BIOLOGY

INTERNAL SCHEME OF THE BODY ASSESSMENT IN AN EXPERIMENT WITH ENVIRONMENTAL UNCERTAINTY

[1]*MD, PhD* ***Lukashevich U. A.,***
[2]*PhD* ***Vasuk V.E.,***
[3]*MD, PhD* ***Tarasevich M. I.,***
[1]*MD, PhD* ***Mankevich S. M.,***
[2]*PhD* ***Paramonova N. A.***

[1] *Belarus, Minsk, Belarusian Medical Academy of Post-Graduate Education;*
[2] *Belarus, Minsk, Belarusian National Technical University;*
[3] *Belarus, Minsk, 2-nd Municipal Clinical Hospital*

ARTICLE INFO

Received 29 September 2017
Accepted 18 October 2017
Published 07 November 2017

KEYWORDS

internal scheme of the body, biomechanical blocks of the pelvic region, posturology, biomechanics, locomotor system

ABSTRACT

Aim. The aim of the work was to analyze the influence of various environmental factors forming environmental uncertainty on the nature of the transformation of the "internal scheme of the body".
Materials and methods. For the study, a group of healthy volunteers (n = 90) was selected. The results in this paper are median, 75 and 25 percentiles (Me [UQ / LQ]). The study was conducted in several stages. At the first stage, the criteria for excluding potential participants from the experiment were formed. At the second stage of the study, a video analysis of the main anatomical orientations of the pelvic region in static and dynamic samples was conducted for all participants.
Conclusion. In the course of the study, specific patterns of spatial deviations of biomechanical blocks of the pelvic region were established, triggered by changes in the qualitative and quantitative parameters of the external environment. So, in conditions of static equilibrium, coordination is activated with involvement of the anterior and posterior half-rings of the pelvis (frontal biomechanical blocks); in conditions of dynamic equilibrium, diagonal biomechanical blocks of the pelvic region are activated; in conditions of deprivation of visual afferentation, the compensatory reactions of the lateral semirings of the pelvic region (lateral biomechanical blocks) are formed.

Introduction. The pelvic region (PR) is a key link in ensuring coordination of the entire locomotor system [1, 2]. PR acts as a biomechanical basis for the trunk and upper extremity belt [3, 4]: on the one hand, the variability of the kinematics of the PR determines the movements of the lumbar spine and hip joints; on the other, the spatial position of the PR has a significant effect on the biomechanics of other sections of the locomotor system [5, 6]. Disturbance of mobility in the articulations of the pelvic ring can lead to the development of pathological motor stereotypes. At the same time, the pathobiomechanics of other regions of the locomotor system provokes the development of non-optimal motor stereotypes of PR [7, 8]. The provision of stable biomechanics in the variable environment is a complex time process that always involves a single person-environment system within which the subject dynamically changes his spatial position with the movement of locomotor links within the motor field. The relationship between environmental factors and the subject is primarily lost in the geometric images of the "internal scheme of the body" (ISB) [9, 10] and, subsequently, is determined by the boundaries of the motor field [11, 12]. At the same time, the "ISB" is formed due to the system of sensory synthesis of polymodal afferentation with active-passive deviations of locomotor links within the motor field. In terms of its qualities, the "ISB" is unstable, its stabilization is achieved due to environmental factor-augmentators, and the frequency of changes in states is directly proportional to the level of external unfavorable uncertainty and inversely proportional to the jumps in the qualitative parameters of individual factors [16, 17]. Despite the urgency of evaluating the system of sensory synthesis in practical biomechanics, at present there are no available technologies capable of objectively assessing the "ISB". Thus, the pelvic region, being an element of the locomotor system with complex neurobiomechanical connections with other regions, has an important role in ensuring effective human interaction with the external environment due to the determining influence on the sensory synthesis system and the "internal body scheme".

The aim of the work was to analyze the influence of various environmental factors forming environmental uncertainty on the nature of the transformation of the "ISB".

Materials and methods. For the study, a group of healthy volunteers (n = 90) was selected. The results in this paper are median, 75 and 25 percentiles (Me [UQ / LQ]). The study was conducted in several stages. At the first stage, the criteria for excluding potential participants from the experiment were formed. The criteria for exclusion from the study were: 1. determined visually non-optimal statics of the PR in the frontal and sagittal planes; 2. presence of functional blocks of sacroiliac joints; 3. asymmetry of the pressure of the feet on the supporting surface exceeding 3 kg; 4. restriction of passive joint mobility of the hip joints with a reduction in the movement reserve; 5. absence of pelvic syncopeesis (involuntary movements accompanying other voluntary or passive movements) with active laparoscopic lumbar region.

At the second stage of the study, a video analysis of the main anatomical orientirs of the pelvic region (MAOPR) in static and dynamic samples was conducted for all participants. As a video capture and video detection system, the Qualisys system was used, consisting of 7 infrared cameras and one Oqus video camera located along the perimeter of the research area and connected to a computer, where cameras are set up, data capture and their subsequent processing.

During the measurements, each participant in the study performed a battery of diagnostic tests with the initial position of the main stance, barefoot. Video capture of markers was carried out with a framing frequency of 50 Hz. Test tasks were performed with open and closed gases, on a stable and unstable support. The video capture of each test task lasted for 5 seconds. The eyes of all participants of the study were fixed at a point located at eye level (in tests with open eyes). At the same time, the specificity of the "open-eyed" tests was to regulate the vertical position of the body through the visual system, and the tests "with deprivation of vision" - in maintaining the vertical position of the body through joint-muscle control.

The sequence and numbering of tests was as follows: test number 1 - "regulation of the vertical posture on a stable support with the eyes open in static"; test number 2 - "regulation of vertical posture on a stable support with closed eyes in static"; test number 3 - "regulation of the vertical posture on the unstable support with the eyes open in static"; test number 4 - "regulation of the vertical posture on an unstable support with closed eyes in static"; test number 5 - "regulation of the vertical posture with open eyes on a stable support in dynamics"; test number 6 - "regulation of the vertical posture with closed eyes on a stable support in dynamics"; test number 7 - "regulation of the vertical posture with open eyes on the unstable support in the dynamics"; test number 8 - "regulation of the vertical posture with closed eyes on an unstable support in dynamics".

The following projections of bone formations were used as MAOPR for which special double-sided globetrotting markers with a diameter of 16 mm were glued using double-sided adhesive tape: 1. a1 - left anterior-superior ostium of the ilium; 2. a2 - right anterolateral superiority of the ilium; 3. p1 - left posterior-superior tip of the ilium; 4. p2 - right posterior-superior ostium of the ilium.

When motion capture is complete, the data received is automatically processed in the QTM program. The result of the processing was the 3D model of MAOPR, in which a number of coordinates were presented for each MAO. Calculation of the final indicators was carried out in the Excel software package. The developed algorithm for analyzing the vertical deviations of the MAOPR coordinates allows one to allocate for each OMAO the D50, which is the value of the average deviation pool in the vertical (UDVP). The value of the indicator was calculated for each OAO by subtracting the value of the 25th percentile from the 75th percentile of vertical deviations. The prefix of this indicator are, through the hyphen, the test number and the marking of the MAOPR.

The results obtained were processed in the STATISTICA 8.0 software package. Spearman's criterion with a correlation coefficient (R) was used to determine the correlation between the phenomena. An alternative hypothesis was taken at a level of statistical significance of 0.05.

Results and their discussion. Automatic calculation of the data of the video sequences of the second stage of testing in the group of participants in the study determined the values of D50 for MAOPR. The calculation results for the second stage of testing are presented in Table 1.

In the analysis of the results, the following statistically significant correlations of the MAOPR deviations were obtained (at $p < 0.05$): weak negative correlation of age with p2 oscillation in the second test task, while increasing the age leads to a decrease in the deviations of the anatomical landmark p2; weak negative correlation of growth with oscillation a2 in the fourth test task, while an increase in growth leads to a decrease in the deviations of the anatomical landmark a2; weak negative correlation with growth oscillation a1 and a2 in the fifth test task and a2 in the seventh test task, with the increase in growth leads to a reduction of deviations of anatomical landmarks; weak positive correlation floor due to the fluctuation of A1 and A2 in the fifth test tasks and a2 in the seventh test tasks, with high values of deviations anatomical landmarks observed in men; a1 and a2 in samples with: closed eyes on a stable support in the static; Closed eyes on unstable support in static; closed eyes on a stable support in dynamics; Open eyes on the unstable support in dynamics; a1 and p1 in samples with: closed eyes on the unstable support in the statics; closed eyes on a stable support in dynamics; a1 and p2 in samples with: closed eyes on the unstable support in the statics; closed eyes on a stable support in dynamics; a2 and p1 in samples with: open eyes on the unstable support in the statics; closed eyes on a stable support in dynamics; a2 and p2 in a sample with: closed eyes on a stable support in the dynamics; p1 and p2 in samples with: open eyes on a static support in the static; closed eyes on a stable support in static; Closed eyes on unstable support in static; Open eyes on unstable support in static; closed eyes on a stable support in dynamics; Open eyes on the unstable support in dynamics. The results are shown in Table 2.

Table 1. Values of D50 for MAOPR in test tasks of the second stage of testing

Variable	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.	Confidence SD -95.000%	Confidence SD +95.000%	Standard Error
Возоаст	18.5526	18.0000	17.0000	21.0000	18.0000	19.0000	1.05772	0.862323	1.36843	0.171585
Рост	170.7105	170.0000	157.0000	186.0000	165.0000	176.0000	7.76655	6.331789	10.04796	1.259901
Вес	63.3158	63.5000	42.0000	90.0000	55.0000	71.0000	11.26608	9.184829	14.57546	1.827600
1-A1 (D50)	1.0732	1.0300	0.1600	2.5275	0.6500	1.3700	0.54937	0.447883	0.71075	0.089120
1-A2 (D50)	1.1556	0.8387	0.2800	3.0500	0.6500	1.4200	0.76899	0.626934	0.99488	0.124747
1-p1 (D50)	0.5949	0.4538	0.1800	1.7775	0.3300	0.6800	0.42132	0.343490	0.54509	0.068348
1-p2 (D50)	0.6966	0.6300	0.1800	1.9600	0.4100	0.9100	0.43041	0.350896	0.55684	0.069821
2-A1 (D50)	1.0585	0.9800	0.2500	2.4550	0.7800	1.3775	0.51291	0.418161	0.66358	0.083206
2-A2 (D50)	0.9927	0.8387	0.1700	2.8500	0.6500	1.3075	0.51858	0.422780	0.67091	0.084125
2-p1 (D50)	0.6322	0.5838	0.2275	1.3200	0.4375	0.8200	0.28088	0.228989	0.36338	0.045564
2-p2 (D50)	0.7331	0.6750	0.1500	2.3400	0.3800	0.9600	0.44685	0.364301	0.57811	0.072489
3-A1 (D50)	16.2250	16.3313	1.3800	32.0625	9.8800	20.9850	7.55795	6.161721	9.77807	1.226061
3-A2 (D50)	16.3253	14.3050	3.8600	37.1250	9.9125	22.0475	8.62114	7.028500	11.15357	1.398533
3-p1 (D50)	8.3759	7.9412	4.3700	28.6550	6.0300	9.2525	3.89163	3.172702	5.03478	0.631305
3-p2 (D50)	7.7570	7.1825	3.1800	13.5325	5.8450	9.2600	2.69674	2.198557	3.48890	0.437470
4-A1 (D50)	14.8034	14.1588	5.0300	33.9625	10.3000	17.8200	6.70406	5.465578	8.67336	1.087542
4-A2 (D50)	15.3136	14.2350	3.1850	36.0500	8.0800	19.5175	8.11897	6.619104	10.50390	1.317071
4-p1 (D50)	7.6970	7.3975	3.3125	18.9100	5.9300	8.7850	2.85194	2.325082	3.68969	0.462645
4-p2 (D50)	7.6602	7.5700	2.8075	14.3800	5.6275	8.8425	2.72440	2.221108	3.52469	0.441957
5-A1 (D50)	2.1837	1.4438	0.4900	19.4850	1.0000	2.1700	3.07461	2.506621	3.97777	0.498768
5-A2 (D50)	1.5145	1.4488	0.4975	3.6075	0.9075	1.8000	0.74660	0.608672	0.96591	0.121114
5-p1 (D50)	1.4650	1.3488	0.5700	3.7075	0.9775	1.6600	0.69954	0.570307	0.90502	0.113480
5-p2 (D50)	1.5536	1.4688	0.0100	3.4100	1.1300	1.7550	0.68136	0.555491	0.88151	0.110532
6-A1 (D50)	2.3272	2.0212	0.9950	7.8450	1.6375	2.9825	1.17776	0.960187	1.52373	0.191058
6-A2 (D50)	2.5705	1.9875	0.7400	11.3200	1.7400	2.9475	1.74231	1.420440	2.25411	0.282640
6-p1 (D50)	2.5855	2.3937	1.2800	6.6975	1.7700	2.9900	1.10358	0.899706	1.42775	0.179024
6-p2 (D50)	2.5522	2.3175	0.8600	4.9125	1.7800	3.0875	1.04961	0.855709	1.35793	0.170269
7-A1 (D50)	16.5526	15.5100	4.3900	42.5025	11.7175	19.3850	7.48144	6.099347	9.67909	1.213650
7-A2 (D50)	16.2100	15.0500	4.2075	33.9100	10.6100	20.4500	7.19815	5.868393	9.31259	1.167695
7-p1 (D50)	8.7135	8.4063	4.8425	13.7725	7.1725	10.2200	2.36743	1.930078	3.06285	0.384047
7-p2 (D50)	9.5610	9.1738	5.0700	17.4800	7.6600	10.7500	2.67785	2.183158	3.46447	0.434405
8-A1 (D50)	15.6313	14.7250	8.2500	30.4700	12.0300	18.3275	5.73490	4.675459	7.41951	0.930324
8-A2 (D50)	16.1357	14.4762	8.6600	39.7400	11.7400	17.7800	7.13854	5.819790	9.23546	1.158023
8-p1 (D50)	10.9198	10.9037	5.4050	19.0100	8.6500	11.9925	3.04304	2.480879	3.93692	0.493646
8-p2 (D50)	11.0219	10.3800	6.2500	18.4400	9.3700	12.7075	2.72405	2.220820	3.52423	0.441899

Table 2. Statistically significant correlation of deviations

Samples	Statics				Dynamics			
	Stable support		Unstable support		Stable support		Unstable support	
	Open eyes	Closed eyes	Open eyes	Closed eyes	Open eyes	Closed eyes	Open eyes	Closed eyes
a1/a2		X		X		X	X	
p1/p2	X	X	X	X		X	X	
a1/p2				X		X		
a2/p1			X			X		
a1/p1				X		X		
a2/p2						X		

MAOPR in the form of frontal biomechanical blocks of the front a1 / a2 and rear p1 / p2 semirings participate in providing static equilibrium with closed eyes on a stable and unstable support, as well as in ensuring dynamic equilibrium on a stable support with closed eyes and unstable support with open ones. In this case, the rear biomechanical unit p1 / p2 provides all the options for static equilibrium on both stable and unstable supports with closed and open eyes.

Thus, the posterior biomechanical block can be a marker of the state of the "internal circuit of the body" when implementing static equilibrium programs. Anterior biomechanical block can be a marker of the state of the "internal body scheme" when implementing static equilibrium programs under conditions of visual deprivation (conditions of proprioceptive control of the motor field).

MAOPR in the form of biomechanical diagonal blocks of left a1 / p2 and right a2 / p2 participate in providing static equilibrium on an unstable support and dynamic equilibrium on a stable support under conditions of proprioceptive control of the motor field, which determines the states of the "internal body scheme" when implementing the appropriate programs.

MAOPR in the form of biomechanical lateral blocks of the left a1 / p1 and right a2 / p2 participate in providing static and dynamic equilibrium in conditions of deprivation of visual afferentation, which determines the states of the "internal body scheme" under conditions of the smallest activity of the visual sensory system.

Indicators of the state of the "internal circuit of the body" in the form of biomechanical pelvis blocks for various states of the external environment are presented in Table 3.

Table 3. Indicators of the state of the "internal circuit of the body" in the form of biomechanical blocks of pelvis for various states of the environment

Biomechanical blocks		Indication of the state of the "internal circuit of the body"
Type	Landmarks	
Diagonal	a1/p2 a2/p1	Static equilibrium on unstable support Dynamic equilibrium on a stable support
Frontal	a1/a2	Static balance in visual deprivation
	p1/p2	Static balance
Lateral	a1/p1 a2/p2	Static and dynamic balance in visual deprivation

The system for managing complex coordination by launching various motor strategies compensates for various environmental uncertainty factors, which specifically reflects on the spatial kinematics of the pelvic region, namely, the coordinated movement of MAOPR. This phenomenon is related to the direct control of the common center of mass. Getting into the variable environmental conditions with a high level of variability of qualitative parameters, the system of sensory synthesis through the "internal circuit of the body" triggers certain postural reactions.

Thus, through the system of sensory synthesis and the "internal circuit of the body" under conditions of static equilibrium, coordination is activated with involvement of the anterior and posterior half-rings of the pelvis - frontal biomechanical blocks; in conditions of dynamic equilibrium, diagonal biomechanical blocks of the pelvic region are activated; the adjustment of the sensory flow with the exclusion of visual afferentation leads to the involvement of lateral semirings of the pelvic region in the formation of compensatory reactions.

Neurophysiological regulation of pelvic region biomechanics should be considered in the context of the interaction of the leading elements of the nervous system that provide complex locomotion. A system-organizing element or an element that determines the structure of sensory synthesis is the "ISB." The internal model of the body is a complex integrated neurophysiological substrate - a matrix that plays a crucial role in providing a communicative way of interaction of a person with the surrounding space, both at the objective and semantic levels. This matrix intelligently regulates a number of the following neurophysiological functions: the formation of the "image of the needful future", which is the end point of the communicative path; Strategic planning of action in the form of an "indicative basis of action"; tactical implementation of "motor corrections" by launching programs aimed at anticipating reflection of reality, and implemented in the form of reactive and proactive control, forming respectively anticipatory and stabilizing motor reactions; the presetting of the sensory apparatus in the form of "efferent scanning" (for example, the periphery of the reference contour and the allowable boundaries of the spatial field, which ensure the efficiency of changing extremely distictive postures); control (dynamic and tonic) of the performed action and evaluation (internal and external) of the result obtained. "The internal circuit of the body" is unstable, and to stabilize it, namely to reduce the jumps in the quality parameters of the external environment, an augmentation effect is needed that allows the motor reactions to be brought to the maximum effective level.

Thus, the main role of augmentation lies in the formation of the most effective corridor of sensory afferentation limited by the minimum amount of sensory information required on the one hand, and the necessary variety of motor responses on the other.

Conclusions. In the course of the study, specific patterns of spatial deviations of biomechanical blocks of the pelvic region were established, triggered by changes in the qualitative and quantitative parameters of the external environment. So, in conditions of static equilibrium, coordination is activated with involvement of the anterior and posterior half-rings of the pelvis (frontal biomechanical blocks); in conditions of dynamic equilibrium, diagonal biomechanical blocks of the pelvic region are activated; in conditions of deprivation of visual afferentation, the compensatory reactions of the lateral semirings of the pelvic region (lateral biomechanical blocks) are formed.

The launch of specific patterns is the result of the adaptation of the sensory synthesis system to unstable environmental conditions by changing the state of the internal circuit of the body.

REFFERENCES

1. Mokhtarinia, H. R. Trunk coordination in healthy and chronic nonspecific low back pain subjects during repetitive flexion-extension tasks: Effects of movement asymmetry, velocity and load / H. R. Mokhtarinia, M. A. Sanjari, M. Chehrehrazi, S. Kahrizi, M. Parnianpour // Journal of Human movement science. – 2016. – Vol. 45. – P. 182–192.
2. Silfies, S. P. Trunk control during standing reach: A dynamical system analysis of movement strategies in patients with mechanical low back pain / S. P. Silfies, A. Bhattacharya, S. Biely, S. S. Smith, S. Giszter // Journal of Gait & posture. – 2009. – Vol. 29. – № 3. – P. 370–376.
3. Sung, P. S. A kinematic analysis for shoulder and pelvis coordination during axial trunk rotation in subjects with and without recurrent low back pain / P. S. Sung // Journal of Gait & Posture. – 2014. – Vol. 40. – № 4. – P. 493–498.
4. Hasebe, K. Spino-pelvic-rhythm with forward trunk bending in normal subjects without low back pain / K. Hasebe, K. Sairyo, Y. Hada, A. Dezawa, Y. Okubo, K. Kaneoka, Y. Nakamura // European Journal of Orthopaedic Surgery & Traumatology. – 2014. – Vol. 24. – P. 193–199.
5. Tafazzol, A. Lumbopelvic rhythm during forward and backward sagittal trunk rotations: combined in vivo measurement with inertial tracking device and biomechanical modeling / A. Tafazzol, N. Arjmand, A. Shirazi-Adl, M. Parnianpour // Journal of Clinical Biomechanics. – 2014. – Vol. 29. – № 1. – P. 7–13.
6. Kim, M. H. Comparison of lumbopelvic rhythm and flexion-relaxation response between 2 different low back pain subtypes / M. H. Kim, C. H. Yi, O. Y. Kwon, S. H. Cho, H. S. Cynn, Y. H. Kim, S. H. Hwang, B. R. Choi, J. A. Hong, D. H. Jung // The Spine Journal. – 2013. – Vol. 38. – № 15. – P. 1260–1267.
7. Wang, W. Biomechanics of high-grade spondylolisthesis with and without reduction / W. Wang, C. E. Aubin, P. Cahill, G. Baran, P. J. Arnoux, S. Parent, H. Labelle // Journal of Medical & Biological Engineering & Computing. – 2016. – Vol. 54. – № 4. – P. 619–628.
8. Averianova, A. Rotational kinematics of pelvis and upper trunk at butterfly stroke: Can fins affect the dynamics of the system? / A. Averianova, T. Nikodelis, V. Konstantakos, I. Kollias // Journal of biomechanics. – 2016. – Vol. 49. – № 3. – P. 423–428.
9. Анохин, П. К. Очерки по физиологии функциональных систем / П. К. Анохин. – М. : Наука, 1978. – 447 с.
10. Анохин, П. К. Философские аспекты теории функциональной системы / П. К. Анохин. – М. : Наука, 1978. – 400 с.
11. Анохин, П. К. Узловые вопросы теории функциональных систем / П. К. Анохин. – М. : Наука, 1980. – 196 с.
12. Пиковский, Д. Л. Элементы телеологии в теоретической медицине и практической хирургии / Д. Л. Пиковский. – Н. Новгород : Изд-во Нижегородской государственной медицинской академии, 2000. – 296 с.
13. Лукашевич В. А., Сиваков А. П. Адаптивная кинезитерапия: инновационное направление восстановительной терапии двигательных нарушений, основанное на оптимизации управления системой пространственного ориентирования сложных локомоций человека // Инновационные технологии в медицине. – 2015. - №1 (04). – С.79-90.
14. Лукашевич В. А., Сиваков А. П., Манкевич С. М. Научные основы адаптивной кинезитерапии / Организация работы многопрофильной клинической больницы на современном этапе : материалы научно-практической конференции посвященной 30-летию УЗ «10-я многопрофильная клиническая больница» (Минск, 28 мая 2015 года) / под общей редакцией главного врача В. П. Исачкина. – Минск, 2015. – С.316-321.