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Postural control in assessing the effectiveness of motor recovery following total hip arthroplasty

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Abstract

Introduction Postural control (PC) is a predictor of gait recovery and can be performed in the early postoperative period following total hip arthroplasty (THA) for adequate appraisal of the treatment and recovery of orthopedic patients. The search for PC markers is practical for relevant evaluation of the effectiveness of motor rehabilitation following THA of one (contralateral) hip or both joints.

The **objective** was to establish specific features of PC assessing effectiveness of motor rehabilitation in patients with hip osteoarthritis after unilateral and bilateral THA.

Material and methods A total of 40 patients with grade III–IV hip osteoarthritis were examined as Group 1 (n = 21) with unilateral THA of the contralateral hip joint and Group 2 (n = 19) with bilateral THA. The PC was assessed using an inertial sensor placed at the L4–L5 projection to record angular and spectral parameters of postural fluctuations from the vertical in the coronal and sagittal axes. Examinations were performed on admission and upon discharge after a course of motor rehabilitation in the inpatient medical rehabilitation department.

Results Improvements in the PC during the inpatient rehabilitation were accompanied by greater deviations in the coronal plane and less deviations in the sagittal plane in the unilateral THA group suggesting frontal instability. There was no increase in frontal axis deviations with sagittal deviations being maintained in the bilateral THA group. Models for predicting the effectiveness of motor recovery were offered.

Discussion Objective indicators of the PC in patients with hip osteoarthritis treated with unilateral or bilateral THA, were obtained with inertial sensor technology and could be used to identify compensatory musculoskeletal mechanisms, determine markers of the effectiveness of rehabilitation and adjust recovery programs.

Conclusion Motor rehabilitation of THA patients suggests that bilateral arthroplasty destabilizes the biomechanics of the hip joint to a lesser extent, limiting excessive deviations in the frontal plane and slows down restoration of statokinetic stability due to proprioceptive insufficiency.

Keywords: postural control, equilibrium balance, hip osteoarthritis, methodology, rehabilitation, hip replacement, Steadis

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INTRODUCTION

Osteoarthritis (OA) is the most common disease of the hip joint, affecting over 4.1 % of the adult population. The increasing number of hip replacement surgeries, coupled with the relative safety, technological advancement, and affordability of the method, makes it the preferred option, with a frequency of 3.3 cases per 10,000 patients treated, and a steady increase in the number of primary and revision surgeries [1, 2].

A steady increase in the incidence of osteoarthritis has been observed, associated with increased life expectancy and physical inactivity [3]. Objective assessment and visualization of functional impairments in patients with HO treated with unilateral or bilateral hip arthroplasty, are challenging in clinical practice. For elderly patients, two-stage hip arthroplasty (6-8 months between surgeries) is preferable in some cases, while unilateral hip arthroplasty (e.g., with aseptic necrosis of the femoral head) can significantly alter gait patterns and the hip joint, necessitating their correction. Gait analysis is an accepted method for assessing functional recovery to allow for a simultaneous evaluation of the function and potential patient activity. The gait test may be difficult early post-op due to pain, functional limitations, and a need for additional support devices in some cases, which may affect accuracy of the results.

Physiological balance of vertical stance, Pediatric Balance Scale (PBS) is a recognized predictor of gait restoration to allow for the assessment of the balance maintenance strategy (physiological "A" or compensatory-adaptive "H"), statokinetic and proprioceptive correction in accordance with clinical recommendations based on objective effectiveness criteria, and the selection of technical rehabilitation aids early post-op [4, 5]. With the algorithms and parameters developed, traditional stabilometry has some limitations and disadvantages. For example, of the external coordinate system adjusted and reset with the feet positioned and strictly centered/at the intermalleolar point, which is often inaccurate (for example, during decompensation and shift of the body's overall center of mass toward the contralateral limb) [6]. Inertial sensor technology, which does not require platform installation, appears more attractive. The validity and appropriateness of information from inertial sensors (designated IMU in foreign literature) were reported in some studies in comparison with the readings of traditional stabilometric platforms [7, 8]. The sensor is capable of distinguishing the three planes of oscillation with a specific frequency [9], and also classifying PBS readings, for example, under the influence of maximum anaerobic fatigue [10], in cerebral palsy in children [11], in the dynamics of stroke [12], depending on the location of application/registration [13]. A method for assessing the PBS using inertial sensors [14] was offered with the normative database being integrated into the automatic “Stadis-Balance” Protocol. The approach to analyzing the amplitude-frequency characteristics of oscillations was adopted by analogy with the author’s method for assessing the extent of stress of compensatory mechanisms in case of knee dysfunction [6].

The **objective** was to establish specific features of postural control assessing effectiveness of motor rehabilitation in patients with hip osteoarthritis after unilateral and bilateral THA.

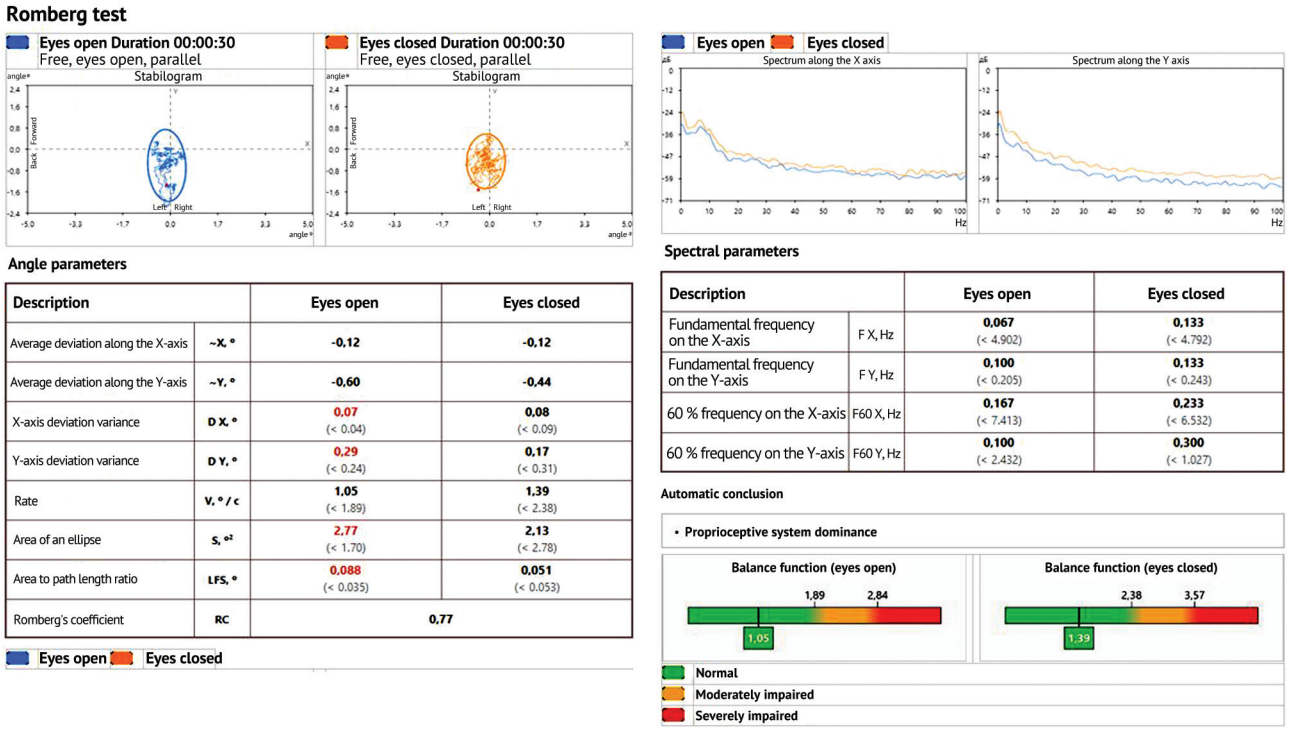
MATERIAL AND METHODS

The study was performed between January and June 2025 in the inpatient medical rehabilitation department of the Ivanovo Regional Hospital for War Veterans. Inertial sensor technology (Neurosens sensor, Neurosoft LLC, Ivanovo, Russia) with Steadis-Balance software (No. RZN 2018/7458 dated July 11, 2022) was used. The sensor was placed in the L4–L5 projection (Fig. 1), the actual center of mass of the human body. The examinations were produced in the Biomechanics laboratory at the same time at a comfortable temperature upon patient admission to the department and

upon discharge. Transient processes were monitored by preliminary monitoring without recording for 1–2 minutes, followed by 30-second recordings with both eyes open and closed (Romberg test). When necessary, support was provided by symmetrical, central unloading (two patients required a walker with a brake lock).

Fig. 1 An example of an inertial sensor installed during a patient examination and balance training using biofeedback

An automatic protocol (Fig. 2) was generated immediately after the examination. The sensor's angular deviations in the lumbosacral spine were recorded in the frontal and sagittal planes (mean deviation and variance in degrees from the vertical; velocity; area; oscillation length and its ratio to the ellipse area; Romberg coefficient as the ratio of the area with the eyes closed to open). Spectral parameters were presented as the prevailing frequency and 60 % of the oscillation frequency power along the axes.



Description		Eyes open	Eyes closed
Average deviation along the X-axis	~X, °	-0,12	-0,12
Average deviation along the Y-axis	~Y, °	-0,60	-0,44
X-axis deviation variance	D X, °	0,07 (< 0.04)	0,08 (< 0.09)
Y-axis deviation variance	D Y, °	0,29 (< 0.24)	0,17 (< 0.31)
Rate	V, ° / c	1,05 (< 1.89)	1,39 (< 2.38)
Area of an ellipse	S, °²	2,77 (< 1.70)	2,13 (< 2.78)
Area to path length ratio	LFS, °	0,088 (< 0.035)	0,051 (< 0.053)
Romberg's coefficient	RC	0,77	

Description		Eyes open	Eyes closed
Fundamental frequency on the X-axis	F X, Hz	0,067 (< 4.902)	0,133 (< 4.792)
Fundamental frequency on the Y-axis	F Y, Hz	0,100 (< 0.205)	0,133 (< 0.243)
60 % frequency on the X-axis	F60 X, Hz	0,167 (< 7.413)	0,233 (< 6.532)
60 % frequency on the Y-axis	F60 Y, Hz	0,100 (< 2.432)	0,300 (< 1.027)

Fig. 2 An example of an automatic protocol for analyzing the PBS

Additionally, the patients' PBS oscillation accelerations were assessed in emulation mode to allow for further identification of up-and-down oscillations in the frontal plane, and criteria for determining the degree of compensatory strain were identified. In addition to the standard Individual Rehabilitation Program, all patients received stabilization training using biofeedback in a game-based environment (7 to 20 minutes, 10 times daily) in accordance with clinical recommendations.

The study included 40 patients with hip arthritis without comorbidities in the decompensation stage, cognitive limitations, diseases of the lumbosacral spine (LSS) and other joints of the lower limbs. The patients were divided into two groups: group 1 (n = 21): patients treated with endoscopic replacement of one hip joint (after the first stage of THA); group 2 (n = 19): patients treated with endoscopic replacement of both hip joints (Table 1). The groups did not differ significantly in gender and age to allow comparison of the findings. Examinations were performed on admission and upon discharge after an inpatient rehabilitation course, which included PBS training using a biofeedback mechanism.

Table 1

Characteristics of the study groups

Description		Group 1 (n = 21)	Group 2 (n = 19)
Males	abs.	10	10
	%	48	53
Average age of men, years		60.10 ± 3.23	53.20 ± 5.76
Females	abs.	11	9
	%	52	47
Average age of females, years		63.18 ± 3.53	69.33 ± 1.86
Purpose of inclusion		Evaluation of the impact of unilateral THA on the BVS in the absence of other THA	Assessing the impact of the transition from unilateral to bilateral THA on the BVS

Purpose of inclusion Evaluation of the impact of unilateral THA on the BVS in the absence of other THA Assessing the impact of the transition from unilateral to bilateral THA on the BVS

Statistical processing of the variables was performed using IBM SPSS Statistics v/23.0. The normality of the distribution of the quantitative data was confirmed using the Shapiro – Wilk test. The significance of differences was assessed using the Student's t-test (for independent and dependent groups), and correlation relationships between parameters were assessed using Spearman's rank correlation. The significance level was taken as $\alpha = 0.05$. The results are presented as (M ± m), where M is the arithmetic mean and m is the standard error of the mean. In the group of frontal deviations, the absolute value was adopted for the X indicator, without considering the side of the involvement.

The study was performed in accordance with ethical principles for medical research involving human subjects stated in the Declaration of Helsinki developed by the World Medical Association of 1964, Federal Law No. 323 "On the Fundamentals of Health Protection of Citizens in the Russian Federation" dated November 21, 2011, Federal Law No. 152 "On Personal Data" dated July 27, 2006.

RESULTS

Oscillations with the inclusion of individual nodes/joints (according to the type of passive closure in flexion contracture) were simulated using the Adams program (Fig. 3). Visual confirmation of highly synchronized oscillations of the spinal ACO and hip joint was obtained with unilateral "closure" with an almost twofold increase in oscillation power (Fig. 3 b, c), and with bilateral "closure" with an increased oscillations in the underlying balance levels (Fig. 3 c, d). A significant

influence of peri- and paraarticular compensation mechanisms on the PBS (with an increase in oscillation power in the frontal plane) was established: correlation analysis using the Spearman criterion showed a significant correlation between the average noticeable and strong high degrees of interrelationship of positive direction (at $p \leqslant 0.05$) according to the Jerk indicators r = 0.64; PWR r = 0.7 and F50 r = 0.70.

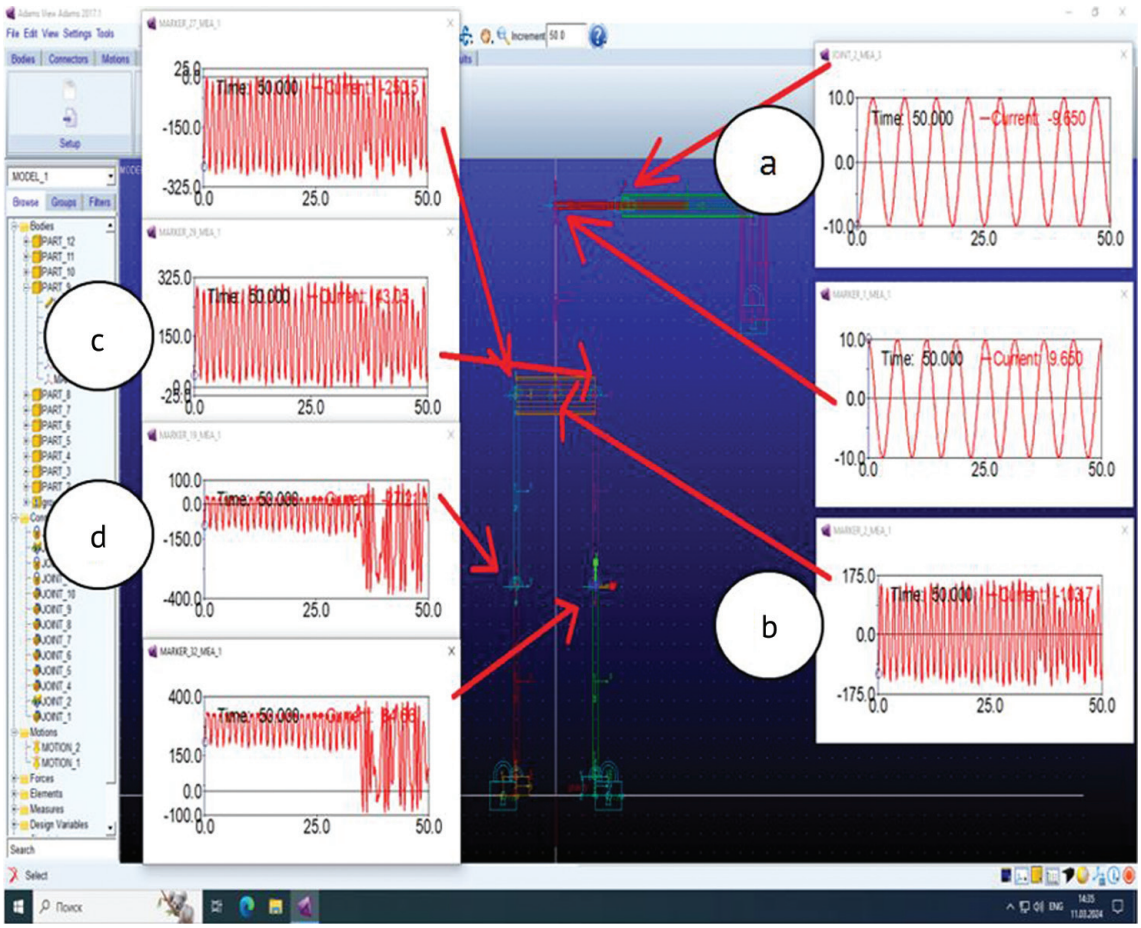


Fig. 3 Modeling of oscillations simulated with the Adams program: (a) deflection/force application node; (b) spectrum of oscillations of central genesis in the lumbosacral spine; (c) spectrum of oscillations in the hip joint; (d) spectrum of oscillations in the knee joint

All indicators of the automatic protocol were analyzed; the results are presented in Table 2.

Visual system predominated in maintaining the PBS in both groups. Clinical condition and motor capabilities improved over the course of medical rehabilitation in a different manner in the two groups, reflecting the restoration of central control of balance through various strategies and synergies.

With all the transformations of the PBS under the influence of rehabilitation, the more pronounced central control of the PBS upon admission reduced its contribution in the group of unilateral THA due to the increased contribution of the so-called “hip strategy” (a significant decrease in the length of the trajectory of oscillations of the angle from the vertical (L, °) with an increased speed of oscillations before/after rehabilitation with open eyes, with an increase of 60 % in the power of oscillations in the sagittal plane when closing the eyes and a decrease in deviations along the Y-axis), in contrast to group 2 without an increase in deviations in the frontal plane X with preservation along the sagittal Y-axis.

Table 2

Vertical stance balance measured with the Romberg test upon admission and after medical rehabilitation (MR), M ± m (n = 40)

	Eyes open (EO)				Eyes closed (EC)				p
	Group 1 (unilateral THA), n = 21		Group 2 (bilateral THA), n = 19		Group 1 (unilateral THA), n = 21		Group 2 (bilateral THA), n = 19		
	on admission	after MR	on admission	after MR	on admission	after MR	on admission	after MR	
	1	2	3	4	5	6	7	8	
RC					2.18 ± 0.62	1.69 ± 0.30	1.85 ± 0.34	1.73 ± 0.39	
~X, º	0.11 ± 0.02	0.08 ± 0.01	0.15 ± 0.03	0.14 ± 0.03	0.11 ± 0.03	0.11 ± 0.2	0.16 ± 0.03	0.16 ± 0.04	
~Y, º	–0.02 ± 0.09	0.07 ± 0.08	–0.01 ± 0.11	0.001 ± 0.09	0.19 ± 0.12	0.18 ± 0.13	–0.18 ± 0.17	0.09 ± 0.16	$p_{7-8} \leqslant 0.001$
D X, º	0.04 ± 0.02	0.01 ± 0.002	0.03 ± 0.005	0.03 ± 0.01	0.05 ± 0.02	0.02 ± 0.002	0.06 ± 0.02	0.03 ± 0.006	$p_{7-8} \leqslant 0.05$
D Y, º	0.13 ± 0.03	0.12 ± 0.03	0.18 ± 0.03	0.23 ± 0.09	0.21 ± 0.04	0.13 ± 0.01	0.27 ± 0.04	0.16 ± 0.02	$p_{7-8} \leqslant 0.05$
L, º	35.02 ± 1.59	38.56 ± 1.17	43.40 ± 3.8	38.61 ± 2.99	45.86 ± 4.06	46.40 ± 3.25	59.94 ± 7.84	48.49 ± 5.09	$p_{1-2} \leqslant 0.05$ $p_{3-4} \leqslant 0.1$ $p_{7-8} \leqslant 0.05$
V, º/c	1.17 ± 0.5	1.29 ± 0.4	1.45 ± 0.1	1.29 ± 0.10	1.53 ± 0.14	1.55 ± 0.11	2.00 ± 0.26	1.62 ± 0.17	$p_{1-2} \leqslant 0.05$ $p_{3-4} \leqslant 0.1$ $p_{7-8} \leqslant 0.05$
S, º²	1.06 ± 0.45	0.63 ± 0.11	1.12 ± 0.19	0.90 ± 0.18	1.46 ± 0.47	0.75 ± 0.09	1.92 ± 0.45	1.02 ± 0.20	$p_{7-8} \leqslant 0.05$
LFS, º	0.02 ± 0.008	0.02 ± 0.002	0.02 ± 0.003	0.02 ± 0.003	0.03 ± 0.007	0.02 ± 0.001	0.03 ± 0.003	0.02 ± 0.002	$p_{7-8} \leqslant 0.05$
F X, Гц	0.56 ± 0.27	0.55 ± 0.27	0.20 ± 0.08	0.08 ± 0.02	1.04 ± 0.49	0.52 ± 0.26	0.17 ± 0.04	0.25 ± 0.11	
F Y, Гц	0.10 ± 0.007	0.12 ± 0.02	0.10 ± 0.02	0.08 ± 0.006	0.11 ± 0.02	0.11 ± 0.02	0.10 ± 0.02	0.11 ± 0.02	
F60 X, Гц	4.05 ± 0.63	3.71 ± 0.41	2.90 ± 0.51	4.15 ± 0.63	3.42 ± 0.59	3.34 ± 0.39	2.70 ± 0.47	2.84 ± 0.59	$p_{3-4} \leqslant 0.05$
F60 Y, Гц	0.25 ± 0.06	0.28 ± 0.05	0.18 ± 0.03	0.17 ± 0.02	0.24 ± 0.04	0.34 ± 0.04	0.23 ± 0.03	0.31 ± 0.03	$p_{5-6} \leqslant 0.1$ $p_{7-8} \leqslant 0.1$

The markers identified suggested an increase in the proprioceptive contribution to statokinetic stability in the A-synergy in the absence of significant correlation strength with the main compensation mechanisms; no signs of a decrease in frontal instability (as measured by (~X, °), the average deviation along the X-axis) were found. In addition, a noticeable direct correlation was found between the change in frontal deviation (~X, °) and the 60 % frequency indicator along the Y-axis (r = 0.52; i.e., an increase in frontal deviation was accompanied by increased frequency power in the sagittal plane), indicating an increase in the contribution of the H-synergy (hip strategy) to statokinetic stability.

With similar responses to motor rehabilitation, the bilateral THA group demonstrated more stable and functionally significant changes, with a trend toward improved statokinetic stability using the energy-efficient "central" approach and an increased contribution of A-synergies to the PBS. More stable functional changes, with physiological deviations predominantly seen in the sagittal plane (ankle, central A-strategy), were observed in the early rehabilitation period in the bilateral THA group due to improved proprioceptive sensitivity (Romberg's test with eyes closed before and after the course of medical rehabilitation, Table 2, columns 8 and 9).

The stress of the compensatory mechanisms with active closure of the hip joint (greater centralization of the hip joint with unchanged oscillation along the X-axis, reliable decreases in the deviations of the deflection angle along both axes, significant decreases in the oscillation length, velocity, and area of the ellipse of the deflection angle) was determined with an increase in the power of oscillation along the sagittal axis. A clinically significant point was the identification of a noticeable strength of correlations between the oscillation along the X-axis (frontal deviations) of the reverse direction with the LFS indicator, the ratio of the oscillation area to the length (r = –0.53) and direct (r = 0.52) with 60 % of the oscillation power along the X-axis, which reflects concordant/decompensatory changes.

All protocol parameters were analyzed in the classification discriminant model by forced inclusion, and if the significance was less than 0.05, the predictors were included in the discriminant model to establish a risk group for a poor prognosis for the success of motor rehabilitation:

— with unilateral THA (group 1) — development of frontal instability (deviation along the X-axis);

— with bilateral THA (group 2) — development of sagittal instability (oscillation velocity).

According to the model, the most significant discriminants were the indicators with open eyes and the Romberg coefficient in unilateral THA: displacement along the X-axis (°) (Xeo — significance 0.009 with Wilks' Lambda 0.695); 60 % of the oscillation power along the Y-axis (°) (60Yeo — significance 0.015 with Wilks' Lambda 0.725); Romberg coefficient (significance 0.063 with Wilks' Lambda 0.829), included in the analysis with a stable trend with an accuracy level of 83.3 %:

$$F1 = -0.894 + 0.199 \times RC - 6.105 \times Xeo + 2.619 \times 60Yeo$$

(centroid for the group with a poor rehabilitation prognosis = 1.575, for the group with a satisfactory prognosis = –0.787).

For bilateral THA, the following indicators were most significant discriminants for eyes closed: the dispersion of oscillations along the Y axis (°) (VSec — significance 0.001 with Wilks' Lambda 0.421); the area of the ellipse of oscillations S (°2) (Sec — significance 0.047 with Wilks' Lambda 0.748); the ratio of the area to the length of oscillations LFS (°) (LFSec — significance 0.027 with Wilks' Lambda 0.698) with an accuracy level of 87.5 %:

$$F1 = -1.802 + 11.677 \times ARec - 0.104 \times Sec - 32.378 \times LfSec$$

(centroid for the group with poor rehabilitation prognosis = –1.316, for the group with satisfactory = +1.24).

Therefore, unilateral THA significantly impacts the biomechanics of the hip joint, necessitating the inclusion of objective methods for monitoring hip joint function in rehabilitation programs, predicting the effectiveness of rehabilitation, and selecting the most effective ones. Bilateral THA has a lesser destabilizing effect on hip joint biomechanics, limiting excessive oscillations in the frontal plane, but it limits the restoration of statokinetic stability due to proprioceptive sensitivity (proprioceptive insufficiency).

DISCUSSION

Innovative treatment methods are introduced into clinical practice, significantly outpacing methods for objective assessment of the results [11–13, 15]. Restoration of the gait and activity is the primary request after THA in most cases [16]. Given the long postoperative period, not only the restoration of gait is required, but also restructuring and retraining the patient needs to learn physiological gait pattern not returning to normal, but compensating changes that have occurred [16–18]. Irreversible changes are a specific challenge that would require objectification and visualization. The multidisciplinary nature of patient care requires accurate numerical results in addition to descriptive results using modern rehabilitation technologies and methods to select their optimal combinations. Traditional clinical and laboratory examination methods addressing issues of anatomical and functional recovery, do not "visualize" a person's ability to function and activity — the targets of modern medical rehabilitation.

Balance function and a person's ability to maintain balance while standing and walking are significant characteristics of a person's overall condition and a predictor of overall motor activity, such as gait quality. The inverted pendulum biomechanical model is often used to simulate balance employing either a single-link or multi-link model depending on the objectives [19–21]. Objective study of the PBS function using instrumented methods has been known since the late 20th and early 21st centuries. A platform with force sensors, which has at various times been

called "posturography," "stabilometry," and "stabilography" is the most common method used [7]. With the algorithms and parameters developed, traditional 2D stabilometry has a number of limitations and disadvantages that are critical for orthopedic patients [6]. The 3D stabilometry technology using inertial/sensor sensors/accelerometers (referred to as IMUs in foreign literature) in clinical practice addresses these issues with PBS automatically provided with an amplitude-frequency spectrum of postural oscillations across the full range of compensatory mechanisms, including higher levels of compensation, that has a role in interpretation in trauma and orthopedic patients. From a biomechanical point of view, the issues of the hierarchy of central and peripheral mechanisms in the implementation of PBS control are still debatable, but most authors are inclined to the leading “central” mechanism of direct control in the presence of “automatic” generation of corrective muscle efforts in response to disturbances in equilibrium, which actualizes the interpretation of equilibrium frequencies [9, 19, 21–23].

For healthy individuals, the human body is modeled as a one-dimensional inverted pendulum, capable of rotating at the ankle joint in the sagittal plane as a single rigid body. In this case, the knee and hip joints are in a closed state, allowing direct measurement of the controlled variable (angular accelerations at the ankle joint) ignoring movements in other joints of the lower limbs. This strategy is called the ankle (A(ankle) strategy), and the mechanisms involved are called ankle synergy. The A-strategy is characterized by a predominant contribution of ankle rotation to the kinematics of movement fro with antigravity restoration of the overall center of mass occurring with "slow" perturbations in the sagittal plane.

When the intact hip joint is locked due to pain, or after THA with the joint flexed, the limb shortens, triggering a cascade of compensatory mechanisms during gait including knee extension, ankle dorsiflexion, limited flexion/extension range of motion in the intact joint, sagittal instability in the lumbosacral spine, etc. For the lumbosacral joint, these changes manifest as a shift in basic balancing movements to the so-called H(hip) strategy. Overall, these movements become more energy-intensive, with the primary load shifting to the gluteal and quadriceps muscles, involving the opposite joint and underlying structures. The need to generate corrective force moments in altered joints and changes in oscillations in each specific case should be considered in terms of the limited high-frequency feedback [20, 21]. For orthopedic patients, the central mechanism is the higher hierarchical level of the spinal PCO and the A-strategy of the PBS, while the peripheral mechanism is additional inclusions of the H-strategy, and their relationships for various diseases require further research. Accelerometric, gyroscopic and magnetometric sensors in IMU systems allow for the simultaneous recording of changes in three mutually perpendicular planes (frontal, horizontal, and sagittal) with a higher frequency than traditional stabilometric platforms, expanding the clinical applications. The reproducibility and stability of IMU parameters using inertial sensor technology have been repeatedly demonstrated in other studies, both in healthy individuals with various developmental and age related characteristics [23, 24], and in patients with mobility impairments [25, 26, 27], cognitive limitations [28–30], and vestibular and neurological diseases [31, 32]. A certain limitation with use of inertial sensor technology is the “accumulation of error” during long-term observations [7, 21], which should be taken into account when limiting the analysis to time and marker (PBS - two samples of 30 seconds).

Lugade et al. [33] reported the importance of identifying frontal and sagittal instability for adequate recovery after THA. The design of the study allowed us to demonstrate that both unilateral and subsequent contralateral THA addressing issues of anatomical restoration, limit and "multilayer" the functional biomechanics of the support moments of standing. Unilateral THA maintaining the central mechanism of balance, high synchronization of oscillations in the hip joint and the lumbar spine, significantly increases the load on the higher hierarchical level of compensation and contributes to the H-strategy and synergy to a greater extent, being more rigid in normalizing the PBS, since it is additionally limited by the altered, diseased joint without THA.

Bilateral THA is less asymmetrical but is more associated with proprioceptive impairment due to the consequences of orthopedic surgery. We found no studies demonstrating the effects of unilateral or bilateral THA on PBS and its changes during motor rehabilitation in the early postoperative period. A number of authors offer variations on the vertical balance test (standing on foam rubber, with arms crossed, etc.), clarifying the mechanisms and extent of proprioceptive impairment in statokinetic stability. The study advances the goal of standardizing the methodology for assessing the hip joint dysfunction for integration into clinical practice. The findings and the identified trends can facilitate objective monitoring and support of the rehabilitation process and improve interdisciplinary care for patients with hip arthritis in the pre- and postoperative periods following two-stage THA.

The study is limited in sample size, preventing the development of a definitive algorithm for the population of patients with hip arthritis. The discriminant analysis revealed significant discriminants, criteria for unilateral and bilateral THA, which encourages further research with a larger sample size, comorbidities to be considered and validation using scale scores for machine learning. Based on the findings and considering the works on the application of inertial sensor technology, the authors of the article suggest that a promising non-invasive, safe and effective method can be used for assessing the balance of equilibrium in a vertical stance to characterize postural control in the dynamics of THA and rehabilitation of patients with hip arthritis.

CONCLUSION

Bilateral THA has a lesser destabilizing effect on hip biomechanics by limiting excessive oscillations in the frontal plane, but it slows the recovery of statokinetic stability due to proprioceptive insufficiency. Contralateral THA has a more significant effect on hip joint biomechanics due to increased frontal instability in the hip PBS strategy.

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Ethical Approval *The study was performed in accordance with generally accepted ethical principles, norms and rules for conducting scientific research.*

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