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Review of Domestic Inventions on Methods for Diagnostics of Postural Disorders of the Musculoskeletal System

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ABSTRACT

The development of the musculoskeletal system depends on many components of anatomically determined changes in the body, the structure of movement patterns and the mechanisms of action involved in it. Postural disorders can arise as a result of various reasons and be a source of further changes in the body, influencing the development of compensatory changes and functional transformations of the motor sphere. Diagnosis of the state of the musculoskeletal system is an urgent task, through which many somatic changes can be corrected or compensated in a timely manner.

This article reviews patent documents from databases such as FIPS, Orbit, Google patents over the past 30 years. It was revealed that the study of postural disorders is carried out in four areas of study: visual assessment in a standing position; diagnostic methods using stabilometric platforms; characteristics of disturbances in the assessment of muscle electrical potentials and analysis of the kinematics of motor actions during movement. In their content aspect, these diagnostic methods are focused on the quantitative and qualitative characteristics of the location of the boundaries of the regions of bone segments, the center of gravity of the body and the parameters of its movement during motor action; assessment of electromyographic indicators of coordination of muscle efforts in static and dynamic positions; analysis of the biomechanics of movement patterns with consideration of various components of the motor act.

Keywords: musculoskeletal system; postural disorders; diagnostic methods; biomechanics of motor action.

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Обзор отечественных изобретений по способам диагностики постуральных нарушений опорно-двигательного аппарата

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АННОТАЦИЯ

Развитие опорно-двигательного аппарата зависит от многих компонентов анатомически обусловленных изменений организма, структуры паттернов движения и участвующих в нём механизмов действия. Постуральные нарушения могут возникнуть вследствие разных причин и быть источником дальнейших перестроек организма, влиять на развитие компенсаторных изменений и функциональных преобразований двигательной сферы. Диагностика состояния опорно-двигательного аппарата является актуальной задачей, посредством которой многие соматические изменения могут быть своевременно скорректированы или скомпенсированы.

В статье проводится обзор патентных документов из таких баз данных, как ФИПС, Orbit, Google patents, за последние 30 лет. Выявлено, что исследование постуральных нарушений проводится по четырём сферам: визуальная оценка в положении стоя; методы диагностики с применением стабилометрических платформ; характеристика нарушений при оценке электрических потенциалов мышц; анализ кинематики двигательных действий при перемещении. В своём содержательном аспекте данные способы диагностики ориентированы на количественную и качественную характеристику расположения границ регионов костных сегментов, центра тяжести организма и параметров его перемещения во время двигательного действия; оценку электромиографических показателей координации мышечных усилий в статическом и динамическом положениях; анализ биомеханики паттернов движения с рассмотрением различных компонентов двигательного акта.

Ключевые слова: опорно-двигательный аппарат; постуральные нарушения; способы диагностики; биомеханика двигательного действия.

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关于诊断姿势障碍的国内发明方法的综述

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摘要

背景：运动系统的发展取决于许多与身体解剖结构相关的变化、运动模式的结构以及参与其中的动作机制。姿势障碍可能由于多种原因引发，并可能成为进一步身体重塑的因素，影响代偿性变化和运动功能的转变。诊断运动系统的状态是一项重要任务，通过这种方式可以及时调整或补偿许多体质性变化。

研究内容：本文综述了过去30年来来自FIPS、Orbit和Google专利等数据库中的专利文献。研究发现，姿势障碍的研究分为四个方面：站立姿势的视觉评估；使用稳定性测量平台的诊断方法；通过评估肌肉电位特征来分析障碍；以及在移动时对运动动作的运动学分析。这些诊断方法主要集中在对骨骼段区域边界的定量和定性特征分析、身体重心的定位及其运动参数的分析；对静态和动态状态下肌电指标的评估；以及通过分析运动模式的生物力学，包括对动作不同组成部分的详细分析。

关键词：运动系统；姿势障碍；诊断方法；运动生物力学。

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INTRODUCTION

Postural disorders are mainly characterized by the person's postural balance, its change during motor actions, and a change in the position of the center of gravity, i.e. the point of intersection of the resultant force of all gravitational forces acting on individual parts of the body.

Any developmental changes (skeletal disorders, asymmetrical muscle function, functional failures) will entail a change in the center of gravity and functional musculoskeletal disorders. Timely diagnosis of musculoskeletal conditions, biomechanics of motor actions performed by a person, is an urgent task as it allows to identify an information resource for further, more targeted rehabilitation and management and to predict compensation mechanisms for impaired functions with more health benefits.

POSTURAL DISORDER RESEARCH AREAS

Over the past 30 years, analysis of patent documents from databases, such as FIPS, Orbit, and Google patents, has revealed that the basic diagnostic methods for postural disorders, in addition to the well-known methods (radiography and podography), may be provisionally divided into four assessment areas:

- Visual assessment in a standing position;
- Diagnostic methods involving stabilometric force platforms;
- Disorder diagnosis by assessing electrical potentials of muscles;
- Analysis of motor kinematics during movement.

Diagnostic methods that involve visual assessment in a standing position provide deep insights into the very nature of balance, which is always dynamic. The combined center of gravity is constantly fluctuating with major changes in all activities performed, even in a static position. With a functionally weak segment, the counterbalancing of bone levers by involving the muscular system occurs with disorders, leading to postural changes, adjustments, and compensatory adaptation of the musculoskeletal system.

Thus, Vasilieva et al. developed a diagnostic method for static disorders in patients with chronic muscle pain by visually analyzing the relative position of the spine and limbs regional boundaries. It was found that by drawing horizontal lines in the frontal, sagittal, and transverse planes through the combined and regional centers of gravity (perpendiculars), it is possible to compare the projections of the combined and regional centers of gravity on the bearing area of the feet and its bias in other regions relative to reference values [1]. This method allows to assess the projection bias degree of the centers of gravity in individual spine and limbs regions, which, in turn, determines the pathobiomechanical condition of the muscles and identifies functional changes.

Another local diagnostic method for postural disorders developed by Goshkoderya et al. [2] analyzes the projection of the regional boundaries of musculoskeletal segments and involves application of reference points of the regional boundaries on the body of the patient, who is placed in the center of a horizontal base platform with plumb lines. Two front and rear view photographs are taken in the frontal projection; and two right and left view photographs are taken in the sagittal projection. After that, the sum of angular deviation of parallel horizontal lines from the lines of spine regional boundaries are graphically processed and analyzed, thereby diagnosing posture disorders.

Vasilevich et al. [3] developed a screening method for musculoskeletal disorders involving image analysis by 3D scanning of digital images in various planes, in the position of flexion, backbend, tilt, and rotation of the trunk and limbs regions to calculate the absolute dimensions of the body, its regions, compare them with reference values, and identify disorders.

Kolyagin [4] proposes to overlay images of a patient with postural disorders and a healthy person with the same somatometric parameters at the same shooting angles using a software processing images taken on a rotating platform with a system used to stabilize the platform's rotation angles.

In considering the issue of balance, many researchers independently highlight the importance of core muscles in maintaining postural balance [5–8], locomotor functions, and the overall stabilization of the body to ensure vertical stability of a person and harmonious movement. This opinion is based on the anatomical location of the muscles in the middle part of the musculoskeletal system and importance of their functions during movement.

In studies of dynamic body dysfunctions, such as Wallden's [9, 10] middle crossed syndrome and Myers' [11] spiral myofascial line disorder, lateralization failures in the control of motor actions definitely occur with the involvement of the core muscles. Often, it is this area that becomes a cause of muscular pain and further structural changes in the body and local diagnostic inventions for this segment are of special importance.

Mikhailov et al. [12] developed a diagnostic method for non-specific muscle pain in the lumbar spine involving visual and palpatory diagnosis of the static and dynamic components of stereotypical motor movements. When muscle hypertension and pain irradiation is detected, the cause of muscle pain is identified.

The diagnostic method for postural imbalance by recording the moire pattern of the back surface sequentially in six periods of transferring body weight to each of the lower limbs from a two-point standing position on scales was developed in 1997 [13]. Based on a series of topograms, graphs of movements in three planes are built subsequently assessing the degree of the body axis bias, including with the body axis shifted in the opposite direction of the supporting limb, emphasizing that the key factor of this adaptation are

muscles of the pelvic girdle, where the body center of gravity is found.

However, if we move slightly away from visual representations, the most extensive area of research on the bias of the center of gravity and the corresponding movement disorders is stabilometry [14, 15]. Quite a few researchers use stabilometric values to develop diagnostic methods for postural disorders to characterize the state of human balance and equilibrium.

For example, Davydov et al. [16] determine the dynamic characteristics of movement and the motion paths of the center of gravity along the plane of the platform to calculate the angular velocity of movement, characterizing the process of maintaining balance by the patient, by comparing the obtained data with reference values.

Kondratyev et al. [17] add biological feedback to the test to develop a polystructural diagnostic method. The method involves an analysis of movement (postures) of varying degrees of complexity for the action performed, where each of them is tested for 20 s with open eyes at the first stage; for 20 s with closed eyes at the second stage; and at the third stage, the individual is asked to minimize the body vibrations using a visual biological connection. Then, the motion path of the center of pressure is examined using vector analysis of the resulting statokinesiogram.

An interesting proposal has been put forward by Istomina et al. [18] to use stabilometry and electromyography, in particular, with electromyogram of the gastrocnemius muscles important for maintaining an upright position, together in a combined diagnostic method.

In general, electromyograms are informative and many use them to develop local diagnostic methods for individual segments. Thus, Ryzhkov et al. [19] developed a method to assess the coordination of bioelectrical activity of paravertebral muscles. Nebozhin et al. [20] assess the severity of biomechanical disorders in the cervical spine using movements in the loading phase with muscle resistance. Zoikin et al. [21] use electromyography for the functional diagnostics of the knee joint. Vasilieva et al. [22], in their electromyographic diagnostic method for impaired coordination of muscle efforts, propose general diagnostic principles for the muscles of the body using the analysis of the advanced initiation of the studied muscle prior to the agonist/synergists to determine the pathogenetic role of its primary contraction for a relevant therapy.

Muscle efforts are coordinated in any motor act, designed for diagnosis of both positions and a natural pattern of movements, such as walking. The study of various locomotions of the motor act both in parts and as a whole is important for the diagnosis of postural disorders as it allows to understand the influence of static disorders on the movement dynamics and to detect promptly locomotion kinematic disorders for subsequent management.

Velikson et al. [23] developed an assessment method for the quality of walking, where goniometers are installed on the joints of the lower limbs (hip, knee, and ankle) to calculate the maximum range of motion in the joints and the length of a double step during walking. By comparing the obtained values and anthropometric measurements, a degree of walking asymmetry and abnormal movement biomechanics are determined.

For hip joint disorders, an invention proposed by Smirnov et al. [24] assesses walking parameters by recording the maximum acceleration of the spinous process region in the sagittal projection recorded using special reflective markers attached to this region.

Zhivaev et al. [25] used an analyzer of kinematic parameters of human walking invented by them (a device with a metal track, contact sensors for the participant's shoes, a rectangular pulse generator for an infrared emitter attached to the participant's body, and an optical distance meter) to measure the parameters by integrating the measurements from the motion sensors and a photosensitive receiver of infrared pulses recording the participant's movement.

Rulev [26] designed a device to assess and adjust the load on the supporting surface of the foot during walking by sound transformation of the support dynamics and projecting signals of different frequencies and tones depending on the location of the test point on the foot and the correct foot placement relative to a reference step. It allows to get a meaningful idea of an abnormal walking pattern and possible management.

CONCLUSION

Thus, the invented diagnostic devices and methods for postural disorders of the human musculoskeletal system focus on the quantitative and qualitative location parameters of the regional boundaries of bone segments, the body center of gravity, and its movement during motor action; electromyographic assessment of muscle effort coordination; biomechanical analysis of movement patterns based on various elements of the motor act.

An important aspect is a comprehensive assessment of the static and dynamic characteristics of postural disorders, allowing to identify the relationship between primary disorders and accompanying changes in the body, the musculoskeletal restructuring and development of compensation mechanisms, their influence on the development pattern of the human motor system.

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and analysis of literary sources, writing the text and editing the article; K.A. Berdyugin — curation, editing the text of the article.

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