endogenous antinociceptive systems, when the initial phase is characterised by a progressive increase in the effect, and the second – by relative stabilisation of the response against the background of adaptation of neuroimmune mechanisms. The optimal parameters of acupuncture protocols are of critical importance for the introduction of the method into Ukrainian medical practice, as they allow maximising results with the rational use of limited resources of the healthcare system. Maintaining an optimal session frequency (2-3 per week) and course duration (4-8 weeks) can provide the best cost-effectiveness ratio, which is essential in wartime and economic constraints.

E. Ginnerup-Nielsen *et al.* [27], in a prospective cohort study, established that patients with rheumatic diseases who received acupuncture displayed a substantial improvement in quality of life on the EQ-5D-3L scale compared to the control group. Subgroup analysis indicated the highest efficacy in patients with fibromyalgia and rheumatoid arthritis. For osteoarthritis of the hip joint, S.C. Chan & J.P. Engkasan [28] found a substantial reduction in pain intensity in VAS and an improvement in functional performance in the Western Ontario and McMaster universities Osteoarthritis Index (WOMAC) after a course of acupuncture. These changes correlated with improved quality of life in SF-36, especially in the areas of physical functioning and social activity. The results of these studies point to an important aspect of the effectiveness of acupuncture – its impact on the overall quality of life, which goes beyond simple pain relief. For Ukrainian patients with chronic diseases of the musculoskeletal system, especially those affected by the hostilities, this complex impact on the quality of life can be of particular importance, contributing not only to physical but also to psychosocial recovery.

It is important to compare acupuncture with other treatments. In a randomised clinical trial, the Integrative Medicine Program for Advanced Cancer Treatment (IMPACT), acupuncture and massage were compared in reducing pain in patients with advanced cancer by A.S. Epstein *et al.* [29]. Both methods showed a statistically significant reduction in pain intensity, with no substantial difference between the two. Thereby, acupuncture has shown better results in reducing fatigue and improving sleep quality. K. Trinh *et al.* [30] established a differential effectiveness of acupuncture in different localisations of pain syndrome. For pain in the hands and wrists, the greatest effect was observed in rheumatoid arthritis and tenosynovitis, while in osteoarthritis of the small joints of the hand, the effect was less pronounced. The researchers also noted improvements in both functional status and overall quality of life in patients with foot and ankle pain syndromes, especially plantar fasciitis and Achilles tendinitis. Comparative analysis of the effectiveness of various non-pharmacological treatment methods is crucial for the formation of comprehensive rehabilitation programmes. In particular, the combination of acupuncture with massage and physical therapy can provide a synergistic effect in the treatment of patients with polymorphic pain syndromes and multiple injuries, which make up a considerable proportion of patients in rehabilitation centres.

The results obtained in real clinical practice are of special interest. M. Lu *et al.* [31], within the framework of the Alberta Complementary Health Integration Project, recorded that after a course of acupuncture, patients reported a substantial reduction in pain intensity (by 75.5%), improvement in sleep quality (by 53.1%), and overall quality of life (by 42.6%). It is important to emphasise that data obtained in real clinical practice often show higher rates of subjective improvement than the results of strictly controlled randomised trials. This phenomenon can be explained by psychological factors, positive expectations, and better individualisation of treatment. For the Ukrainian healthcare system, this fact means that the introduction of acupuncture in clinical practice can give even better results than predicted on the basis of experimental studies.

Systematic monitoring of the psychoemotional state of patients indicated additional therapeutic effects of acupuncture. C.-T. Tang *et al.* [32], in their clinical audit using the standardised PROMIS system, found that acupuncture substantially improves both physical performance and psychoemotional state, particularly the levels of anxiety and depression. The psychoemotional component of the

therapeutic effect of acupuncture is fundamental in the context of post-traumatic stress disorders and anxiety-depressive states, the prevalence of which has substantially increased in Ukraine as a result of military operations. The introduction of acupuncture in psychological rehabilitation programmes can provide a comprehensive approach to restoring the physical and mental health of victims.

Generalisation of the results of these studies allows formulating a triune concept of the therapeutic effect of acupuncture, covering physiological, functional, and psychoemotional components. The physiological component is implemented through a direct reduction in pain symptoms, the functional component provides restoration of motor activity, and the psychoemotional component contributes to the normalisation of the patient's psychological state. This conceptual model explains the complex effect of acupuncture on various aspects of the quality of life of patients with diseases of the musculoskeletal system and justifies the synergistic nature of the therapeutic effect. The proposed triune concept expands the traditional understanding of the mechanisms of action of acupuncture, integrating modern scientific data from various fields of medicine. This model can become a theoretical basis for the development of comprehensive rehabilitation programmes using acupuncture, aimed at the comprehensive recovery of patients. Available clinical data strongly demonstrate that acupuncture provides statistically and clinically substantial improvements in pain scores, functionality, and quality of life. Systematic application of the method in accordance with optimised protocols creates an opportunity to achieve sustainable positive results, thereby forming a reliable evidence base for wider implementation of acupuncture in clinical guidelines and protocols for the treatment of diseases of the musculoskeletal system.

Physiological mechanisms and neurobiological bases of acupuncture effectiveness. Studies conducted in 2019-2025 majorly expanded the understanding of the neurophysiological mechanisms by which acupuncture modulates pain perception and reduces inflammatory processes in the tissues of the musculoskeletal system. Data analysis allows identifying several key mechanisms of action. According to the studies by Z. Lyu *et al.* [33], central sensitivity of pain pathways is substantially reduced under the influence of acupuncture due to normalisation of neuroglial cross-communication and regulation of synaptic plasticity. Researchers have recorded a decrease in glutamate levels in the ascending excitatory pathways of pain with simultaneous activation of opioid systems, GABA-ergic, noradrenergic, and serotonergic mechanisms in the descending pain modulation system. An additional effect is inhibition of the production of pro-inflammatory cytokines (interleukin-1β, interleukin-6, tumour necrosis factor-α) against the background of increased levels of anti-inflammatory interleukin-10, which reduces both peripheral and central sensitisation. The integration of these data makes it possible to consider acupuncture as a method of multimodal neuromodulation, which simultaneously affects different parts of the pathological process. Special attention is paid to the mechanism of normalisation of neuroglial cross-communication, which indicates the profound effect of acupuncture not only on neuronal populations, but also on glial cells, which play a key role in maintaining chronic pain.

Electroacupuncture demonstrates additional mechanisms of action described by M. Zhou *et al.* [34]. The authors determined that this method activates serotonergic, noradrenergic, endocannabinoid, and purinergic pathways, forming a complex effect on the pain circuits of the central nervous system. Frequency-dependent analysis showed that 2-10 Hz stimulation effectively suppresses neuropathic pain through simultaneous activation of endogenous opioid and monoaminergic mechanisms. An optogenetic study by I.-H. Hsiao *et al.* [35] established a specific mechanism of action of acupuncture in inflammatory pain. Inhibition of somatosensory cortex and anterior cingulate cortex activity was observed due to reduced expression of the CaMKIIα signalling protein, which plays a critical role in the formation of pathological plasticity in central pain networks. These data support the ability of acupuncture to modulate the central mechanisms of pain at the cortical level by inhibiting the pathological excitation of neural ensembles. A comparative analysis of these studies reveals an important pattern – the existence of various mechanisms of anaesthesia, depending on the nature of the pathological process. In neuropathic pain, serotonergic and endocannabinoid mechanisms dominate, while in inflammatory pain, changes in CaMKIIα expression and decreased somatosensory cortex activity are of primary importance. This differentiation explains why acupuncture can be effective in different types of pain syndromes, acting through the most relevant mechanisms for a particular pathology.

The study by Y. Gao *et al.* [36] demonstrated activation of μ- and κ-opioid receptors in the spinal cord under the influence of acupuncture. This process is accompanied by inhibition of Toll-like microglial receptors responsible for initiating an inflammatory response, resulting in a decrease in central sensitisation. Furthermore, S.-S. Ding *et al.* [37] determined that acupuncture modulates a local inflammatory response by activating neutrophils that release endogenous opioid peptides involving the Motif Chemokine ligand 1/Motif Chemokine Receptor 2 (CXCL1/CXCR2) signalling pathway. The identified link between the immune and opioid systems is of particular theoretical interest, as it demonstrates the neuroimmune nature of the analgesic effect of acupuncture. This mechanism may explain the therapeutic effectiveness of acupuncture in autoimmune joint diseases, such as rheumatoid arthritis, where impaired immune regulation is the basis of the pathological process. Modulation of Toll-like microglial receptors via opioid pathways forms the molecular basis for reducing neurogenic inflammation, which is of primary importance in inflammatory arthropathies.

The integration of these scientific data allows forming a holistic view of multi-level neurophysiological modulation under the influence of acupuncture. The method

implements its analgesic and anti-inflammatory effects through a complex effect on endogenous opioid mechanisms, neurotransmitter systems, central sensitisation processes, and neuroimmune cross-communication. Such a multicomponent mechanism of action justifies the therapeutic effectiveness of acupuncture and opens up prospects for its integration into the complex treatment of chronic pain syndromes of the musculoskeletal system. The neurophysiological mechanisms underlying the analgesic effect of acupuncture in diseases of the musculoskeletal system are multifaceted and involve interactions at different levels of the nervous system. Based on the analysis of scientific data, the key mechanisms and the level of their scientific confirmation are summarised in Table 2.

Table 2. Neurophysiological mechanisms of action of acupuncture in modulating musculoskeletal pain

Mechanism of action	Neurophysiological pathways involved	Clinical effect	Level of scientific confirmation
Endogenous opioid system	Release of β-endorphins, enkephalins, activation of μ- and κ-opioid receptors	Analgesia, reduced perception of pain	High
Modulation of inflammatory mediators	Reduced levels of IL-1β, TNF-α, IL-6; increased levels of IL-10	Anti-inflammatory effect, reduction of oedema	Medium
Activation of downstream inhibitory pathways	Serotonergic (5-HT) and norepinephrine pathways	Inhibition of pain signal transmission	High
Effects on the autonomic nervous system	Balancing sympathetic and parasympathetic activity	Improvement of local blood circulation and tissue trophism	Medium
Neuroplastic changes	Inhibition of CaMKIIα-signalling in the somatosensory cortex and anterior cingulate gyrus	Long-term reduction of chronic pain	High
Local tissue reactions	Release of adenosine through activation of A1 receptors	Local tissue regeneration, pain reduction	Medium
Brain stem activation	Stimulation of the periaqueductal grey matter and the suture nucleus	Activation of internal analgesic mechanisms	High
GABA-ergic transmission modulation	Increased activity of GABA and its receptors	Reduced neuronal hypersensitivity	Medium

Source: compiled by the author based on I.-H. Hsiao *et al.* [35] and X. Ma *et al.* [38]

Grouping mechanisms by confirmation level indicates that the rapid analgesic effect in the acute period is more due to the activation of the opioid system and descending inhibitory circuits, while neuroplastic changes provide stable adaptations in the cerebral cortex. Less-researched pathways – autonomic modulation, local tissue responses, and GABA-ergic transmission – are likely supporting factors that enhance anti-inflammatory processes and promote trophic regulation. The comparison of central and peripheral links (from the regulation of cytokines and adenosine in tissues to changes in the conduction of pain signals) highlights the multi-level nature of acupuncture and indicates the need for further examination of the relationships between these systems, in particular in the context of the interaction of opioid and glutamatergic transmission. The existence of potential synergistic interactions between different mechanisms is notable. For example, activation of the opioid system not only directly reduces pain sensitivity but also helps reduce neurogenic inflammation, which in turn lowers nociceptor sensitisation. Similarly, inhibition of CaMKIIα signalling in the somatosensory cortex may increase the efficiency of GABAergic transmission by reducing the excitability of neural networks. This interaction of various mechanisms forms a complete system of neurophysiological response to acupuncture stimulation, which explains its complex therapeutic effect.

Neuroimaging techniques, including functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), have provided objective evidence for the central mechanisms of acupuncture's action. M. Qi *et al.* [39] performed a meta-analysis using the activation probability estimation (ALE) algorithm, covering 15 studies. The results showed a substantial increase in activity in the left side of the varolian bridge and posterior insula, and a decrease in activity in the cerebellum, temporal lobe, and right precentral gyrus compared to baseline. These changes suggest a complex, targeted neuromodulation of pain pathways and emotional processes that distinguishes true acupuncture from placebo effects. Of particular importance is the detected activation of the posterior insula, which is responsible for interoceptive awareness and processing of visceral sensations. This area of the brain combines somatosensory information with an emotional assessment of pain, forming a subjective experience of pain sensation. Changes in activity in this area under the influence of acupuncture can explain not only a decrease in the intensity of pain but also a decrease in its emotional component, which is critical in chronic pain syndromes, where the emotional component often increases pain.

Innovative approaches to integrated analysis of PET and fMRI data, presented in a paper by D.K. Saha *et al.* [40], demonstrated that acupuncture affects the functional and molecular connectomes of the brain. The Neuromark PET technique enables the assessment of holistic functional and molecular relationships in the brain, including sensorimotor, visual networks, and the brain's default mode system. This provides a deeper understanding of how acupuncture can affect not only local changes in activity but also the

integrated interregional interaction of brain networks. Analysis of molecular connectomes opens up a new dimension in understanding the mechanisms of action of acupuncture, moving research from the level of macroscopic changes in brain activity to the level of molecular interactions. Changes in the brain's default mode system, which is activated during rest and self-referential thinking, explain the effect of acupuncture on the cognitive and emotional aspects of pain perception. This complements the purely physiological model of acupuncture's action with a cognitive-behavioural component, which is important for understanding its therapeutic potential in complex pain syndromes. A substantial contribution to understanding neuroplastic changes under the influence of acupuncture was made by the meta-analysis by Q. Lv *et al.* [41], who demonstrated that in patients after stroke, acupuncture causes hyperactivation in the basal ganglia and insula, and normalisation of activity in the primary motor cortex (Brodmann area 4) and additional motor cortex (Brodmann area 6). These changes were directly correlated with improved motor function, which confirms the neuroplastic nature of the therapeutic effect of acupuncture.

A combined FDG-PET/fMRI study conducted by S.S. Madsen *et al.* [42] confirmed that acupuncture affects not only functional brain activity but also glucose metabolism in somatosensory and motor networks. Active brain regions after acupuncture stimulation are characterised by increased metabolic activity, which confirms the relationship between changes in hemodynamics and metabolism in response to therapeutic intervention. Although this study focuses on patients after stroke, its results are important for understanding the mechanisms of action of acupuncture in musculoskeletal disorders. Normalisation of activity in the motor cortex can contribute to the restoration of correct motor patterns in myofascial syndromes and arthropathies, where violation of motor stereotypes is often an important pathogenetic factor. Hyperactivation of the basal ganglia, which are responsible for automating movement, may explain the improvement in motor function after a course of acupuncture, even in chronic degenerative joint diseases. These results consolidate the understanding that acupuncture is not limited to local stimulation of peripheral receptors, but causes complex changes at the level of integrated brain networks, which provides a long-term modification of pain perception and supports the restoration of impaired musculoskeletal functions. The latest data also highlight the importance of standardised neuroimaging applications for verifying the therapeutic mechanisms of acupuncture in high-quality clinical trials.

In parallel with the central mechanisms, local tissue responses to acupuncture stimulation are important. Z. Liu *et al.* [43] demonstrated using mathematical modelling that under the influence of a magnetic field created by an acupuncture needle, interstitial blood flow and active oxygen transport are substantially enhanced. This helps restore mitochondrial metabolism and accelerate regenerative processes in muscle fibres. A notably pronounced effect is observed in tissues with increased permeability, such as oedematous areas. Thus, local tissue changes caused by acupuncture stimulation include improvements in tissue oxygenation, activation of neuro-immune mechanisms, stimulation of cell repair, and remodelling of the extracellular matrix.

Acupuncture stimulation also causes complex systemic effects by modulating neuro-immune-endocrine interactions. W.-L. Yu *et al.* [44], in a systematic review of experimental studies, demonstrated that acupuncture activates local immune cells, including neutrophils, macrophages, and mast cells. This is accompanied by an increase in the expression of chemo- and mechanosensitive molecules that trigger signalling cascades through the cholinergic, adrenal, and splenic nervous systems, integrating a local immune response with systemic neuro-immune regulation. J.A. Perdrizet *et al.* [45] established that stimulation of certain acupuncture points, such as the GV-14 point, leads to an increased humoral immune response, as evidenced by an increase in the level of neutralising antibodies after vaccination. This indicates the ability of acupuncture intervention to modulate the activity of the adaptive immune system by affecting Meridian networks. The ability of acupuncture to influence the adaptive immune response is important in the context of autoimmune diseases of the musculoskeletal system, such as rheumatoid arthritis and ankylosing spondylitis. Modulation of antibody production and T-cell activity can alter the course of immunopathological processes, reducing the destruction of joint tissue. However, the exact mechanisms of this effect require further investigation, especially regarding the specificity of immunomodulation and its long-term effects. This area of research opens up prospects for the development of targeted acupuncture protocols aimed at correcting immune disorders in specific pathologies.

A.Y. Fan [46] demonstrated that at the level of the autonomic nervous system, specific acupuncture stimulation, in particular, electroacupuncture, activates the vagus-adrenal axis. This leads to the release of catecholamines from the adrenal medulla and promotes an anti-inflammatory response. The mechanisms of action of acupuncture are not limited only to the activation of one pathway, but also cover multisystem modulation at various levels, including parasympathetic and sympathetic regulation, which provides for adapting immune responses according to the stage of the pathological process. Activation of cholinergic anti-inflammatory pathways, especially the vagus-adrenal axis, is one of the key mechanisms of systemic action of acupuncture. This mechanism explains why stimulation of distant points can affect local inflammatory processes in joints and muscles. The vagal nerve inhibits the production of pro-inflammatory cytokines by macrophages through activation of nicotinic acetylcholine receptors of the α7 subtype. It is noteworthy that this effect is realised without suppression of protective immune functions, which makes acupuncture a safe method of immunomodulation, unlike many pharmacological immunosuppressants. This

mechanism is particularly important for the treatment of systemic inflammatory diseases such as rheumatoid arthritis, where long-term anti-inflammatory therapy is required. Regarding the effect on the endocrine system, J. Halámková *et al.* [8] discovered that acupuncture can activate the hypothalamic-pituitary-adrenal axis by stimulating neural transmission in the spinal cord and midbrain. This leads to the regulation of the release of stress hormones and anti-inflammatory factors such as cortisol. The secretion of endogenous opioids is stimulated, which helps to reduce the perception of pain and improve the overall homeostasis of the body. Thus, the combination of neuroimaging, tissue, and systems studies forms a holistic view of the multi-level mechanisms of action of acupuncture. Integration of central neuroplastic changes, local tissue responses, and systemic neuro-immune-endocrine effects provides a comprehensive therapeutic effect of acupuncture in diseases of the musculoskeletal system, which is confirmed by objective research methods.

Modern innovations and scientifically based adaptations of traditional acupuncture methods. During 2019-2025, TCM techniques underwent a substantial transformation in their application to diseases of the musculoskeletal system. This evolution has covered several critical areas of development of treatment protocols, improvement of techniques, and models of service delivery. The study by Y.-C. Hwang *et al.* [47] analysed randomised controlled trials to pinpoint the most effective acupuncture points for pain control. Their results identified SP6, ST36, LI4, and LR3 as particularly effective points, while recognising state-dependent variations. For example, migraine treatment showed an optimal response to GB20, LR3, GV20, Taiyang, LI4, and TE5 points, while dysmenorrhea treatment benefited from the use of SP6, CV4, SP8, LR3, and BL32 points. This systematic analysis provided the basis for the development of structured therapeutic protocols. It is noteworthy that the identification of universal points such as LI4 and LR3, which demonstrate effectiveness in various pathological conditions, changes the paradigm of acupuncture treatment from a purely syndromic approach to a systematic methodology with elements of evidence-based medicine. Systematic mapping of the effectiveness of different points in specific pathologies allows rationalising therapeutic protocols, reducing the subjectivity of the choice of acupuncture points, which has conventionally been considered a limitation of the method.

A fundamental advance in the treatment strategy was the integration of regional and distal points within a single session. As demonstrated by L.L. DeBar *et al.* [16], this approach allows purposefully influencing both local and systemic pathological processes, giving better results compared to monofocal stimulation. The same team determined that including acupuncture in interdisciplinary rehabilitation programmes increases clinical efficacy, especially when point selection is based on assessments of muscle dysfunction and segmental movement disorders. Therapeutic regimens were further enhanced by the inclusion of microsystem acupuncture, in particular, scalp acupuncture, auricular therapy, and limb acupuncture. In post-stroke rehabilitation studies, Q. Lv *et al.* [41] demonstrated that stimulation of the motor zones of the scalp in combination with traditional channel points gives a pronounced effect through simultaneous peripheral and central neuromodulation.

The development of personalised treatment protocols was another substantial achievement. The study by I.-H. Hsiao *et al.* [35] and Y. Gao *et al.* [36] showed that the inclusion of biomarkers, such as inflammatory cytokine levels and indicators of autonomous regulation, in treatment planning allows for more precise individualisation of point selection and stimulation parameters. The evolution from subjective diagnosis to objective point selection based on biomarkers transforms acupuncture from an empirical art to a precision therapeutic tool. The implementation of laboratory and instrumental methods for evaluating effectiveness allows overcoming the historical barrier between TCM and the modern biomedical model, creating an integrative approach that combines thousands of years of empirical knowledge with precise methods of molecular medicine. The use of polymorphisms of opioid receptor genes and neurotransmitter systems to predict individual sensitivity to acupuncture opens a new era of pharmacogenomics of non-invasive interventions. Comparative studies of the effectiveness of specialised acupuncture techniques have provided important clinical results. J.J. Mao *et al.* [48] determined that electroacupuncture is more effective than auricular acupuncture in reducing chronic musculoskeletal pain among cancer patients, with therapeutic effects lasting up to 24 weeks. Further, studies by T. Bao *et al.* [49], involving women who survived breast cancer, confirmed that personalised electroacupuncture outperformed combat auricular acupuncture in terms of pain reduction.

Laser acupuncture has also shown promising results. Meta-analyses of Y.C. Hung *et al.* [50] indicate that this method substantially reduces pain levels, functional limitations, and disability in patients with musculoskeletal disorders, demonstrating a substantial effect compared to dummy treatment. Papers of J. Comachio *et al.* [13] and M.J. Dastjerdi *et al.* [14] also proved that personalisation of method selection optimises therapeutic outcomes while minimising side effects. The emergence of technologically advanced methods of acupuncture stimulation, such as laser acupuncture, electroacupuncture with controlled stimulation parameters, and magnetic acupuncture, substantially expands the therapeutic arsenal beyond classical acupuncture. Meanwhile, the difficulty of objectively comparing these methods lies in the different mechanisms of their action – if mechanical stimulation with a needle activates mainly mechanoreceptors and nociceptive fibres, then laser and magnetic acupuncture directly affect tissue metabolism through photobiomodulation and electromagnetic induction, respectively. Most comparative studies focus on clinical outcomes without a detailed analysis of differences in molecular mechanisms of action, which creates

methodological dissonance and makes it difficult to develop optimal combined protocols. Integrative treatment approaches have received substantial evidence-based support. S. Pugazhendi *et al.* [51] evaluated comprehensive protocols combining physical therapy, pharmacological interventions, and, if necessary, surgical care with acupuncture. Their large-scale study in India indicated that such comprehensive non-invasive physical therapy with acupuncture reduced the need for surgery and decreased pain levels. In postoperative rehabilitation, C.A. Dilaveri *et al.* [52] established that the combination of massage and acupuncture effectively reduces stress, pain, and anxiety levels.

A review of randomised controlled trials of D. Ha *et al.* [53] confirmed that integrative treatment that combines acupuncture with pharmacotherapy or physical therapy demonstrates higher efficacy compared to monocomponent interventions. In particular, 83% of the analysed studies showed improved results when using integrative methods, while maintaining a low risk of side effects. The synergy of integrative treatment protocols is manifested both in the arithmetic summation of therapeutic effects and the potentiation of the action of individual components. For example, acupuncture analgesia increases exercise tolerance during rehabilitation exercises, which in turn accelerates functional recovery. Pharmacological agents can modify the neurochemical environment, increasing the effectiveness of acupuncture neuromodulation. Another advantage of the integrative approach is the ability to reduce the dosage of pharmacological drugs, which lowers the risk of side effects and drug dependence, especially in the long-term treatment of chronic pain. Modern rehabilitation practice has seen innovations in models of acupuncture care. M.D. McKee *et al.* [54] investigated group treatment protocols and found that this approach allows multiple patients to be treated simultaneously without substantially reducing quality. Their study showed that group acupuncture is comparable to individual treatment in reducing chronic pain, thereby increasing accessibility for economically disadvantaged segments of the population.

Development of telemedicine models for self-guided acupuncture applications explored by S. Ribagin *et al.* [55] demonstrated that video consultations effectively teach patients the exact location of acupuncture points and correct self-stimulation techniques. This approach ensures continuous rehabilitation even in remote regions. Standardisation of treatment protocols through the development of point selection algorithms was investigated by Y.-B. Jiang *et al.* [56] showed effectiveness in balancing evidence-based approaches with personalised care. In spinal cord injury rehabilitation studies, combining standardised acupuncture with rehabilitation techniques resulted in substantial improvements in motor function and quality of life compared to traditional rehabilitation.

Diversifying the channels of acupuncture care addresses accessibility issues while contributing to the integration of this method into multidisciplinary treatment protocols, which is supported by the findings of S.L. Kolasinski *et al.* [19], L. Cavaggioni *et al.* [24], and G. Litscher [10]. The transformation of models for providing acupuncture services through the introduction of group sessions, telemedicine consultations, and self-help programmes is no less important an innovation than technological improvements to the method itself. The transition from the traditional "one patient – one doctor" model to flexible treatment formats ensures wide availability of acupuncture, despite the global shortage of qualified specialists. Paradoxically, the technologisation and standardisation of acupuncture, which originally developed as the art of individualised treatment, can lead to the loss of a personalised approach. Therefore, developing models that balance cost-effectiveness, accessibility, and maintaining individualisation of treatment is a critical challenge. The innovations introduced between 2019-2025 laid the foundation for the further development of acupuncture as a scientifically based, cost-effective, and clinically substantial component of modern rehabilitation programmes. Developments in the field of digitalisation and personalisation of acupuncture interventions using AI tools to predict individual therapeutic responses and optimise treatment protocols are especially promising. The integration of acupuncture into digital medicine is a natural evolutionary stage in the development of this ancient method of treatment. Machine learning algorithms that analyse data sets on the effectiveness of various acupuncture protocols allow identifying non-obvious correlations between the clinical characteristics of patients and their response to specific stimulation methods. Therewith, automated diagnostic systems that use computer vision to analyse patients' pulse and tongue in accordance with the principles of TCM can overcome the subjectivity of traditional diagnostics, ensuring reproducibility of assessment and point selection. Thus, the synthesis of the millennial tradition of acupuncture with modern technologies creates a new paradigm of personalised medicine, where empirical knowledge is enhanced by the capabilities of analytical data processing.

Practical recommendations for effective optimisation of acupuncture practice. Based on the analysis of modern studies on acupuncture in diseases of the musculoskeletal system, it is advisable to highlight the following recommendations for acupuncture practice. A necessary step in the development of acupuncture practice should be the introduction of standardised treatment protocols. It is advisable to develop and approve at the national level clinical protocols for the use of acupuncture in the most common diseases of the musculoskeletal system. Such protocols should include clear algorithms for selecting points according to the clinical picture, optimal stimulation parameters, and performance evaluation criteria that ensure consistency and reproducibility of therapeutic outcomes.

Substantial improvements in treatment outcomes can be achieved through the integration of acupuncture into multidisciplinary rehabilitation programmes. Acupuncture should become a mandatory component of rehabilitation programmes for patients with chronic pain and functional

disorders. Special attention should be paid to coordinating acupuncture interventions with physical therapy, kinesiotherapy, and psychological support to achieve a synergistic therapeutic effect. Increasing the availability of acupuncture services requires diversification of their delivery models. It is advisable to ensure the development of group forms of treatment and telemedicine consultations to expand the coverage of the population. An important element should be the introduction of patient training programmes for self-stimulation of simple acupuncture points, which will allow maintaining the therapeutic effect between sessions and reduce the burden on the medical system.

Technological improvement of acupuncture practice requires expanding the use of modern diagnostic methods, including analysis of biomarkers and heart rate variability, to objectify the choice of stimulation points and parameters. The introduction of electronic clinical decision support systems to optimise acupuncture protocols will improve the effectiveness and safety of procedures. High-quality training of specialists requires strengthening training and advanced training programmes. It is necessary to modernise the training for acupuncture specialists, focusing on integrating traditional knowledge with modern scientific data. The development of interdisciplinary educational initiatives for doctors of various specialities will help to expand understanding of the role of acupuncture in complex treatment and overcome professional barriers.

Further development of acupuncture requires prioritisation of scientific research. Research efforts should focus on investigating the molecular mechanisms of action of acupuncture, especially in pathologies with a low level of evidence, such as rheumatoid arthritis and fibromyalgia. Developing high-quality research projects to evaluate the long-term effectiveness and economic feasibility of various acupuncture techniques will help strengthen the evidence base of the method. The implementation of these recommendations will optimise the use of acupuncture in clinical practice, improve the quality of medical care for patients with diseases of the musculoskeletal system, and promote the integration of traditional and modern methods of treatment into a single healthcare system.

Conclusions

The study highlighted a high clinical efficacy of acupuncture in chronic lower back pain, knee osteoarthritis, and myofascial pain syndrome, which is confirmed by a decrease in pain intensity by 2.87-4.1 points on the visual-analogue scale and an improvement in functional indicators by 9.5-20.3%. Optimal therapy parameters included 2-3 sessions per week with a total course duration of 4-8 weeks, while the effectiveness varies depending on the nosology, with the advantage of electroacupuncture and dry acupuncture in certain pathologies. Data from clinical studies indicated a stable therapeutic effect of acupuncture, persisting for a long time after the end of treatment, which is especially valuable for patients with chronic conditions. The 2019-2025 papers deepened the understanding of the neurophysiological mechanisms of acupuncture, confirming the complex effects on the endogenous opioid system, modulation of inflammatory mediators, activation of downstream inhibitory pathways, and induction of neuroplastic changes in the central nervous system. Local tissue responses and systemic neuroimmune modulation were identified as important components of the therapeutic effect. Neuroimaging studies demonstrated substantial changes in activity in the left side of the varolian bridge, posterior insula, and other key brain structures under the influence of acupuncture, which correlates with clinical improvement in patients' condition. Modern innovative approaches, including group forms of treatment and telemedicine models, have expanded the possibilities of clinical application of the method, and integrative strategies combining acupuncture with traditional methods have shown better results in 83% of the analysed publications. Based on the research, recommendations were developed for the introduction of standardised treatment protocols, integration of acupuncture into multidisciplinary rehabilitation programmes, diversification of service delivery models, technological improvement of practice, and strengthening of scientific research.

Based on the results obtained, two theoretical models were developed: a triune concept of the therapeutic effect of acupuncture (physiological, functional, and psychoemotional components) and an integrative model of effectiveness in chronic pain (short-term anaesthesia, improvement of microcirculation, and functional tissue repair). These models enabled a better understanding of the multi-level nature of the therapeutic effects of acupuncture and justified an integrated approach to its application in clinical practice. A limitation of the study was the heterogeneity of primary clinical trials and the variety of methodological approaches, which complicated the direct comparison of the results of different studies. Prospects for further research include assessing the long-term effectiveness of acupuncture in less-known nosologies, optimising personalised biomarker-based protocols, and modernising traditional acupuncture practices through the use of AI and telerehabilitation.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Огляд сучасних підходів до лікування пацієнтів із порушеннями та захворюваннями опорно-рухового апарату за допомогою традиційної китайської медицини (ТКМ) – голковколювання

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Анотація. Актуальність дослідження зумовлена значним поширенням захворювань опорно-рухового апарату та потребою в ефективних немедикаментозних методах лікування. Метою даної роботи був аналіз наукових даних щодо клінічної ефективності, фізіологічних механізмів дії та інноваційних підходів до застосування акупунктури при лікуванні патологій опорно-рухового апарату. Дослідження являє собою літературний огляд наукових публікацій 2019-2025 років з використанням комплексного триетапного методологічного підходу, що включав аналіз опублікованих даних щодо клінічної ефективності акупунктури за стандартизованими шкалами та опитувальниками, узагальнення досліджень нейрофізіологічних механізмів дії та систематизацію сучасних інноваційних протоколів, представлених у науковій літературі. Аналіз клінічних досліджень, виявив, що ефективність акупунктури варіюється залежно від технік і нозологічних форм, з найвищим рівнем доказовості для хронічного болю в нижній частині спини та остеоартриту. Після курсу акупунктури (2-3 сеанси на тиждень, загальною тривалістю 4-8 тижнів) зафіксовано зниження інтенсивності болю за візуально-аналоговою шкалою на 2,87-4,1 бала та покращення функціональних показників на 9,5-20,3 %. На основі узагальнення даних було сформульовано дві теоретичні моделі: триєдину концепцію терапевтичної дії акупунктури, що охоплює фізіологічний (зниження больової симптоматики), функціональний (відновлення рухової активності) та психоемоційний (нормалізація психологічного стану) компоненти, та інтегративну модель ефективності при хронічному болю, яка включає короткострокове знеболення через нейромодуляцію, покращення локальної мікроциркуляції та функціональне відновлення м'язово-фасціальних структур. Дослідження нейрофізіологічних механізмів продемонструвало, що терапевтичний ефект акупунктури опосередковується активацією ендогенної опіоїдної системи, модуляцією запальних цитокінів та нейропластичними змінами в мозкових мережах, що було підтверджено нейровізуалізаційними методами. У дослідженні також було систематизовано сучасні інновації акупунктурної практики, включаючи оптимізацію протоколів лікування, групові форми терапії та телемедичні моделі. Інтегративні підходи, що поєднували акупунктуру з традиційними методами лікування, продемонстрували кращі результати у 83 % проаналізованих досліджень порівняно з монокомпонентними втручаннями. Результати дослідження підтверджують клінічну ефективність різних технік акупунктури при захворюваннях опорно-рухового апарату, що обґрунтовано комплексним впливом на нейрофізіологічні механізми больової модуляції та доводить доцільність включення методу в стандартні терапевтичні протоколи

Ключові слова: хронічний біль; функціональний стан; терапевтичний ефект; больовий синдром; інтегративний підхід