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Novel technology for assessing the functional status of Olympic athletes using bioimpedance electroacupuncture rapid diagnostics in the pre-competition period: a pilot study. Part 1

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Abstract. *The aim* of this work is to present a novel medical technology for integrated assessment of the functional status of Olympic athletes in the pre-competition period, combining a biomedical morphofunctional model (MFM) of the human organism, bioimpedance electroacupuncture (BEP) rapid diagnostics, and millimeter-wave (MMW) acupuncture therapy. The proposed MFM conceptualizes the organism as a "system of systems" comprising 20 morphofunctional systems (MFS) that integrate embryogenesis, tissue specialization, neurohumoral regulation, and the biophysical properties of biologically active points (BAP). On this basis, BEP diagnostics, implemented on the "RAMED-EXPERT" platform, separately records the active (**G**) and reactive (**B**) components of complex conductance at BAP, reflecting the state of the extracellular milieu and cell-membrane structures of the corresponding MFS.

Studies in cohorts of Olympic athletes demonstrated that BEP profiles at control BAP of 20 MFS provide a sensitive tool for early detection of adaptive strain and preclinical dysregulation in cardiorespiratory, lymphatic, and neuroendocrine clusters that remain undetectable by standard cardiological and laboratory methods. The combination of BEP monitoring with targeted MMW-acupuncture protocols forms a closed loop of "model – diagnostics – intervention – re-evaluation", enabling truly personalized adjustment of training and recovery loads and prevention of overtraining and stress-induced decompensation. The technology shows clear translational potential beyond sports medicine: portable BEP-diagnostic modules for monitoring key MFS may become a foundational layer of future digital health ecosystems focused on proactive management of adaptive potential and quality of life.

Keywords: BEP rapid diagnostics, millimetre-wave acupuncture, morphofunctional systems of athletes, functional status, adaptive potential.

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Новітні технології оцінки функціонального стану олімпійських спортсменів з використанням біоімпедансної електроакупунктури для швидкої діагностики в період перед змаганнями: пілотне дослідження. Частина 1

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Резюме. *Мета роботи* – представити нову медичну технологію інтегральної оцінки функціонального стану олімпійських спортсменів у передзмагальному періоді, що поєднує біомедичну морфофункціональну модель (далі – МФМ) організму, біоімпедансну електропунктурну (далі – БЕП) експрес-діагностику та крайвисокочастотну (далі – КВЧ) акупунктурну терапію. Запропонована МФМ розглядає організм як ієрархічно організований цілісний комплекс з 20 морфофункціональними системами (далі – МФС), які інтегрують ембріогенез, тканинну спеціалізацію, нейрогуморальну регуляцію та біофізичні властивості біологічно активних точок (далі – БАТ). На цій основі БЕП-діагностика, реалізована на платформі RAMED-EXPERT, окремо реєструє активну (**G**) та реактивну (**B**) компоненти комплексної провідності БАТ, що відображають стан позаклітинного середовища та клітинно-мембранних структур відповідних МФС.

Дослідження в групах олімпійських спортсменів показали, що профілі БЕП діагностики в контрольних БАТ 20 МФС забезпечують чутливе виявлення ранніх ознак напруження адаптації та доклінічної дизрегуляції кардіореспіраторного, лімфатичного та нейроендокринного кластерів, які залишаються непомітними для стандартних кардіологічних і лабораторних методів. Поєднання БЕП-моніторингу з цілеспрямованими КВЧ-акупунктурними протоколами формує замкнений цикл «модель – діагностика – втручання – переоцінка», що дає змогу персоналізувати тренувальні й відновні навантаження та профілактувати перетренованість і стрес-індуковану декомпенсацію. Технологія має виражений трансляційний потенціал поза спортивною медициною: портативні модулі БЕП-діагностики для моніторингу ключових МФС можуть стати основою майбутніх цифрових екосистем охорони здоров'я, орієнтованих на проактивне управління адаптаційним потенціалом та якістю життя.

Ключові слова: БЕП експрес-діагностика, КВЧ-акупунктурна терапія, морфофункціональні системи спортсменів, функціональний стан, адаптаційний потенціал.

Introduction. Assessment of the functional status of Olympic athletes during the pre-competition period remains one of the foremost tasks in sports medicine, as it directly influences the optimization of training processes, prevention of overtraining, and reduction of risk for injuries and psycho-emotional stress. Traditional diagnostic procedures-such as exercise tests, spirometric and cardiac monitoring-are typically performed outside of competitive settings and are primarily aimed at cardiorespiratory function. However, under the conditions of intensive training and preparation, there arises a clear demand for rapid, noninvasive, and repeatable monitoring capable of providing real-time insights into the state of all morphofunctional systems (MFS) in the athlete while in situ, thereby enabling timely adjustments to workload and rehabilitation measures.

To address this requirement, we have developed and implemented a bioimpedance electroacupuncture (BEP) rapid diagnostic protocol, based on the «RAMED-EXPERT» hardware platform. The method evaluates the complex conductance (CC) of biologically active points (BAP), distinguishing two principal components: the active (resistive, **G**) component, reflecting the conductivity of interstitial media (extracellular fluids, lymph, etc.), and the reactive (capacitive, **B**) component, characterizing the state of cell membranes and intracellular structures. Unlike the classic R. Voll approach, which relies on direct current, BEA employs ultralow alternating signals ($\leq$0.1 V) and multiparametric analytical algorithms, enabling detection of sensitive biophysical markers associated with both rapid (inflammatory processes, lymphatic disturbances) and slow (adaptation, dystrophic changes) biological responses.

The BEP-diagnostic profile for selected BAPs or their combinations-mapped to twenty identified MFS-reflects the state of anatomical-functional

units, level of autonomic innervation, regional blood flow, and lymphatic drainage. This enables real-time evaluation of the athlete's functional readiness and forecasting of recovery and adaptation dynamics. The method is realized as a rapid, noninvasive protocol suitable for use at training facilities and allows for daily monitoring of large groups of athletes with minimal resource expenditure.

Over a 20-year period of practical application, clinical data has been collected from practitioners, resulting in a preliminary normative database and interpretation algorithms for CC parameters. In combination with targeted millimeter-wave (MMW) acupuncture stimulation, BEP-diagnostics not only permits detection of pre-competition imbalances associated with overexertion or stress, but also enables evaluation of the dynamics and efficacy of interventions.

This article presents the conceptual framework and protocol for this novel athlete functional status assessment technology, alongside pilot implementation results, and discusses the methodological, ethical, and practical aspects of its use in the pre-competition period.

Materials and Methods. The foundation of our study was the application of an integrated methodological framework comprising the biomedical morphofunctional model (MFM) of the human organism, BEA rapid diagnostics, and millimeter-wave (MMW) acupuncture therapy. These three components form a unified loop for analysis and correction of an athlete's functional status.

The MFM provides the conceptual platform, enabling the organism to be viewed as a "system of systems", in which each morphofunctional unit contributes to the overall adaptive potential. On this theoretical basis, BEP-diagnostics delivers precise, reproducible, and standardized digital-format measurements of conductance at BAP, reflecting the status of both cellular structures and the humoral environment. MMW acupuncture, in turn, serves as a regulatory tool able to selectively activate the body's internal reserves without pharmacological intervention.

The principal advantage of such integration lies in its cyclic nature: the model sets interpretive boundaries, diagnostics provide objective data, and therapy enables immediate verification of intervention efficacy and tracking of response dynamics. This synergy enables a shift from static assessment to an actively managed process for supporting athletes in the pre-competition period, where not only monitoring but also the fine-tuning of adaptive mechanisms is required.

Biomedical Morphofunctional Model of the Human Organism. Biomedical modeling represents a key trend in contemporary medicine, especially in the age of personalized approaches and integrative diagnostic and therapeutic modalities [3]. Models and modeling of biological systems have become critically important tools for both fundamental research and clinical practice [4]. They are particularly prominent in functional genomics, bioinformatics, systems biology, as well as in developing preventive and therapeutic strategies for complex, multifactorial diseases, including neurodegenerative, oncological, and autoimmune conditions [3; 4].

In the classical paradigm, models served as surrogates for direct in vivo studies, which were limited by ethical or technical constraints. Modern biomedicine, however, is advancing towards personalized models based on empirical biophysical, biochemical, and morphofunctional data obtained directly from the patient's body [4; 5]. This approach allows for comprehensive modeling of the organism's behavior, accounting for individual characteristics of both physiological and pathological processes [5].

The core of our biomedical MFM [1] is not merely a mechanical amalgamation of traditional Chinese and European frameworks, but their profound integration. On one hand, the model inherits ancient Chinese concepts of disease phase progression as dynamic processes reflective of energetic and functional shifts. On the other, it incorporates the European tradition of clinico-anatomical analysis and physiological regularities. Coupled with modern concepts of adaptive physiological responses to therapeutic interventions, the MFM provides a tool for elucidating pathogenesis from diverse perspectives, forecasting the trajectory of patient conditions, and developing personalized therapeutic strategies [2].

The goal in developing our MFM is not only to systematize anatomical and physiological knowledge, but also to construct a logical architecture of the human organism as an integrated system in which each morphofunctional unit participates in metabolism, energy production, neurohumoral regulation, and the formation of adaptive responses. The MFM facilitates interpretation of clinical and physiological data within the context

of dynamic interactions between body systems, thereby expanding the diagnostic and therapeutic capabilities of modern medicine.

Our biomedical human MFM as presented here is the result of integrating key findings from embryogenesis and histogenesis [6], molecular cell biology [7], anatomical and physiological relationships [8; 9], bioelectrical activity of BAPs and the meridian system of traditional Chinese medicine (TCM) [10], principles of systems medicine, and elements of Eastern tradition, including the Wuxing (**Five Phases**) concept and the meridian framework of TCM [10].

Of particular importance are the experimental data on the influence of electromagnetic radiation on organogenesis obtained in a series of studies summarized in our monograph [41]. These investigations demonstrated that controlled exposure to low-intensity electromagnetic fields can modify critical stages in the formation and differentiation of organ primordia, including the vascular bed, nervous system and endocrine system, without inducing gross morphological damage. Such findings conceptually support the view of MFS as regulatory blocks sensitive to biophysical stimuli and reinforce the notion of a field-dependent organization of developing and mature MFS within the MFM framework.

This model enables not only the description of morphogenesis and tissue differentiation [6], but also the logical reconstruction of functional linkage chains underlying adaptive regulatory mechanisms and the integration of Eastern and Western medical frameworks [11; 12]. Figure 1 illustrates the biomedical MFM of the human organism

The MFM of the human body is represented as a circular diagram consisting of seven concentric rings of increasing radius, divided into four symmetrical sectors. The sectors are formed by two mutually perpendicular diameters passing through the center, corresponding to four principal functional blocks of the organism: adaptive, transitory, productive, and structural. Each sector spans all rings, reflecting the embryogenetic and functional stages of organismal development from the center outward. The model is utilized for interpreting BEP-diagnostic results and analyzing organismal status, integrating embryologic, morphologic, and functional characteristics.

The innermost circle depicts the primordial cell pool, comprising the endoderm, ectoderm,

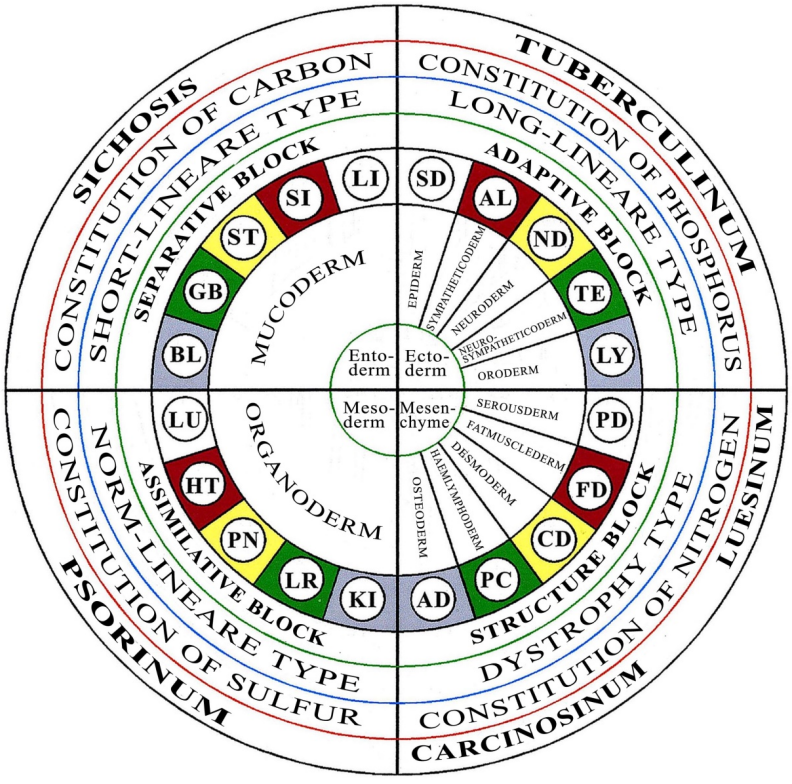

Fig. 1. Biomedical Morphofunctional Model of the Human Body

mesenchyme, and mesoderm-foundational elements of embryonic development.

The first annular segment contains derivatives of these germ layers: the endoderm gives rise to the **mucoderma**; the ectoderm forms the **epiderma, sympathoderma, neuroderma, neurosympathoderma,** and **oroderma**; the mesenchyme differentiates into **seroderma, feto-myoderm (feto-musculoderma), desmoderm, and osteoderma; the mesoderm gives rise to organoderma**.

The second annular segment incorporates twenty MFS, organized according to the Wuxing (**Five Elements**) principle of traditional Chinese medicine and the principle of similarity. Each sector encompasses five MFS, grouped according to their dominant function and color-coded to reflect their correspondence to organ functional circles.

The third annular segment comprises four sectors-each representing one of the four functional blocks: adaptive, transitory, productive, and structural. Each block includes five MFS by leading function, defining their role and position in the organismal model.

The fourth annular segment also includes four sectors, each describing a morphological type of constitution-leptosomic (longilineal), pyknic (brevilineal), normosthenic (normolineal), and dystrophic-determined by the respective group of MFS and reflecting individual variations in body structure.

The fifth annular segment is likewise divided into four sectors, each indicating the homeotherapeutic response type: **tuberculinum, medorrhinum, psorinum,** and **luetic / carcinosinum** (based on the miasmatic theory of homeopathy). This response type reflects how the organism reacts to external influences or therapy, for example, to a homeopathic remedy or MMW acupuncture.

Each of the four sectors of the second ring contains five MFS, for each of which both its origin and dominant function can be traced. Functional block structure was analyzed from an embryogenetic viewpoint, specifying the origin of tissue systems by germ layer. MFS are grouped according to their predominant morphogenetic lineage, specifically:

— The MFS of lymphatic drainage (**Ly**), endocrine glands (**TR**), brain and spinal cord (**Nd**), allergy (**Al**), and skin (**Sd**) share leading adaptive function and are classified as the adaptive block, largely with ectodermal origins (**oroderma, neurosympathoderma, neuroderma, sympathoderma, epiderma**);

— The MFS of large intestine (**GI**), small intestine (**IG**), stomach (**E**), biliary system (**Vb**), and urogenital organs (**V**) constitute the transitory block with excretory function, derived primarily from **endoderm** (**mucoderma**);

— MFS of lung (**P**), heart (**C**), spleen/pancreas (**RP**), liver (**F**), kidney (**R**) form the productive block of mesodermal origin, with storage (accumulative) function (**organoderma**);

— MFS of bone and cartilage tissue (**Ad**), vessels (**Mc**), connective tissue (**Cd**), muscle and adipose tissue (**Fd**), and parenchymal-epithelial tissue (**Pd**) represent the structural block of mesenchymal origin, reflecting the cellular level of functional organization (**osteoderma, hemo-lymphoderma, desmoderm, feto-myoderm, seroderma**).

Morphofunctional System as a Key Element of the Biomedical Model of the Human Body. In the proposed model, the MFS is considered a multilevel energy-informational structure that integrates an anatomical organ or tissue complex with the corresponding skin areas, functionally related BAP, segmental-reflex formations, as well as psycho-emotional and behavioral characteristics. This structure represents the basic element of the biomedical MFM of the organism, since it provides continuous coupling between morphology and function at all levels of organization, from the cellular and tissue levels to the organ, systemic, and behavioral levels. In contrast to traditional "organ-centric" models, the MFS framework makes it possible to describe integral adaptive responses of the organism while taking into account the totality of biophysical, biochemical, and energy-informational interactions, which is of fundamental importance for personalized diagnostics and therapy [13; 14].

The key role of MFS within the MFM of the organism is determined by its ability to serve as a "bridge" linking embryogenesis, histogenesis, and functional specialization. During embryonic development, the displacement of cell masses, the progressive differentiation of cell populations, and the formation of germ layers are accompanied by intensive metabolite exchange and multilevel interactions-ionic, electrical, molecular, and quantum-field. By the time of birth, each cell

population represents the outcome of a long trajectory from the zone of its initial formation to its final position within the structure of organs and systems. This trajectory leaves a characteristic "imprint" in the form of altered metabolism and functional activity of those cells and tissues with which the migrating populations have sequentially interacted [10; 18; 40].

The system-forming factor of an MFS is the organ or leading function around which all of the above components are organized. In generalized form, the structure of an MFS includes:

– an anatomical "organ" or organ complex, its functional "meridian," and the corresponding BAP that define the leading function;

– a functionally "paired" organ and its corresponding channel, related to the primary organ according to TCM principles (functional analogy or complementarity);

– a specific body "segment" associated with the given MFS at the level of innervation and vascular supply;

– a body "layer" that includes musculo-fascial structures, the vertebral-motor segment, dentoalveolar and sinus projections, and endocrine glands;

– modalities of subjective perception (warmth/cold, dryness/moistness, pressure, etc.) that are most characteristic of overload of the given MFS;

– typical behavioral responses and dominant emotions that reflect the psychophysiological profile of the system.

As a result of this coherent spatiotemporal organization of embryonic development, stable morphofunctional blocks are formed, whose constituent elements are MFS united by common origin, similar conditions of formation, and closely related functions. These integrative functional blocks reflect the coordinated operation of several morphofunctional systems within a single regulatory–adaptive contour. Each MFS comprises:

– an "internal" organ component (one or more organs/tissue complexes linked by common histogenesis and function);

– an "external" somatic component (the body segment and "layer" corresponding to the given system, including muscles, fasciae, dental structures, accessory sinuses, endocrine structures, and others);

– a projection onto the skin through the system of BAP and associated reflex arcs;

– behavioral and psycho-emotional patterns consolidated within this MFS (the predominant type of emotion, the nature of the stress response, and the subjective perception of external factors such as warmth, cold, pressure, etc.).

In this context, the skin MFS (**Sd**), although histogenetically related to the ectoderm and covering structures, is assigned to the adaptive block rather than to the structural mesenchymal framework within the MFM of the organism. This reflects its leading function as a dynamic interface between the external environment and internal regulatory circuits: the skin serves as the primary platform for the implementation of autonomic responses, thermoregulation, sensory reactions, and psychovegetative manifestations, integrating somatic and psycho-emotional components of adaptation.

Thus, within the proposed MFM of the organism, the MFS ceases to be an exclusively anatomical or energetic construct. It becomes an "operational" unit within which data from noninvasive BEP-diagnostics and the effects of external interventions (including MMW-acupuncture therapy) can be interpreted, allowing disorders of adaptive mechanisms to be tracked at the preclinical level. This makes the MFS a convenient yet strictly structured tool for integrating morphological, functional, and regulatory aspects within a unified biomedical MFM of the human organism [35].

Capabilities of the Biomedical Morpho-functional Model of the Human Organism. The MFM of the human body, as an integrated holistic system, offers extensive opportunities for both fundamental research and clinical practice-particularly in the field of personalized medicine. Its key value lies in its ability to reconstruct the dynamics of interactions between morphological structures and functional processes at all levels of organization, from the cellular to the systemic. This enables not only descriptive analyses but also predictive modeling of the organism's adaptive responses, thus uncovering hidden interrelations that often go unrecognized in traditional models. Within the context of systems biology and biophysics, the MFM serves as an instrument for modeling multifactorial diseases and conditions, including those associated with physical stress, where homeostatic imbalance can lead to overtraining or reduced performance [19; 20].

One of the fundamental strengths of the MFM is its capacity to establish causal relationships

in the initiation and progression of pathological processes. The model makes it possible to trace how perturbations at the cellular level, such as changes in ion transport or membrane potential, evolve into systemic dysfunctions. This is particularly significant for understanding multifactorial conditions-such as neurodegenerative and autoimmune diseases-where early deviations in metabolism and energy balance precede clinical manifestations. Based on analysis of BAP parameters within the MFS, the model supports the development of unified systems of medical technologies for diagnosis and therapy, combining biophysical measurements (e.g., conductance and dielectric permittivity at BAPs) with neurohumoral regulation. As a result, a strategy for organismal restoration is formed in the context of a multilevel biological system, with each MFS acting as a node for targeted intervention [21; 22].

The MFM also provides tools for studying the functional interrelationship between organs and tissue systems, the effects of internal and external factors on physiological and pathological changes, and the dynamics of BAP biophysical parameters under both normal and pathological conditions. For example, BEA diagnostics of the adaptive block allow for evaluation of those MFS most actively involved in adaptation processes, detecting asymmetries that indicate the risk of functional decompensation. This not only enables identification of the pathological core at preclinical stages but also allows tracking of pathology dynamics and planning of preventive and therapeutic measures tailored to individual characteristics. In sports medicine, where intense physical loads induce excitation of the autonomic nervous system and increased energy expenditure, the MFM helps optimize autonomic support, promote efficient resource allocation, and prevent overloads [23; 24].

Ultimately, the biomedical MFM extends the horizons of modern biomedicine by offering a unified platform for the interpretation of noninvasive diagnostic data-such as BEP rapid diagnostics-and for their translation into algorithms for personalized intervention. On this basis, individualized protocols for each subsequent MMW-acupuncture therapy procedure are generated, allowing dynamic adaptation of treatment to the patient's current status. The advantages of the MFM are found not only in its predictive value but also in its ability to integrate systemic TCM principles with modern biophysical techniques. Thus, the model becomes a key tool for the development of innovative medical technologies aimed at maintaining and preserving the organism's adaptive potential and preventing its depletion [25].

Bioimpedance Electroacupuncture Rapid Diagnostics. Within the present study, BEP rapid diagnostics is considered a specialized non-invasive method for assessing the state of MFS, as defined in the organism's MFM, based on registration of CC at BAP that are topologically linked to the corresponding MFS under exposure to a low-intensity alternating test signal. In contrast to classical segmental bioimpedance analysis, which is primarily aimed at assessing body composition, and to electroacupuncture approaches based on R. Voll's concept [17] and organ—meridian interpretations, BEP-diagnostics was originally designed as an instrument for rapid, multiparametric assessment of the state of integral MFS and functional blocks [1] of the organism under conditions of high functional load.

In the context of this work, BEP-diagnostics [1; 19; 26] is used for real-time assessment of the functional state of Olympic athletes during the pre-competition period. In a single session, the method enables recording of CC in a standardized panel of BAP corresponding to 20 key MFS (heart, nervous system, endocrine glands, lymphatic drainage, vascular bed, parenchymal—epithelial, connective, muscle—fat and other MFS), thereby forming an individual morphofunctional portrait of the athlete. This portrait reflects the distribution of functional load across major systems, the degree of their regulatory strain, and early signs of prepathological shifts while physiological compensation is still preserved.

Technically, BEP-diagnostics is implemented as registration of CC under short-term exposure to a stabilized, ultra-low-amplitude alternating test signal of fixed frequency at standard and control BAP. Measurements are performed under standardized conditions (controlled ambient temperature, automated preparation of the skin in the BAP area by wetting with physiological saline, standardized electrode placement), which minimizes the contribution of non-specific factors such as variations in local hydration, stratum corneum thickness, and mechanical pressure. The recorded values of the active (**G**) and reactive (**B**) components of CC are expressed in conditional

units, which facilitates comparison across different BAP, corresponding MFS, and time points of monitoring and subsequently allows construction of individual adaptive corridors.

The key features of BEP-diagnostics are as follows:

– multiparametricity: the active and reactive components of conductance, their ratio, and dynamics are recorded, enabling simultaneous assessment of humoral and cellular processes in each of the 20 MFS [1; 19];

– high selectivity: each BAP is a representative point carrying information about the state of a specific system-from its innervation to energy supply-thus forming a natural map of the organism's internal interconnections, consistent with studies showing organ-related changes in meridian and acupoint signals [22; 28; 31];

– unified digital format: data are presented in a standardized structure, which opens possibilities for automated analysis, machine learning, and integration into medical digital platforms [1; 19; 26];

– rapidity: primary diagnostics requires no more than 20 minutes, making the method applicable not only in clinical settings but also in dynamic monitoring, including sports, rehabilitation, and preventive medicine, analogous to other rapid whole-body bioimpedance-based screening technologies such as Electro Interstitial Scan [30].

From the perspective of informational output, in the present study BEP-diagnostics is used not as a tool for establishing nosological diagnoses but as a method of functional monitoring. At the level of primary data, it yields:

– maps of G and B distribution across the 20 MFS;

– integral indices for groups of MFS reflecting, in particular, the state of regulatory (CNS, ANS, endocrine coordination), transport (circulation, lymphatic drainage), and structural–tissue blocks.

At the interpretive level, these indicators are then used to construct the morphofunctional portrait of each athlete, to compare it with reference profiles, and to analyze its dynamics during the pre-competition period.

The practical advantage of BEP-diagnostics in a high-performance sports context lies in the combination of several key properties: the method is non-invasive, does not require administration of contrast agents or pharmacological tests, is characterized by minimal examination time, and can be repeated multiple times without compromising safety or tolerability. An additional and strategically important advantage is the inherently digital format of data across all 20 MFS, which enables rapid remote processing, dynamic comparison with individual historical profiles, and integration into intelligent analysis algorithms for detecting adaptive shifts and prognostic patterns.

Taken together, these features make BEP-diagnostics suitable for inclusion in routine pre-competition assessment protocols for Olympic athletes, providing the opportunity for early detection of functional overstrain in individual MFS, reduction of adaptive reserve, and initial signs of disintegration of morphofunctional organization without waiting for clinical manifestations.

Nonlinear Parameters of Bioimpedance Response and Spectral Analysis as Integral Indicators of the "Cell–Extracellular Environment" System. The fundamental methodological premise underlying BEP rapid diagnostics is the understanding of the cell not as an autonomous structural unit, but as a spatially localized process maintained by continuous exchange of matter, energy, and information with its surrounding extracellular environment. In this context, the cell exists solely as an element of a broader open system that encompasses the intracellular milieu, membrane structures, and the extracellular (humoral) phase-components that are functionally and regulatory inseparable [33].

The intracellular medium is characterized by a high degree of structural organization, spatial confinement, and maintenance of states far from thermodynamic equilibrium. In contrast, the extracellular environment-interstitial fluid, blood, and lymph-is far less geometrically constrained, exhibits high ionic and molecular mobility, and fulfills the functions of a buffer, resonant mediator, and amplifier of regulatory processes. Within this system, the cell membrane acts not as a passive boundary, but as a selective, nonlinear, and spectrally sensitive interface through which rapid environmental changes synchronize with the more inertial intracellular processes [7; 33].

Regulation of the "cell-environment" system is largely achieved through electrodynamic and hydration mechanisms: ionic gradients, membrane potentials, hydration shells, and the conformational

mobility of protein structures. These parameters vary on timescales from microseconds to seconds and reflect collective molecular ensemble behavior rather than sequential chemical reactions. Consequently, the system exhibits pronounced nonlinear properties-threshold effects, temporal delays, saturation, and hysteresis-which preclude adequate description within linear models of regulation.

A key feature of this system is the disparity in temporal inertia among its components. The extracellular humoral phase responds to external perturbations almost instantaneously, whereas membrane-associated cellular structures possess mechanisms of temporal stabilization and delayed adaptation. This distinction underlies the diagnostic informativeness of the BEP method, which separately registers the active and reactive components of CC at BAP. The active component reflects the state of the rapidly changing liquid and ionic medium, whereas the reactive component characterizes the inertial adaptation of membrane structures that exhibit threshold sensitivity and temporal response delay [34].

Thus, BEP rapid diagnostics captures not static parameters, but the dynamics of asynchronous responses from different regulatory levels within the same system. This enables detection of early signs of strain, adaptation, and dysregulation well before the emergence of clinically expressed disturbances. Unlike conventional methods focused on final functional outcomes, BEP-diagnostics effectively records the temporal architecture of regulatory processes, placing it within the domain of dynamic systems physiology and justifying its use for rapid assessment of functional state under high adaptive loads.

A conceptual expansion of BEP-diagnostic capabilities arises from recognizing that measured CC at BAP reflects not only the linear electrical properties of tissues but also the nonlinear dynamics of interactions between cellular structures and their surrounding humoral medium. In real biological systems, the response to an ultra-low-intensity test signal is not strictly proportional to the stimulus; it results from the interplay of threshold, resonant, and delayed processes that collectively define the system's integrated nonlinear behavior.

An additional and methodologically independent analytical level within the BEP framework is the measurement of the spectral composition of the ultra-low-intensity test signal at BAP. The spectral characteristics of the electrical response, recorded at test amplitudes not exceeding physiologically safe limits (typically up to 100 mV), enable detection of subtle biochemical and biophysical changes associated with early stages of pathological processes in organs and tissue systems. Unlike integral conductivity indices, spectral analysis is sensitive to variations in phase relationships and frequency components of electrical oscillations reflecting molecular events-activation of ion channels, rearrangement of membrane potential, mediator release, and alteration of water—protein domain structure.

The source of bioimpedance nonlinearity and spectral sensitivity lies in the structural organization of living tissues themselves. Cellular membranes, ion channels, and receptor complexes represent ensembles with discrete energy states and pronounced frequency selectivity. The extracellular fluid medium, with its high ionic mobility and low geometric restriction, provides closure of feedback loops, such that even minimal perturbations in the spectral content of the test signal may induce disproportionately large changes in the phase—amplitude profile of the response. Hence, spectral parameters serve as indicators of early desynchronization between cellular structures and their environment [34].

Within this context, BEP-diagnostics utilizes an additional independent information channel reflecting the degree of system nonlinearity-beyond the absolute values of the active and reactive components of CC. The character of the spectral response-its stability, reproducibility, and energy distribution across frequency ranges-reveals the integral state of regulatory circuits encompassing membrane, humoral, and autonomic mechanisms.

Practically, when the physiological state is stable, the system exhibits a reproducible spectral profile and quasi-linear bioimpedance response within a narrow range of test influences. As functional strain increases or subclinical dysregulation develops, nonlinear effects become more pronounced: spectral stability decreases, phase relationships shift, parameter variability rises upon repeated measurements, and the **G/B** ratio departs from the individual adaptive corridor. These deviations typically precede structural damage and clinical manifestations, marking the transition to a condition of reduced regulatory reserve.

In BEP rapid diagnostics, measured CC parameters at BAP are recorded in conditional (normalized) units in a digital format, distinguishing this approach from conventional impedanceometry. The use of conditional units is not a technical limitation, but a deliberate methodological decision aimed at registering integrated, functionally meaningful states of biological media rather than absolute electrical metrics in a narrow physical sense.

Conditional units in BEP-diagnostics represent normalized measures derived from tissue responses at BAP to a stabilized, ultra-low-intensity test signal of fixed frequency. Such normalization minimizes the influence of individual anatomical factors (skin thickness, local hydration, electrode contact area) and emphasizes relative changes in electrophysiological properties that reflect regulatory and adaptive dynamics.

CC is thus decomposed into two components-active (**G**) and reactive (**B**)-each expressed in its respective scale of conditional units and conveying distinct physiological information.

The active component ($\mathbf{G = 1/R}$) reflects ionic conductivity and characterizes the state of the extracellular and interstitial liquid media. Under physiological conditions, its values generally fall within 55–70 conditional units. This range is not fixed, as the active component is sensitive to dynamic parameters of the humoral environment-hydration level, electrolyte concentration, microcirculation, metabolic activity, and local inflammatory reactions. Consequently, **G** responds rapidly to internal and external perturbations and reflects primarily the current functional mobility of the medium rather than structural tissue properties.

The reactive component ($\mathbf{B = \omega C}$), by contrast, is determined by the capacitive and dielectric properties of cellular membranes and tissue barriers. It reflects membrane permeability, integrity, and structural organization of cellular ensembles. Normative **B** values typically range from 50 to 65 conditional units and depend on membrane potential stability, preservation of ionic gradients, and metabolic competence of cells. Unlike the active component, B exhibits greater inertia and slower variability, making it particularly informative for assessing organ or MFS functional activity and for detecting early structural changes-dystrophic, degenerative, or proliferative.

Spectral analysis of the test signal at BAP provides an independent channel of information about the degree of nonlinear organization of the "cell–environment" system. Coincidence of the physiological Δ**(G–B)** interval with stable spectral patterns confirms that this range corresponds to the optimal regime of ionic gradient and membrane regulation, whereas its excess or inversion correlates with qualitative changes in the frequency structure of the response characteristic of adaptive strain, pre-pathology, or exhaustion.

The natural mismatch between normal ranges of **G** and **B** reflects their distinct physiological roles and temporal dynamics. The active component primarily registers rapid humoral and ionic processes, whereas the reactive component captures deeper and more persistent alterations at the membrane-cellular level. This divergence should not be regarded as a methodological artifact of scaling but rather as a diagnostic resource enabling analysis of the "cell-environment" system in two complementary dimensions.

Accordingly, the use of normalized conditional units in BEP-diagnostics enhances rather than reduces diagnostic accuracy, allowing direct comparison of **G** and **B** values across different BAP, MFS, and temporal monitoring stages. Combined analysis of CC parameters and spectral characteristics of the bioimpedance response establishes a multilayered model of the organism's functional state, wherein nonlinearity serves as an integrated marker of the "cell-environment" system. It synthesizes information about membrane stability, dynamics of liquid media, and efficacy of closed-loop regulatory circuits. On this basis, BEP rapid diagnostics enables identification of adaptive, compensatory, and maladaptive conditions at a preclinical level, distinguishing it fundamentally from conventional end-point measurements and positioning it as a method of early, proactive, and system-based assessment of the organism's adaptive potential.

Morphofunctional and Embryogenetic Foundations of BEP-Diagnostics. Current concepts of the relationship between the state of internal organs and the parameters of the skin allow the skin to be regarded as a highly organized information system. Independent studies have demonstrated that BAP with a diameter on the order of 0.1–10 mm are localized on the skin surface and exhibit characteristic biophysical features: reduced electrical resistance, distinct temperature and gas-exchange profiles, and increased receptor density [22; 28]. Stimulation of BAP

elicits reproducible systemic responses-changes in regional blood flow, mediator secretion, and electrical activity of the nervous system-which is supported by morphological and functional observations [22].

From the standpoint of systems biology and biophysics, BAP can be viewed as information-energy nodes of a specialized MFS interface. This interface forms part of the integral information field of the skin and provides bidirectional regulatory integration of signals between internal organs and the external environment.

Formation of MFS begins during embryogenesis. At early stages of development, the primordia of internal organs, skin areas, muscles, and tendons are linked by shared primary innervation and coordinated morphogenesis; as tissues grow and migrate, the segmental organization of these connections is preserved. In the mature organism, this is expressed as stable axial trajectories of interaction: each internal organ is associated with a specific spinal cord segment that innervates corresponding myotomes, sclerotomes, vasotomes, and dermatomes. The spinal cord and afferent—efferent pathways ensure rapid reflex exchange between deep and superficial structures.

Viscero-somatic and somato-visceral reflexes, as well as autonomic pathways, play a key role in interlevel information transfer. Irritation in the region of an organ or disturbance of its function alters afferentation in the corresponding segment; this is reflected in vascular tone, microcirculation, regulation of the intercellular milieu, and receptor activity in representative skin zones. In parallel, humoral and neuroimmune mechanisms are engaged, which can prolong or modulate these relationships on time scales ranging from seconds to days.

The idea of embryogenetic "connectivity" has been further developed in concepts describing "functional corridors" and trajectories of the Jing-Luo channels: during organogenesis, cells migrate along specific axes while receiving inductive signals, and these axes retain functional significance in the postnatal period [35; 36]. Recent studies refine this picture by highlighting the role of fascial and intertissue structures as the morphological substrate of meridians and regulatory signal transmission pathways, as well as the anatomical and histological features of acupuncture points themselves [37; 38].

In the mature organism, the functioning of embryogenetic "axes" is realized through MFS. Each MFS can be represented as a sequence: germ layer → tissue specialization → MFS → its control BAP → functional block that defines the leading function and, on this basis, unites the MFS that have formed.

Table 1 shows the relationships between germ layer, tissue specialization, MFS, primary function, control BAP, and the leading function of the adaptive block.

The adaptive block integrates those MFS that are responsible for signal perception, process regulation, and protective responses of the organism. These systems originate from ectodermal derivatives and are associated with regulatory functions.

Disturbance of an organ or tissue system function initiates a cascade of changes in autonomic regulation, microcirculation, and the composition of the intercellular milieu, leading to detectable alterations in hydration, perfusion, and electrical properties of the control BAP. It is precisely these changes that are captured by bioimpedance measurements at BAP, where the active (**G**) and reactive (**B**) components of CC provide information on the state of the humoral environment and cellular structures of the corresponding MFS.

For a clearer understanding of the relationship between BEP-diagnostics and the model, all elements of the model diagram are summarized in Table 2. The table shows the relationships between germ layer, tissue specialization, MFS, control BAP, and leading function within the MFM.

Thus, control BAP act as operative integrative markers of MFS activity, uniting the embryological legacy of segmental connections, anatomical—fascial trajectories of signal transmission, and contemporary mechanisms of neurohumoral regulation. At the same time, it is important to emphasize that although the accumulated data consistently support the proposed model, its elements require further validation using combined approaches (morphological studies, functional imaging, correlational bioimpedance investigations, and experimental models).

Biophysical Concept and Diagnostic Algorithms of BEP-Diagnostics. BEP-diagnostics is based on the fundamental property of the skin and BAP to reflect the functional state of internal organs and MFS. These points are not merely local

TABLE 1 – **Relationship between germ layer, tissue specialization, MFS, primary function, control BAP, and leading function of the adaptive block**

Germ layer	Tissue specialization	MFS	Primary Function	Control BAP	Adaptive Functional Block (leading function)
Ectoderm	Epidermis	Skin (**Sd**)	Sensory perception, protection	**Sd4 (1.3)**	Perception of external environmental stimuli to trigger responses that sustain vital activity (adaptive function)
	Neuroderma	Brain and spinal cord (**Nd**)	Neural regulation, coordination	**Nd3 (1b)**	
	Neuro-sympatoderma	Endocrine glands (**Tr**)	Trophic and endocrine regulation	**Tr4 (1b)**	
	Sympatoderma	Allergy (**Al**)	Regulation of allergic responses	**Al4 (1b)**	
	Oroderma	Lymphatic drainage (**Ly**)	Lymphatic drainage, immune protection	**Ly3 (1.2)**	

TABLE 2 – **Relationship between germ layer, tissue specialization, MFS, control BAP, and leading function**

Germ layer	Tissue specialization	Morphofunctional system	Control BAP	Functional block (leading function)
Ectoderm	Epidermis	Skin (**Sd**)	**Sd4 (1.3)**	**Adaptive block** Perception of external environmental stimuli to trigger responses that sustain vital activity (adaptive function)
	Neuroderma	Brain and spinal cord (**Nd**)	**Nd3 (1b)**	
	Neuro-sympatoderma	Endocrine glands (**Tr**)	**Tr4 (1b)**	
	Sympatoderma	Allergy (**Al**)	**Al4 (1b)**	
	Oroderma	Lymphatic drainage (**Ly**)	**Ly3 (1.2)**	
Endoderm	Mucoderma	Large intestine (**Gl**)	**Gl4 (1b)**	**Transitory block** Reception and processing of nutrients for organismal development (absorption, excretion)
		Stomach (**E**)	**E4 (44b)**	
		Biliary tract (**Vb**)	**VB4 (43b)**	
		Small intestine (**IG**)	**IG4 (1b)**	
		Urogenital organs (V)	**V4 (66b)**	
Endo-mesoderm (mesoderm)	Organoderma	Lung (**P**)	**P3 (10c)**	**Productive block** Transformation of nutrients and production of structural material (storage, energy)
		Spleen (**RP l**) Pancreas (**RP r**)	**RP2 (1a)l** **RP2 (1a)r**	
		Liver (**F**)	**F2 (1a)**	
		Heart (**C**)	**C5 (8c)**	
		Kidney (R)	**R4 (1-3)**	
Ecto-mesoderm (mesenchyme)	Seroderma	Parenchymal–epithelial tissue (**Pd**)	**Pd4 (1b)**	**Structural block** Interstitial–cellular apparatus, microcirculation (blood, lymph, lymphoid and other tissues), musculoskeletal system (protective and drainage function, cellular level of functional organization)
	Desmoderma	Connective tissue (**Cd**)	**Cd2 (1b)**	
	Feto-musculoderma	Muscle–fat tissue (**Fd**)	**Fd2 (1b)**	
	Hemo-lymphoderma	Vessels (**Mc**)	**Mc4 (8d)**	
	Osteo-cavoderma	Bone–cartilaginous tissue (**Ad**)	Ad4 (1b)	

areas of altered conductance but complex sensory structures capable of integrating information on the state of deep regulatory processes in the organism.

The method relies on recording the complex conductance (CC, $\mathbf{Y} = \mathbf{G} + \mathbf{jB}$) of tissues in the region of BAP under the influence of an ultra-low alternating signal (no more than 0.1 V), which makes the examination fully safe and noninvasive. In contrast to the classical R. Voll method [17], which uses direct current and primarily captures properties of the extracellular fluid, BEP-diagnostics provides a fundamentally different level of analysis. It allows CC to be decomposed into its active (**G**) and reactive (**B**) components, each carrying unique physiological information:

– the active component of CC ($\mathbf{G} = \mathbf{1/R}$) reflects ion movement and characterizes the conductance of the intercellular medium. Changes in this parameter are associated with blood flow, microcirculation, electrolyte balance, and the state of the extracellular space (for example, in edema or inflammation);

– the reactive component of CC ($\mathbf{B} = \omega\mathbf{C}$) is determined by the capacitive properties of cell membranes and tissue barriers. It serves as an indicator of metabolic activity and structural

changes at the cellular level, including membrane integrity and processes of proliferation and degeneration.

Thus, BEP-diagnostics provides a dual analytical perspective: on the one hand, the state of fluid compartments and microcirculation, and on the other, deep cellular and membrane processes. By integrating these data into a unified coordinate system, the method generates a multilevel model of the organism's functional state that simultaneously captures humoral, cellular, and regulatory mechanisms.

Parameters of BAP play a pivotal role in BEP-diagnostics, among which two hypothalamic points (**TR20 L** and **TR20 R**) occupy a special position. The hypothalamus is the central regulator of homeostasis, governing interactions among the nervous, endocrine, and immune systems. The corresponding hypothalamic BAP can be regarded as key regulatory points of the organism, reflecting the state of its central integrative mechanisms. The slightest imbalances in hypothalamic function manifest earlier than clinical changes in peripheral organs. Therefore, measurement of parameters at these points serves as the starting point for interpreting the entire diagnostic profile.

The next analytical level is formed by 40 control BAP of 20 MFS (20 on the left and 20 on the right), each of which functions as an integrative sensor of the state of an organ and its associated regulatory connections. Beginning the diagnostic procedure with control BAP is of principal importance, since they represent the most informative "representative BAP" of each MFS. In contrast to local BAP, which may reflect focal or situational changes, control points accumulate the integral response of all BAP within a given MFS. This makes them specific "indicators" of the organism's state: even minimal deviations in control BAP parameters allow detection of strain or disturbance in the corresponding MFS long before overt clinical symptoms arise. In this way, diagnostics that begin with control BAP ensures analytical coherence, accuracy of the initial assessment, and provides the basis for correct interpretation of all subsequent information. If the parameters of a control point lie within the "corridor of normal values", additional BAP of that MFS are not measured, making the procedure as rapid and efficient as possible.

In addition to control BAP, other BAP are used in BEP-diagnostics, most of them located on the distal segments of the limbs (hands and feet). R. Voll established that each meridian contains several types of BAP [17]:

– BAP informationally linked to a specific organ or its part, i.e., organ-related points, for example **R1 (1)** – renal pelvis;

– BAP corresponding to a serous membrane (pleura, pericardium, peritoneum, etc.), for example **R5 (1-4)** – renal peritoneum;

– BAP of a regional autonomic plexus (regulating a given system or organ), for example **R3 (1c)** – renal plexus;

– BAP of lymphatic drainage or regional lymph nodes, for example **R2 (1-1)** – lymphatic system of the kidney and adrenal gland;

– summary BAP (providing information on the functioning of an entire organ system or structure, e.g., venous system, systemic arteries, fat and cholesterol metabolism, etc.), for example **Mc1 (9)** – total BAP of arteries of the whole body.

Figure 2 shows 10 MFS topologically distributed along the lateral surfaces of the fingers of the hand. Orientation is based on the standard anatomical position: the palm is open, the fingers slightly abducted, and the palmar surface facing downward. In this position, the lateral surface of a finger oriented radially (toward the thumb) is considered the outer surface, whereas the surface oriented ulnarly (toward the little finger) is considered the inner surface.

The thumb is an exception: its outer (lateral) surface faces the radial edge of the hand, while the inner (medial) surface faces the index finger. This clarification is important, as it explains the correct distribution of MFS across the fingers and eliminates anatomical ambiguity.

MFS and their control BAP have a strict topological relationship to the joints and lateral surfaces of the fingers. BAP are localized predominantly at the heads of phalanges and near joint creases, making them accessible for reproducible measurements and clinically meaningful palpation. The proposed anatomical orientation makes it possible to formalize the relationship between a specific finger surface and a given MFS, thereby creating a convenient diagnostic and therapeutic map.

It is important to note that such localization of BAP on the terminal segments of the fingers has

a fundamental rationale within the growth control model of acupuncture, where many acupoints are predicted and empirically supported to concentrate at singular points and boundaries of body structures, including the distal tips of the digits, as detailed in [10].

It is important to note that such localization of BAP on the terminal segments of the fingers has a fundamental rationale, described in detail in the work According to his concept, distal segments of the extremities represent the most informative zones of the body, because during embryogenesis they form as projection "outputs" of key morphogenetic axes. This explains the high density of receptor structures, specific biophysical activity, and marked informativeness of BAP located on the fingers and toes. Thus, the distribution of MFS and the anchoring of their BAP to the phalangeal heads reflect not a random anatomical fact, but the result of deep regularities of embryogenesis and morphofunctional integration of the organism.

The correspondence between fingers and MFS is as follows:

– thumb – outer surface: MFS of lymphatic drainage (**Ly**); inner surface: MFS of the lung (**P**);

– index finger – outer surface: MFS of the large intestine (**GI**); inner surface: MFS of the brain and spinal cord (**Nd**);

– middle finger – outer surface: MFS of vessels (**Mc**); inner surface: MFS of allergy (**Al**);

– ring finger – outer surface: MFS of parenchymal–epithelial tissue (**Pd**); inner surface: MFS of endocrine glands (**Tr**);

– little finger – outer surface: MFS of the heart (**C**); inner surface: MFS of the small intestine (**IG**).

Figure 2 illustrates the main types of BAP used in BEP-diagnostics, together with their color coding:

– control BAP are highlighted in red;

– summary BAP (reflecting the functional state of an entire organ system or structure) are marked in black;

– BAP of autonomic regulation (regional points associated with the autonomic plexus regulating a given system or organ) are shown in purple;

– BAP of lymphatic drainage (points of lymph nodes and regional lymphatic drainage) are shown in green;

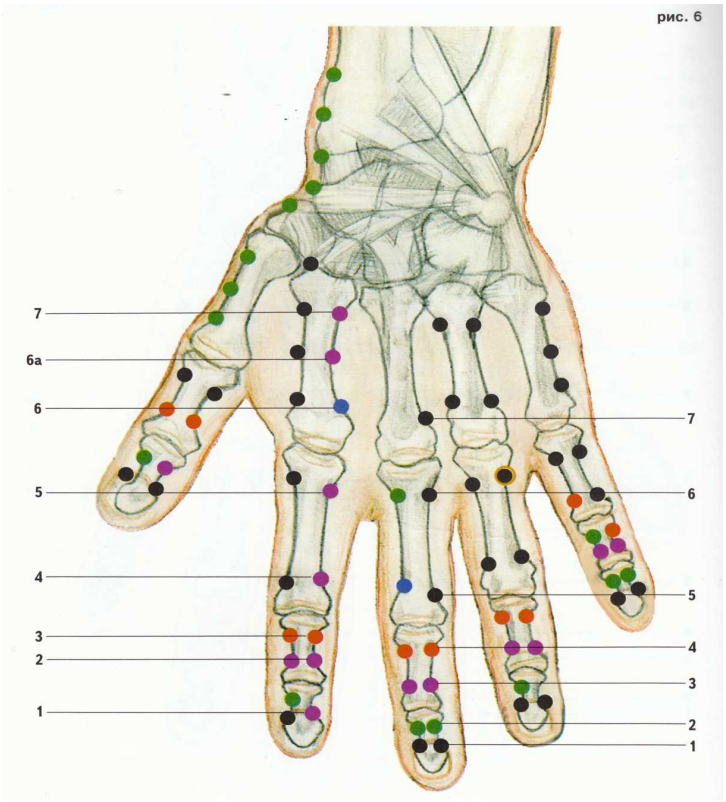

Fig. 2. Localization of BAP of the MFS of the brain and spinal cord (**Nd**) (shown on the left) and the MFS of allergy (**Al**) (shown on the right)

– organ-related BAP (points informationally linked to a specific organ or its part) are highlighted in black;

– BAP of serous membranes (points reflecting the functional state of the corresponding serous membrane: pleura, pericardium, peritoneum, etc.) are likewise indicated in black.

To clarify the importance of the information obtained during BEP-diagnostics, Table 3 presents the designations of BAP of the MFS of the brain and spinal cord (**Nd**) and their functional characteristics.

In cases where the parameters of a control BAP fall outside the normal range (either above or below), an in-depth assessment is performed: an additional 3–4 points of the same morphofunctional system are measured. This approach refines the characterization of deviations and reduces the likelihood of artifacts. If at least one of the additional BAP shows a value above or below the normal range, a full examination of all BAP of the corresponding MFS is carried out. In this way, a stepwise diagnostic algorithm is implemented-from general assessment to detailed analysis-which provides high selectivity of the method while optimizing examination time and minimizing burden on the patient.

The human organism is an integrated system in which homeostasis and adaptation to changing environmental conditions are maintained through the interaction of metabolism, neuroendocrine regulation, and the blood and lymph circulatory systems. According to the biomedical model [1; 26], this unity is ensured by 20 self-regulating MFS that coordinate physiological processes from the molecular to the organismal level. The function of each MFS is directed toward preserving the integrity of the organism and is characterized by quantitative (e.g., electrophysiological parameters) and qualitative (e.g., type of adaptive response) indices. In addition to its barrier role, the skin serves as a unique information interface that reflects the state of internal organs through the biophysical properties of BAP. Figures 3 and 4 show the process of BEP-diagnostics for the MFS of muscle–fat tissue (**Fd**). In Figures 5 and 6, the external appearance and interface of the express diagnostic bioelectronic system "RAMED EXPERT–05" are shown.

BAP are local skin areas with increased conductance that are functionally connected to organs via meridians and form MFS that include the organ, the corresponding tissue system, and their associated BAP. Representative BAP of each MFS integrate the electrophysiological characteristics of all acupuncture points, acting as sensors of physiological change. Self-regulation of an MFS is implemented through interactions among the regulated parameter (e.g., metabolite levels), receptors in BAP, neuroendocrine mechanisms, and effector tissues that restore homeostasis. For example, during inflammation, cellular swelling reduces the volume of extracellular fluid, altering **G**, whereas destructive processes in membranes affect the parameter **B**.

BEP-diagnostics captures these shifts through changes in **G** and **B**, as well as **G–B**, which reveal subtle metabolic and regulatory alterations, ranging from local to integrative adaptive responses. For instance, a sharp increase in **G** with relatively stable **B** may indicate acute stress, whereas a decrease in B below the normal corridor signals structural chronic disturbances, which is critical for athletes in the pre-competition period. Compared with the Voll method, BEP addresses MFS as integrated systems, providing both quantitative and qualitative assessment of functional state. This opens prospects for early detection of dysfunctions, prediction of adaptive capacity, and personalized monitoring in sports medicine and clinical practice.

TABLE 3 – **Designations of BAP of the MFS of the brain and spinal cord (Nd) and their functional characteristics**

Left side			Right side		
Nd1 (1)L	-	Lumbar and sacral segments of the spinal cord	**Nd1 (1)R**	-	Lumbar and sacral segments of the spinal cord
Nd2 (1a)L	-	Integrated autonomic nervous system	**Nd2 (1a)R**	-	Integrated autonomic nervous system
Nd3 (1b)L	-	Control BAP of the central and peripheral nervous system	**Nd3 (1b)R**	-	Control BAP of the central and peripheral nervous system
Nd4 (1c)L	-	Meninges of the brain and spinal cord	**Nd4 (1c)R**	-	Meninges of the brain and spinal cord
Nd5 (2)L	-	Cervicothoracic segment of the spinal cord	**Nd5 (2)R**	-	Cervicothoracic segment of the spinal cord
Nd6 (3)L	-	Brain, brainstem, and their vascular network	**Nd6 (3)R**	-	Brain, brainstem, and their vascular network
Nd7 (3a)L	-	Parasympathetic ganglia of the head	**Nd7 (3a)R**	-	Parasympathetic ganglia of the head
Nd8 (4)L	-	Cranial nerves	**Nd8 (4)R**	-	Cranial nerves

Fig. 3. The process of diagnosing the MFS (**Fd**)

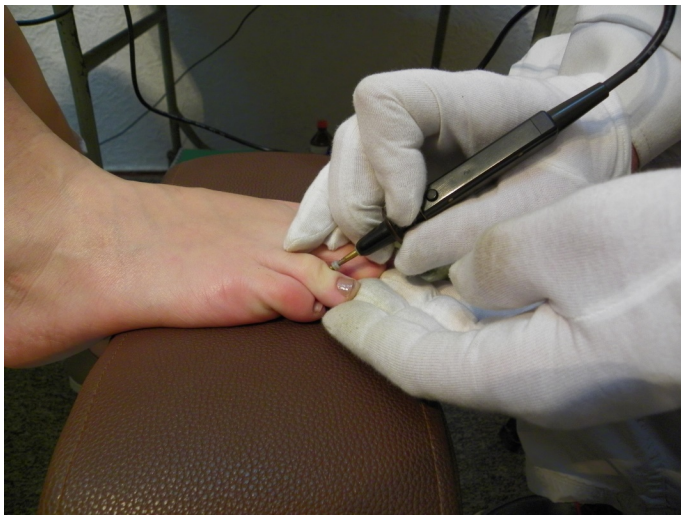

Fig. 4. The process of diagnosing the BAP **Fd4 (1b)R**, MFS (**Fd**)

Fig. 5. Unit for BEP express-diagnostics "RAMED EXPERT-05"

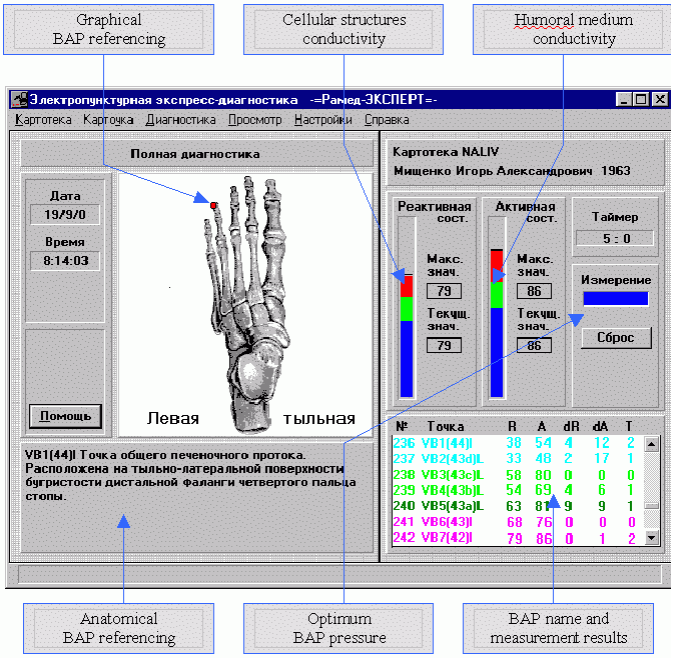

Fig. 6. BEP-diagnostics interface “RAMED EXPERT-05”

The difference between **G** and **B** ($\Delta = G-B$) normally ranges from 5 to 15 arbitrary units, reflecting the physiological balance of ion exchange between the cell and its environment. Exceeding this range (>15) or a negative value (<0) indicates imbalance characteristic of pre-pathological states such as inflammation, exhaustion, or metabolic disturbances. For example, a substantial increase in **G** with stable **B** may indicate enhanced ion transport in response to acute stress, whereas a decrease of **B** below the normal range with normal **G** suggests degenerative changes in membranes.

The dual analysis of **G** and **B** enables BEP-diagnostics to provide an integrated assessment of health, combining static (structural) and dynamic (functional) information. This makes the method indispensable for early detection of disturbances, monitoring of adaptive processes in athletes and patients with chronic diseases, and personalized therapy selection. Compared with traditional electroacupuncture diagnostic techniques, BEP-diagnostics offers a deeper analysis of cellular processes, opening new perspectives for integrative medicine.

Functional Role of the Autonomic Nervous System in the Adaptation Processes of Elite Athletes (According to BEP Diagnostics). Adaptation is a fundamental property of living organisms, ensuring their adjustment to changing environmental conditions and physical loads. The leading role in adaptation to muscular activity belongs to the oxygen transport systems-circulatory, respiratory, and hematopoietic-as well as to the autonomic nervous system (ANS), which exerts regulatory control over visceral functions and intersystem interactions [60; 61].

Restoration of impaired functional states of the organism is achieved through activation of compensatory and adaptive reactions aimed at maintaining homeostatic constants. The efficiency of these reactions is determined by the degree of coherence between intersystem and intrasystem interactions, the formation of which is largely mediated by the ANS. It is precisely the ANS that ensures the transition of functional systems to a new steady state of regulation and the establishment of stable somatovisceral synchronization [62; 63].

The ANS regulates the activity of all visceral systems and participates in homeostatic and adaptational–trophic reactions, thereby supporting tissue trophism and metabolic stability. Intensive physical exercise is accompanied by generalized activation of the ANS, leading to a functional restructuring of internal organ activity and a temporary increase in energy expenditure. As stable motor skills are developed, steady mechanisms of autonomic support emerge, allowing the athlete to perform physical work in a more

energy-efficient mode. At this stage, changes in internal organ function begin to precede the execution of motor activity itself, reflecting a high level of adaptive readiness of the organism.

Under regular training loads, elite athletes exhibit characteristic changes in the functional state of the ANS. At rest, parasympathetic tone usually predominates, manifested by reduced heart rate, arterial pressure, and respiratory rate, which ensures a more economical mode of physiological functioning. During intense physical exertion, conversely, the sympathetic division of the ANS becomes activated, promoting mobilization of energy resources and implementation of adaptive responses.

One of the key mechanisms of adaptation is sympathetic regulation of vascular tone and blood flow distribution. During physical exercise, vasoconstriction occurs in functionally nonessential regions, whereas vessels dilate in actively working organs-skeletal muscles, heart, and lungs-ensuring adequate oxygen and nutrient supply and reflecting a high level of adaptive efficiency [64].

Within the framework of BEP-diagnostics, the primary parameter reflecting the state of regulatory processes is the active component **G** of the CC, which serves as a sensitive marker of sympathetic activation within the ANS and the mobilization of functional reserves. An increase in **G** values indicates stimulation of the sympathoadrenal axis, enhanced vascular regulation, and redistribution of blood flow toward working muscles. According to experimentally established reference corridors [1], **G** values exceeding **70** relative units characterize degrees of sympathicotonia (**71—80** — normergic; **81—90** — hyperergic; **91—100** — extreme hyperergic).

The reactive component **B** of the CC, in turn, represents a universal marker of the condition of cellular structures, membrane function, and local metabolic activity. The **B** parameter responds to alterations in tissue trophism, microinflammatory processes, and the degree of utilization of internal physiological reserves. **B** values within the range of 50—65 relative units correspond to physiological norms and reflect an optimal state of cellular structures and metabolic processes; deviation above or below this range indicates either strain of adaptive mechanisms or signs of early functional exhaustion.

A combined analysis of parameters **G** and **B**, as well as their relationship-the Δ(**G—B**) index-provides an integrative understanding of the interaction between regulatory and effector mechanisms of the organism. The **G** parameter characterizes the level and direction of autonomic activation, whereas the **B** parameter reflects the structural—metabolic basis of MFS operation. Such a combined assessment allows for an objective evaluation of the adaptive status, differentiation between physiological mobilization and overstrain, and the establishment of a methodological foundation for monitoring and predicting functional shifts in elite athletes.

Methodological Foundations for Establishing Value Corridors of the Active (G) and Reactive (B) Components of Complex Conductance. The development of diagnostic value corridors for the active (**G**) and reactive (**B**) components of the CC was based not on a priori normative assumptions but on stepwise clinical and experimental verification of the BEP-diagnostic method. At the first stage, the method underwent clinical trials at leading medical institutions-Dnipro State Medical University, the Institute of Pediatrics, Obstetrics and Gynecology of the National Academy of Medical Sciences of Ukraine, and the Institute of Gerontology of the National Academy of Medical Sciences of Ukraine. In this framework, BEP-diagnostics and MMW-puncture therapy were viewed as an integrated system encompassing diagnostics, therapeutic intervention, and objective monitoring of functional state dynamics.

Following completion of clinical testing and certification of the diagnostic and therapeutic devices, a second stage was implemented, aimed at refining and substantiating the value corridors of **G** and **B** and identifying patterns of their dynamic behavior. This stage was carried out over three years through collaboration between the developer (RAMED Medical Center) and specialized departments of Dnipro State Medical University. During this period, six BEP-diagnostic devices “RAMED EXPERT-05” were used to examine 256 practically healthy individuals (students) and 86 patients with various nosological conditions. The obtained BEP-diagnostic data were compared with independent clinical diagnoses and the results of standard examination methods.

Analysis of the data array, including absolute values and dynamic profiles of the **G** and **B** parameters, allowed empirical identification of

stable ranges corresponding to distinct physiological and pathological states. As a result, value corridors for the active and reactive components of the CC were formalized-reflecting, on the one hand, the level of autonomic regulation, and on the other, the condition of cellular and membrane structures. These corridors became the foundation for the interpretive scales presented below and are employed as an objective tool for assessing adaptive status and functional reserves of the organism, including applications in sports medicine.

Correlation of the Reactive Component of Complex Conductance with the Functional State of the Organism. BEP-diagnostics enables quantitative assessment of the organism's functional state based on measurements of the reactive component **B** of the CC at the BAPs of 20 MFS. The scale presented in Table 4 establishes the correlation between **B** values (within the range of **10—110** relative units) and the corresponding functional states of the organism. This correlation has fundamental importance for monitoring adaptive processes, including those in elite athletes.

B values exceeding the physiological norm corridor (**66—110** relative units) correspond to a continuum of borderline and pathological physiological states, ranging from the phase of preinflammatory activation to subacute and acute inflammatory reactions. The **B** parameter serves as a key diagnostic marker because it reflects the condition of cellular structures, their membrane organization, and the associated structural—metabolic properties of tissues that determine functional stability and adaptive capacity of an organ or MFS.

Values within the **66—80** relative unit range (violet) correspond to the phase of pronounced physiological strain and preinflammatory activation. This state is characterized by enhanced cellular activity, altered membrane permeability, and intensified metabolic processes without the formation of morphological signs of inflammation. This range has particular diagnostic value in sports practice, as it allows detection of early signs of adaptive mechanism disruption, especially in the pre-competition period.

Values in the range of **81—95** relative units (red) indicate a subacute inflammatory process, where cellular structures are already involved in a pathological continuum, although the intensity of reactions remains lower than in the acute phase. In athletic contexts, such parameters may point to incomplete recovery and persistent functional overstrain.

Values between **96—110** relative units (brown) reflect an acute inflammatory process accompanied by pronounced activation of metabolic and immune responses at the cellular level. These indicators signify the maximal strain of adaptive mechanisms and a high risk of homeostatic destabilization.

Values of **B** below the normal corridor (**10—49** relative units) indicate a decline in functional activity of cellular structures and suppression of metabolic processes. Such changes are characteristic of chronic and degenerative states, accompanied by membrane integrity disruption, reduction of tissue energy potential, and weakening of regulatory mechanisms.

The **35—49** relative unit range (light green) corresponds to a chronic inflammatory process and early manifestations of cellular dystrophy. In sports medicine, such indicators are interpreted as signs of delayed recovery and reduced load tolerance, requiring adjustment of training and rehabilitation regimes.

Values within the **20—34** relative unit range (blue) reflect progressive dystrophy, in which cellular structures lose the capacity to sustain adequate metabolic activity. For athletes, this

TABLE 4 — **Reactive (B) component of CC and its correlation with physiological states**

B values (relative units)	Color code	Physiological state
96–110	Brown	Acute inflammatory process
81–95	Red	Subacute inflammatory process
66–80	Violet	Prepathological state, physiological strain
57–65	Green	Normal physiological state (normal corridor)
35–49	Light green	Chronic inflammation, early dystrophy
20–34	Blue	Progressive dystrophy
10–19	Grey	Degeneration, atrophy

represents a serious indicator of depletion of adaptive reserves.

Values in the **10—19** relative unit range (grey) characterize processes of degeneration and atrophy of cellular structures, reflecting a critical decrease in functional activity of an organ or system and requiring immediate corrective measures.

Thus, the reactive component **B** of the CC serves as a fundamental integrative criterion for evaluating the functional state of the organism. It enables detection of both early stages of physiological strain and adaptive dysfunction, as well as deep destructive processes beyond the detection limits of standard express-diagnostic methods.

Correlation of the Active Component of Complex Conductance with Autonomic Regulation. BEP-diagnostics evaluates the functional state of the organism through the parameters of the active component **G** of the CC measured at the BAPs of 20 MFS. Table 5 establishes the correlation between **G** values (ranging from **10** to **100** relative units) and autonomic regulation, which is critical for monitoring athlete adaptation during the pre-competition period. The active component **G**, reflecting the conductance of extracellular fluids, is sensitive to humoral changes such as ionic composition and blood flow, and complements the reactive component **B**, which characterizes the state of cellular membranes.

Values of the active component **G** above 70 relative units reflect varying degrees of activation of the sympathetic branch of the ANS and are of primary importance for assessing the adaptive status of athletes.

Normergia-values within **71—80** relative units (violet)-corresponds to physiological sympathicotonia optimally aligned with the training process. This state indicates mobilization of functional reserves without signs of overstrain and serves as a marker of an adequate adaptive response of the organism to physical load. In athletes, this level of regulation signifies high readiness for intense performance and balanced functioning of the sympathoadrenal system.

Hyperergia-values ranging from **81—90** relative units (red)-denotes increased sympathicotonia and significant mobilization of functional reserves. In the short term, this may represent an adaptive response to intensive training or stress exposure. However, its persistent presence indicates a high level of regulatory strain and limited recovery capacity.

Extreme hyperergia-values within **91—100** relative units (brown)-reflects pronounced sympathicotonia and hyperactivation, characteristic of pathological stress, overtraining, or early stages of maladaptation. Under these conditions, the risk of sympathoadrenal exhaustion increases, potentially leading to homeostatic disruption, reduced load tolerance, and a higher likelihood of functional disorders.

Thus, **G** values above 70 relative units mark a transition from physiological mobilization to regulatory overload. Their dynamic assessment in combination with the reactive component **B** provides an objective basis for identifying the balance between adaptation and the onset of maladaptive states. The use of color coding facilitates data interpretation, while integrated analysis of **G** and **B** offers a holistic view of the athlete's functional condition.

Values of the active component **G** below 55 relative units indicate decreased activity of the sympathetic branch and a shift in autonomic balance toward vagotonia, which in athletic practice reflects different degrees of depletion of adaptive resources.

Hypoergia-values between **43—54** relative units (light green)-corresponds to moderate vagotonia and is characterized by reduced functional activity of the sympathoadrenal system. This condition

TABLE 5 — **Correlation between the active (G) component of CC and autonomic regulation**

G values (relative units)	Color code	Autonomic regulation
91–100	Brown	Extreme hyperergia (marked sympathicotonia)
81–90	Red	Hyperergia (increased sympathicotonia)
71–80	Violet	Normergia (physiological sympathicotonia)
55–70	Green	Eutonia (autonomic balance, normal corridor)
43–54	Light green	Hypoergia (enhanced vagotonia)
30–42	Blue	Pronounced hypoergia (pronounced vagotonia, sympathoadrenal depletion)
10–29	Grey	Anergy (protective inhibition)

may develop due to insufficient recovery after exertion or pre-competition energy deficiency. In the short term, moderate vagotonia may serve a compensatory function, but its persistence indicates declining adaptive reserves.

Pronounced hypoergia-values ranging from **30—42** relative units (blue)-reflects marked vagotonia and indicates exhaustion of the sympathoadrenal system. This state is associated with chronic fatigue, reduced stress tolerance, and impaired ability to adequately mobilize resources. In athletes, it manifests as diminished endurance, prolonged recovery, and increased risk of functional disturbances.

Anergy-values between **10—29** relative units (grey)-characterizes a state of protective inhibition associated with profound energy deficiency and critically low activity of autonomic regulatory mechanisms. Anergy represents a critical level of reduced adaptive potential and corresponds to the phase of maladaptive decompensation, where continuation of training loads entails a high risk of pathological outcomes.

Hence, **G** values below 55 relative units reflect a progressive decline in the organism's adaptive capacity-from moderate functional deficit to critical maladaptation. Their timely detection using BEP-diagnostics provides a basis for preventing overtraining and for rational adjustment of training and recovery programs.

Devices for MMW Acupuncture Therapy and Their Capabilities. Over the past decades, a distinct class of medical devices has emerged that are designed to deliver low-intensity MMW exposure to skin projections of internal organs, Zakharyin—Ged zones and BAP. These devices were initially developed as instruments of reflexotherapy using MMW radiation; however, they are now regarded as part of a broader spectrum of non-invasive biophysical technologies aimed at personalized correction of the organism's regulatory and adaptive circuits.

The basic requirements for medical MMW equipment include strict limitation of power flux density (at the level of single mW/cmI), stable generation of fixed biologically active resonant frequencies, and the ability to finely adjust amplitude and frequency modulation parameters. Spectral control of the signal is also essential: the modulation bandwidth should be no narrower than the width of the biologically active resonant frequency, and the operating frequency range should be confined to a narrow interval around the target resonant values.

From a clinical standpoint, the equipment must provide the ability to act on various body zones functionally linked to internal organs and MFS, including BAP, Zakharyin—Ged zones, skin projections of visceral organs and regions of large joints. This enables both local and systemic MMW acupuncture protocols tailored to the patient's specific morphofunctional profile. An important task is also to ensure ergonomics and reproducibility of procedures: stable positioning of emitters, convenient fixation of MMW modules on the skin surface, standardized exposure modes and the ability to document the parameters of each session.

The current stage of MMW device development is characterized by trends toward miniaturization of generator modules, increased automation of control, integration of the entire MMW unit with autonomous power supply into a single housing, and expansion of the number of independent treatment channels. Whereas earlier devices were generally single-channel and focused on pointwise exposure, newer systems implement multichannel architectures with the capability for simultaneous stimulation of multiple BAP, organ projections and zones. This reflects a shift from purely quantitative improvements (power, frequency stability, convenience) to a qualitative change in the principles by which MMW exposure to the organism is organized.

In this context, it becomes essential to address not only the physical parameters of the MMW signal, but also its informational significance within the framework of the organism's MFM. It is necessary to consider how spectral characteristics, modulation mode, spatiotemporal structure of exposure and mapping of application zones relate to the topology of MFS, their resonant properties and their role in systemic regulation. At this stage, engineering decisions regarding the architecture of MMW devices begin to directly determine their potential as instruments of systemic neuromodulation rather than merely local physiotherapy.

The Cell as an Electromagnetically Sensitive System: Homeostasis, Membranes, and Biophysical Mechanisms of Regulation. Homeostasis is a dynamic equilibrium of the physicochemical parameters of the body's internal environment [9; 45]. Through negative feedback

mechanisms — neural, hormonal, and immune — the organism maintains stability under changing conditions. Contemporary studies expand this concept to include electromagnetic homeostasis, which refers to the maintenance of electrical and magnetic parameters at the molecular, cellular, tissue, and systemic levels [46; 47].

Living organisms are open non-equilibrium systems requiring external energy input. Biochemical reactions accompanied by photon transfer generate electromagnetic information at the subatomic level — from dipole oscillations of cell membranes in the millimeter-wave and terahertz ranges to optical emissions in the visible and near-UV spectra produced by cells [48; 49]. External EMFs act upon this system by modulating its electromagnetic equilibrium. Changes in the dielectric properties and conductivity of cells lead to shifts in biochemistry and functional activity. Electromagnetic homeostasis perceives external information and transmits it through resonant interactions across different levels of biological organization [50].

The physical mechanism of EMF influence involves the absorption of energy quanta, which facilitates the enhancement of physiological processes. Cells can accumulate and emit coherent EMFs: signals corresponding to healthy states exhibit high order, whereas pathological states are marked by its disruption [51]. Centrosomes function as infrared receptors capable of detecting external signals. Under such stimulation, cells form elongated extensions oriented toward sources of infrared radiation [52].

Low-intensity MMW exposure at BAPs interacts with cellular membranes, inducing changes in their vibrational activity (Frohlich effect) that promote the recovery of cellular functional activity [49; 53]. Membranes respond to the spectral components of external EMFs by converting them into biophysical signals: resonant frequencies induce modifications in the oscillatory dynamics of protein structures [49; 53]. Biochemical reactions are accompanied by electromagnetic emission, forming electromagnetic "pathways" within the organism.

Cellular structures represent multifunctional modules uniquely capable of perceiving, processing, and transmitting electrical, biophysical, and biochemical information, thereby ensuring integrative system functioning [50]. The biophysical and radiophysical aspects of cellular functioning provide the foundation for understanding electromagnetic homeostasis — the ability of the organism to maintain a balance of complex electromagnetic interactions within its external electromagnetic environment [50]. Biological aspects encompass cellular heredity and reproduction, mechanisms that support genetic information transfer and tissue renewal [54]. These processes maintain the structural and functional integrity of the organism, particularly under the intense physical loads typical for athletes [55].

Biophysical aspects include the physical mechanisms underlying cellular activity, such as membrane potential, which regulates electrical activity; ion transport, which supports signaling and metabolic processes; mechanical motility; and optical properties — for example, light absorption and scattering — that determine cellular interaction with electromagnetic radiation [56]. The membrane potential (the difference in electric charge across the cell membrane, typically −70 mV in neurons) plays a central role in signal transmission. Variations in this potential, caused by ionic fluxes (Na^+, K^+, Cal^+), ensure neuronal excitability and muscle contraction [9].

Radiophysical aspects view BAPs as electromagnetic wave receptors capable of receiving and conducting signals in the millimeter range (30–300 GHz) through corresponding MFSs. These fields are modulated depending on organ functional status, influencing biochemical processes and sustaining homeostatic mechanisms. The electromagnetic homeostasis system interacts with neural, immune, and hormonal regulatory systems through resonant effects [47].

According to current understanding, low-intensity MMW effects on BAPs [53] are primarily realized at the skin–neurovascular interface. Due to the superficial nature of MMW absorption, which does not exceed 500 μm [53; 56], key processes include modulation of free nerve endings and unmyelinated C-fibers [9], neuropeptide release, local microcirculatory shifts, activation of endothelium-dependent relaxation (NO) [9], and the formation of directed viscero-somatic reflexes [9; 45]. At the cellular level, attention is focused on alterations in the physical properties of the membrane hydration layer and ion exchange [46], with potential involvement of ion channel transducers (e.g., TRP channels) [57], regarded as a primary pathway for weak external signal detection. Collectively, this cascade of events spans

stages from local cutaneous sensory modulation, through neurovascular and immune responses, to complex systemic regulatory changes [9; 45; 46].

A particularly important component of these mechanisms involves membrane proteins, considered potential primary receptors of MMW radiation [53]. Due to their high sensitivity to local electrostatic fluctuations [49], protein macromolecules can undergo conformational changes even under extremely weak electromagnetic fields [50; 53]. These modifications dynamically restructure their functions — from ion transport to activation of enzymatic and signaling systems [50; 53]. Such conformational transitions induced by MMW exposure fundamentally alter ionic currents (Cal^+, Na^+, K^+), affect calcium channel activity, and trigger key intracellular signaling cascades [53; 58].

An equally significant MMW effect concerns membrane structure and interfacial processes. MMW irradiation increases plasma membrane permeability through fine modulation of lipid layers, changes in the structure of associated water, and alterations in lipid domain dynamics [59]. This leads to a profound reorganization of interactions among proteins, lipids, and water, thereby facilitating or impeding passive ion transport across membranes and regulating the initiation or suppression of intracellular signaling pathways, including secondary messenger translocation (e.g., Cal^+, cAMP) [59].

The interplay between protein and membrane mechanisms forms a unified platform of biophysical transformations in which initial electrophysical and structural rearrangements at the molecular level unfold into a cascade of rapid biochemical and cellular reactions. Importantly, all these processes occur without significant thermal tissue damage, which defines both the specificity and high biological significance of low-intensity MMW radiation effects on the human organism.

Thus, the biophysical sensitivity of cell membranes and skin—neurovascular interfaces to weak MMW signals imposes fundamental requirements not only for radiation parameters but also for the architecture of devices that implement multipoint and spatiotemporally coordinated exposures — a topic addressed in the following section.

Architecture and Engineering Features of Multichannel MMW Devices. The transition from single-channel to multichannel MMW devices is primarily driven by the need to act simultaneously on several anatomically and functionally distinct body zones under predefined conditions. This requires a device architecture fundamentally different from classical single-point generators: multiple independent radiation channels must be organized within the same frequency range, with the possibility of individually adjusting parameters for each line.

From an engineering perspective, a multichannel MMW device is a modular system comprising a central unit for signal generation and control, a distribution module that routes the radiation to individual channels, and a set of external MMW emitters. The central unit ensures stabilization of frequency and power, formation of specified amplitude and frequency modulation modes, and temporal synchronization of channels. The distribution module allows independent configuration of the number of channels, their intensity and operating mode, thereby providing a basis for flexible programming of MMW acupuncture therapy session schemes.

External generator MMW modules of two main types-“point” and “horn”-play a key role. Point-type modules have a small exposure area (on the order of 0.25 cml) and are intended for targeted stimulation of BAP in strictly localized regions. Horn-type modules act on a larger zone (approximately 7 cml) and are used to irradiate skin projections of organs, Zakharyin—Ged zones and regions of large joints. This combination allows a single device to implement both pointwise and zonal MMW acupuncture modes without changing the basic hardware configuration.

The architecture of multichannel systems of the “RAMED-EXPERT” series illustrates the practical implementation of these principles [2, 19]. These devices provide up to 12 independent channels: eight channels for BAP and four for skin projections of organs. Paired zones are addressed using two point-type modules, which ensures symmetrical placement of emitters, whereas for organ projections a single horn-type module per target zone is sufficient. This configuration simplifies the selection of emitter placement schemes and facilitates the standardization of treatment protocols.

Operational experience and the results of technical and clinical testing indicate that multichannel architecture increases the efficiency of MMW equipment by enabling multipoint exposure schemes within a single procedure. Various device modifications (e.g., “RAMED-EXPERT—09”

and "RAMED-EXPERT–12") demonstrate an evolution from simpler configurations toward instruments with an extended number of channels and more advanced control systems, which broadens the range of clinical applications and simplifies the integration of MMW therapy into standard diagnostic and treatment pathways. The visual representation of design solutions (Figures 7–10) reflects the main variants of generator block and external MMW emitter layouts, as well as the evolution from simpler to more complex multichannel MMW configurations. This not only describes the technical characteristics of the devices, but also establishes a common language for developing and comparing MMW acupuncture therapy protocols in clinical practice.

Figures 7–10 present various models of devices for MMW acupuncture therapy.

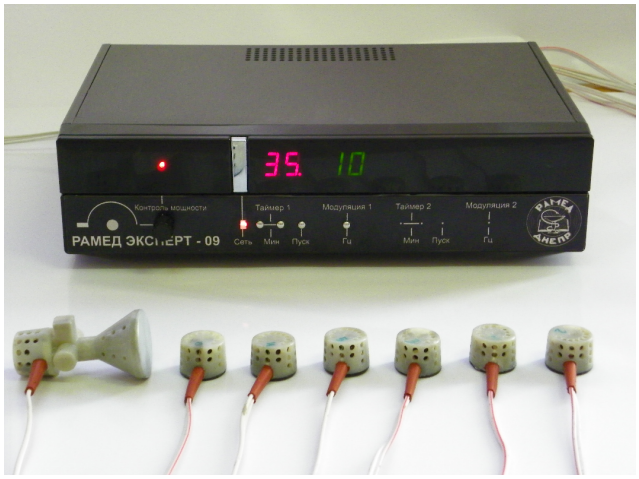

Fig. 7. Unit for EHF-SLI-puncture therapy "RAMED EXPERT – B – 07"

Fig. 8. Unit for EHF-SLI-puncture therapy "RAMED-EXPERT – B – 12"

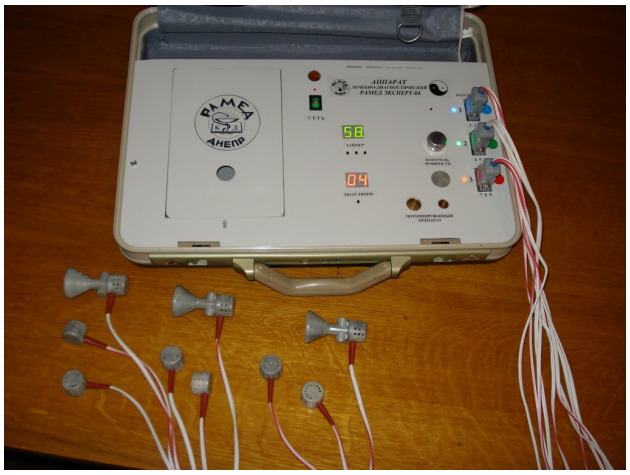

Fig. 9. Unit for EHF-SLI-puncture therapy "RAMED-EXPERT – 09"

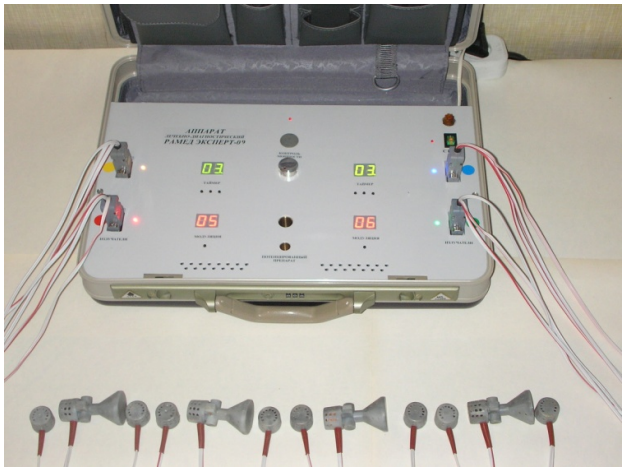

Fig. 10. Unit for EHF-SLI-puncture therapy "RAMED-EXPERT – 12"

Multichannel Low-Intensity MMW Exposure at BAP as an Instrument of Systemic Regulation. Low-intensity MMW exposure at BAP at biologically active resonant frequencies has traditionally been implemented as pointwise, single-frequency stimulation primarily aimed at local effects such as analgesia, anti-inflammatory action and improvement of microcirculation. Within the framework of the MFM of the organism, however, this approach is inherently incomplete: a functional disturbance is never confined to a single organ or an isolated MFS, but unfolds as a cascade of changes within integrated neurohumoral and microcirculatory circuits [40; 41]. Each organ is embedded in a network of MFS interconnected via innervation, lymphatic drainage, blood flow and shared regulatory systems (CNS, ANS, endocrine and immune systems).

Consequently, purposeful modification of adaptive responses requires simultaneous targeted action on several interrelated MFS rather than on a single BAP or a single organ projection.

Experimental data on the effects of electromagnetic radiation on organogenesis, obtained in a series of studies summarized in our monograph [39], are of particular importance in this context. These investigations demonstrated that controlled exposure to low-intensity electromagnetic fields can modify critical stages in the formation and differentiation of organ primordia, including the vascular bed, nervous system and endocrine system, without inducing gross morphological damage [39; 41]. Such findings conceptually support the view of MFS as regulatory modules sensitive to biophysical stimuli and provide a logical rationale for the use of low-intensity MMW signals for selective neuromodulation and correction of adaptive circuits in the adult organism [40].

From this perspective, next-generation multichannel MMW systems of the "RAMED-EXPERT" series differ fundamentally from classical single-channel devices. These multichannel MMW acupuncture units provide synchronous stimulation of a set of BAP together with one of the active zones (Zakharyin—Ged zones, organ projections, large joints), thereby simultaneously engaging several regulatory "nodes" such as the MFS of the heart (**C**), vessels (**Mc**), lymphatic drainage (**Ly**), and the neuroendocrine cluster (**Nd—Tr**), among others. In terms of the MFM, this means that during a single session several regulatory circuits are activated and coordinated, each represented by at least a pair consisting of a BAP and the corresponding organ projection, with subsequent redistribution of functional load among them. This multidimensional mode of exposure is much closer to physiological schemes of systemic regulation, in which any local function is maintained by the concerted operation of neural, endocrine, immune and vascular MFS [42].

The key biophysical rationale for the multichannel approach rests on the concept of biological membranes and MFS as multiresonant adaptive filters in the MMW range [43; 44]. Contemporary data indicate that membranes and associated protein complexes exhibit a frequency-selective response to electromagnetic fields in the gigahertz range, accompanied by changes in ion channel activity and transmembrane processes [41; 43; 44]. In this analogy, each BAP representation of an MFS acts as the input to a high-Q filter whose parameters (Q-factor, set of modes, excitation threshold) depend on the current morphofunctional state, which is consistent with the notion of resonant sensitivity of membranous structures to low-intensity MMW exposure [43; 44].

Single-channel MMW exposure, even when precisely tuned in frequency, inevitably runs the risk of missing the individual resonance spectrum of a given patient or activating only a fragment of the relevant regulatory subnet. In contrast, multichannel exposure-both in space (simultaneous stimulation of several BAP corresponding to different MFS) and in frequency (several narrowly tuned channels or adaptive scanning around the biologically active resonant frequency)-is inherently better aligned with the multiresonant nature of membranes and enables more refined, selective neuromodulation within an entire cluster of MFS [41; 43].

Clinically, this translates into a qualitative shift in the aims and architecture of therapeutic protocols. Whereas single-channel techniques are predominantly focused on alleviating a local symptom or modulating a single dominant function (e.g., pain), multichannel MMW systems implement a strategy of systemic correction of adaptive circuits [40—42]. Concurrent stimulation of the MFS of a target organ and its regulatory "envelope" (innervation, microcirculation, lymphatic drainage) makes it possible not only to reduce local strain but also to restore disrupted connections within the MFS network. Acting on several interconnected MFS (for example, **C—Mc—P—Ly** or **Nd—Tr—Ly—C**) provides synchronous correction of the cardiorespiratory, vascular, lymphatic and neuroendocrine components, thereby accelerating the transition from a state of decompensation to a stable functional equilibrium [41]. The possibility of individually selecting combinations of BAP and frequencies opens the way to "calibrated" treatment schemes tailored to the patient's morphofunctional profile as determined by BEP-diagnostics and clinical assessment [41; 42].

A representative example is provided by multichannel systems of the "RAMED-EXPERT-12" type [2; 19], which allow simultaneous action on four MFS and, accordingly, on four coordinating circuits. In this mode, MMW therapy ceases to be a local physiotherapeutic procedure and becomes an instrument of controlled adaptation: in real time, functional load can be redistributed between

regulatory circuits, overloaded links (for example, lymphatic or neuroendocrine) can be selectively unloaded, and less active segments of the respective circuits can be reinforced. From the standpoint of the MFM of the organism, this corresponds to a transition from a state of chaotic, decentralized compensation to a more ordered, energetically economical regime with an increased adaptive reserve.

The most promising direction for further development of multichannel low-intensity MMW exposure at BAP is its integration into a closed-loop "model–diagnostics–intervention–reassessment" framework, in which:

– the MFM of the organism defines the map of MFS and their interconnections;

– BEP-diagnostics provides a quantitative assessment of MFS tension and reactivity (via **G** and **B** parameters at BAP); multichannel MMW intervention implements targeted correction of a selected mini-cluster of MFS;

– repeated BEP assessment documents the degree of restored connectivity and reduction of adaptive strain [41].

In this configuration, multichannel MMW systems function not merely as tools for "enhancing the reserves" of individual MFS, but as key functional modules of systemic neuromodulation that support a shift from symptomatic treatment to active management of homeostasis and functional stability of the organism [41; 42].

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