



CHARACTERISTICS OF BODY BALANCE DISORDER IN CHILDREN WITH UNILATERAL LOWER LIMB SHORTENING

© I.E. Nikityuk¹, E.L. Kononova¹, Yu.E. Garkavenko^{1, 2}

¹ The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia

² North-Western State Medical University n.a. I.I. Mechnikov, Saint Petersburg, Russia

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Background. In modern orthopedics, the problem of unilateral shortening of the lower limbs in children is extremely important. In the process of child growth, there occurs progression of the shortened segment, which leads to anatomical asymmetry of the lower limbs and an increase in the imbalance of the limb load. Secondary deformities of the pelvis and spine aggravate the patient's disability. The features of abnormal postural balance of the body depending on the etiology of the disease, such as congenital or acquired, as well as the degree of preservation of motor stereotypes in children with unilateral shortening of the lower limbs, are still understudied.

Aim. The aims of this work are to study postural stability in children with unilateral shortening of the lower limbs and to assess the disorders of body balance depending on the etiology of the lesion.

Materials and methods. The standard stabilometric values of 11 healthy children (average age, 11.9 ± 0.73 years) were determined (group 1), as well as the statokinesiogram parameters in 22 patients with unilateral shortening of the lower limb. The second group included 11 children (average age, 11.9 ± 1.05 years) with congenital shortening of the lower limb (average shortening, 4.8 ± 0.8 cm). The third group also consisted of 11 children (average age, 12.2 ± 0.78 years), but with acquired shortening of the lower limb (average shortening, 4.5 ± 0.38 cm). Statistical research included correlation analysis.

Results. A significant decrease in the stability of the vertical balance was observed in both groups of patients, which was demonstrated by pronounced deviations from the nominal values of stabilometric parameters, compared with healthy children: an increased center of pressure displacement, large values of the statokinesiogram area, and the length of the pressure displacement path. It was possible to determine the state of adaptive postural mechanisms for assessing the formation of the degree of adequacy of the motor strategy in patients with unilateral shortening of the lower limb, depending on the etiology of the lesion, owing to the method of stabilometry.

Conclusion. An appropriate adaptive motor stereotype has been formed in patients with acquired shortening of the lower limb; in the new conditions, the system for ensuring postural balance is stabilized. There is a different strategy for maintaining posture stability characterized by a nonoptimal motor stereotype in patients with congenital shortening of the lower limb. The stabilometric assessment of the asymmetry of the lower limb load is a promising method for studying the formation of compensatory mechanisms for controlling the locomotion system, which is important when planning rehabilitation measures.

Keywords: shortening of the lower limb; postural control; stabilometry; limb load asymmetry.

ОСОБЕННОСТИ НАРУШЕНИЯ БАЛАНСА ТЕЛА У ДЕТЕЙ С ОДНОСТОРОННИМ УКОРОЧЕНИЕМ НИЖНЕЙ КОНЕЧНОСТИ

© И.Е. Никитюк¹, Е.Л. Кононова¹, Ю.Е. Гаркавенко^{1, 2}

¹ ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России, Санкт-Петербург;

² ФГБОУ ВО «СЗГМУ им. И.И. Мечникова» Минздрава России, Санкт-Петербург

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Обоснование. Проблема одностороннего укорочения нижних конечностей у детей является чрезвычайно актуальной для современной ортопедии. В процессе роста ребенка укорочение пораженного сегмента прогрессирует, что приводит к анатомической асимметрии нижних конечностей и нарастанию дисбаланса нагрузки на них. Инвалидизацию пациента усугубляют вторичные деформации таза и позвоночника. Остаются малоизученными особенности нарушения постурального баланса тела в зависимости от этиологии заболевания —

врожденного или приобретенного, степень сохранности двигательных стереотипов у детей с односторонним укорочением нижних конечностей.

Цель — изучить поструральную стабильность у детей с односторонним укорочением нижних конечностей и оценить нарушения баланса тела в зависимости от этиологии поражения.

Материалы и методы. Были определены нормативные значения стабилметрических показателей 11 здоровых детей, средний возраст которых составил $11,9 \pm 0,73$ года (первая группа), а также параметры статокинезиограмм у 22 пациентов с односторонним укорочением нижней конечности. Из них во вторую группу вошли 11 детей с врожденным укорочением нижней конечности (среднее укорочение — $4,8 \pm 0,80$ см, средний возраст — $11,9 \pm 1,05$ года). Третью группу составляли также 11 детей, но с приобретенным укорочением нижней конечности (среднее укорочение — $4,5 \pm 0,38$ см, средний возраст — $12,2 \pm 0,78$ года). Статистическое исследование включало корреляционный анализ.

Результаты. В обеих группах пациентов выявлено значимое снижение стабильности вертикального баланса, проявляющееся выраженными отклонениями от номинальных значений стабилметрических параметров по сравнению со здоровыми детьми: повышенным смещением центра давления, большими значениями площади статокинезиограммы и длины траектории центра давления. При помощи метода стабилметрии определяли состояние адаптивных поструральных механизмов для оценки формирования у пациентов с односторонним укорочением нижней конечности степени адекватности двигательной стратегии в зависимости от этиологии поражения.

Заключение. У пациентов с приобретенным укорочением нижней конечности сформирован адекватный адаптивный двигательный стереотип, система обеспечения пострурального баланса стабилизирована в новых условиях. У пациентов с врожденным укорочением нижней конечности была иная стратегия поддержания позной устойчивости, характеризующаяся неоптимальным двигательным стереотипом. Стабилметрическая оценка асимметрии нагрузки на нижние конечности может быть использована для изучения формирования компенсаторных механизмов управления системой локомоции, что важно при планировании реабилитационных мероприятий.

Ключевые слова: укорочение нижней конечности; поструральный контроль; стабилметрия; асимметрия нагрузки на нижние конечности.

Background

The problem of unilateral shortening of the lower extremities in pediatric patients is particularly urgent for contemporary orthopedics. During the growth of the child, due to congenital or acquired damage to the metaepiphyseal areas of growth of the tubular bones, the shortening of the affected segment progresses, which leads to secondary pelvic and spinal deformities and disability of the patient. The pathology is often caused by congenital or acquired dysfunction of the metaepiphyseal growth zones of the long tubular bones of the lower extremities, which develop along with trophic disorders [1]. However, the activity of the metaepiphyseal cartilage changes, even with the complete prevention of cellular humoral effects [2]. Moreover, the anatomical asymmetry of the lower extremities progresses with age in children, which leads to an increase in the imbalance of the load when standing and walking [3]; this, in turn, causes an uneven distribution of mechanical load on the epiphyseal plate and further impairment of its function [4].

While sufficient attention has been given to the study of the load imbalance on the lower extremities in various physiological [5, 6] and

pathological [7, 8] conditions, the adaptive capabilities of the musculoskeletal system with unilateral shortening of the lower extremity have not been as well-studied [9]. The characteristics of impaired postural function, depending on the etiology of the shortening of the lower extremity, also remains largely unexplored, as well as the degree of preservation of motor stereotypes, the assessment of which is particularly important when planning orthopedic rehabilitation [10]. Studying the aspects of maintaining the vertical balance of the body with the asymmetry of the lower extremities enables an analysis of the mechanisms of postural control impairment and evaluation of possible recovery after surgical alignment of the length of the lower extremities [11]. The method of stabilometry used for these purposes is important for studying the formation of adaptive reactions of the body in controlling muscle activity, as well as for creating new technical systems for controlling movements [12].

The current work aimed to determine postural stability in pediatric patients with unilateral shortening of the lower extremities and to assess the imbalance of the body depending on the lesion etiology.

Material and methods

Study design: A one-stage retrospective study was performed.

Study conditions: The standard values of the stabilometric indicators were determined in 11 healthy children aged 8 to 16 years (average age, 11.9 ± 0.73 years).

The patient records and results of radiation examination of the main groups of pediatric patients were analyzed. Group 1 was the control group, and group 2 included 11 pediatric patients aged 8 to 16 years (mean age, 11.9 ± 1.05 years) with congenital shortening of the lower extremity and hypofunction of metaepiphyseal epiphyseal cartilage of the femur and tibia. The degree of involvement in the pathological process of the epiphyseal zones of the affected extremities was not evaluated. The average difference in the length of the lower extremities was $\Delta l = 4.8 \pm 0.80$ cm (Fig. 1, *a*). Group 3 included 11 patients aged 9 to 16 years (mean age, 12.2 ± 0.78 years) with acquired shortening of the lower extremity with destructive changes in the proximal metaepiphyseal femoral growth zone after acute hematogenous osteomyelitis. The average difference in the length of the lower extremities was $\Delta l = 4.5 \pm 0.38$ cm due to the shortening of the femoral length (Fig. 1, *b*). Patients of both groups had hypotrophy of the soft tissues of the thigh and lower leg of the affected extremity of varying severity.

The study groups were homogeneous in age composition and magnitude of shortening of the affected lower extremity. In addition, the key criterion for inclusion in each group was the absence of knee joint angular deformity.

Exclusion criteria: Patients with lesions of the growth cartilage of the bones forming the knee joint were excluded from the sample due to the fact that angular deformity of the knee joint of various directions developed in the majority of cases.

Methods: A stabilometric study was performed using MBN Biomechanika (scientific and medical company MBN) software and hardware complex with the “European” position of the child’s feet, namely the feet were placed on the platform with the heels approximated and the forefeet apart with an angle of 30° between the inner edges of the feet. The patient was offered to take a comfortable, upright position, with their arms lowered along the



Fig. 1. Panoramic radiographs of the lower extremities: *a* — patient K, 10 years old, with congenital shortening of the right lower extremity by 4.5 cm; *b* — patient A., 16 years old, with acquired shortening of the right lower extremity by 4.0 cm

body, resting on both lower extremities. In cases of significant shortening of the lower extremity, its support function was compensatorily implemented by loading only the forefoot. The studies were conducted according to a standard functional test with open and closed eyes, with the registration of the parameters of the displacement of the projection of the body pressure center (PC). A stabilogram represented by an elliptical figure of different directions and with different expressions of eccentricity (degree of the ellipse elongation) was used as a graphic presentation of the PC oscillations (Fig. 2). The PC deviations in the frontal x (mm) and sagittal y (mm) planes were calculated, and the ratio of the y to x parameters was calculated, that is, the ratio of the length of the statokinesiogram ellipse to its width (y/x) was determined in order to identify the vertical balance strategy (frontal or sagittal) in patients [13].

The parameters were determined, namely the PC coordinates X (mm) and Y (mm), the average length of the trajectory of the PC (L , mm), and the area S (mm^2). The sign and the average value of the angle of the preferred direction of the oscillation relative to the sagittal plane Al ($^\circ$) and its change in the test with open and closed eyes ΔAl ($^\circ$) were calculated.

Statistical processing methods: Since the character of the stabilometry indices distribution according to

the Shapiro–Wilk test was defined as nonparametric, the Mann–Whitney test was used to compare the values of unrelated samples. The data are presented as the median and interquartile range (25%–75%). The threshold level of statistical significance was taken at a value of the criterion of $p < 0.05$. The Wilcoxon test was used when analyzing related samples. A correlation analysis was used, using the non-parametric Spearman coefficient r_s to study the linear relationship of the two attributes.

Results

In all pediatric patients with shortening of the lower extremity, pronounced disorders of the postural balance were revealed, as indicated by the data of quantitative indicators (Table 1). This was

manifested by a significant increase in comparison with the norm of the average values of L and S of the oscillations of PC in both groups of patients, and there were no significant differences in the said indicators between the pediatric patients of groups 2 and 3.

Analysis of the displacement of PC in the frontal plane (X -axis, mm) enabled confirmation of the asymmetric distribution of body weight on the lower extremities in patients of both groups. In this case, the affected extremity was compensatorily unloaded, and the body weight was redistributed towards the intact lower extremity. The average values of the lateral displacement of PC were significant for patients with congenital and acquired shortening but did not differ between the groups of patients. Moreover, the correlation between the

Table 1
Statokinesiogram indices of healthy children and patients with unilateral shortening of the LE

Parameters		Groups of pediatric patients examined			Mann–Whitney test, p -value
		Healthy children (1) Me (Q_1 – Q_2) $n = 11$	Patients with congenital shortening of the LEs (2) Me (Q_1 – Q_2) $n = 11$	Patients with acquired shortening of the LEs (3) Me (Q_1 – Q_2) $n = 11$	
X (mm)	OE	0.3 (0.1–0.4)	21.9 (2.2–26.0)	11.8 (7.6–27.7)	$p_{1-2} < 0.0001$ $p_{1-3} = 0.0001$ $p_{2-3} = 1.0$
	CE	0.3 (0.1–0.4)	21.6 (3.3–25.2)	11.4 (4.8–19.1)	$p_{1-2} = 0.0007$ $p_{1-3} < 0.0001$ $p_{2-3} = 0.646$
Y (mm)	OE	3.7 (2.4–5.2)	24.2 (3.9–37.8)	32.8 (28.4–49.4)	$p_{1-2} = 0.293$ $p_{1-3} < 0.0001$ $p_{2-3} = 0.057$
	CE	7.7 (4.4–9.5)	25.6 (3.3–38.2)	37.5 (30.7–51.8)	$p_{1-2} = 0.088$ $p_{1-3} < 0.0001$ $p_{2-3} = 0.03$
L (mm)	OE	637 (532–705)	835 (723–1152)	986 (811–1035)	$p_{1-2} = 0.004$ $p_{1-3} = 0.0005$ $p_{2-3} = 0.646$
	CE	766 (650–911)	1206 (902–1430)	1041 (848–1296)	$p_{1-2} = 0.003$ $p_{1-3} = 0.007$ $p_{2-3} = 0.694$
S (mm ²)	OE	366 (344–621)	529 (365–1109)	880 (570–1343)	$p_{1-2} = 0.066$ $p_{1-3} = 0.007$ $p_{2-3} = 0.115$
	CE	698 (386–806)	861 (598–1035)	1184 (419–1571)	$p_{1-2} = 0.056$ $p_{1-3} = 0.087$ $p_{2-3} = 0.599$
y/x		1.39 (1.23–1.67)	1.18 (0.95–1.40)	1.13 (0.86–1.51)	$p_{1-2} = 0.015$ $p_{1-3} = 0.010$ $p_{2-3} = 0.664$

Note. $p_{1-2, 1-3, 2-3}$ — significance level of differences between groups. Me — median; LE — lower extremities; OE — open eyes; CE — closed eyes.

Table 2

Correlation analysis of linear dependence of the PC displacement along the X and Y axes on the value of shortening the LE Δl in patients

Groups of patients examined		Spearman correlation coefficient r_s	
		Dependence $X \sim \Delta l$	Dependence $Y \sim \Delta l$
With congenital shortening of LEs ($n = 11$)	OE	0.51	0.43
	CE	0.61	0.49
With acquired shortening of LEs ($n = 11$)	OE	0.58	0.22
	CE	0.51	0.45

Note. PC — pressure center; LE — lower extremities; OE — open eyes; CE — closed eyes.

Table 3

Values of the angle of the preferred oscillation direction of the PC of statokinesiograms of healthy children and patients with unilateral shortening of the LE

Параметры	Groups of pediatric patients examined			Mann-Whitney test, p -value	
	Healthy children (1) Me (Q_1 - Q_2) $n = 11$	Patients with congenital shortening of the LEs (2) Me (Q_1 - Q_2) $n = 11$	Patients with acquired shortening of the LEs (3) Me (Q_1 - Q_2) $n = 11$		
$ A , ^\circ$	OE	2.6 (1.1-2.8)	5.3 (2.4-7.7)	2.7 (1.4-5.3)	$p_{1-2} = 0.013$ $p_{1-3} = 0.1$ $p_{2-3} = 0.149$
		$p = 0.859$	$p = 0.026$	$p = 0.006$	
	CE	1.4 (0.1-2.9)	14.4 (11.5-20.9)	9.1 (5.3-20.4)	$p_{1-2} < 0.0001$ $p_{1-3} < 0.0001$ $p_{2-3} = 0.149$
$\Delta A, ^\circ$		2.5 (0.4-3.0)	9.8 (7.2-16.2)	7.9 (5.4-19.7)	$p_{1-2} = 0.0005$ $p_{1-3} = 0.007$ $p_{2-3} = 0.599$

Note. $p_{1-2; 1-3; 2-3}$ — significance level of differences between groups; p — significance level of differences in the group with tests with open and closed eyes (Wilcoxon test); $| |$ — module of indicators. PC — pressure center; LE — lower extremities; OE — open eyes; CE — closed eyes.

magnitude of the lower extremity shortening, Δl , and the X coordinate was moderate in both groups with open and closed eyes (Table 2). This nature of the asymmetric distribution of the body weight to the lower extremities may indicate a compensatory redistribution of the static load when standing in favor of a healthy lower extremity due to a decrease in the support function of the affected lower extremity.

Analysis of the PC displacement in the sagittal plane (Y-axis, mm) revealed a significant anterior deviation only in patients with acquired shortening of the lower extremity. Moreover, the average value of the Y coordinate in this group differed significantly from that in healthy children, as well as in patients with congenital shortening of the extremity. In the same group of patients, a weak correlation was found between the magnitude of the shortening of the lower extremity, Δl , and the Y coordinate with visual control, which turned into a moderate relation when testing with eyes closed. However, in

patients with congenital unilateral shortening of the lower extremities, regardless of participation in the control of posture of visual afferentation, correlation analysis revealed a stable moderate dependence of the Y coordinate on the magnitude of shortening of the lower extremity, Δl .

When analyzing the shape of the stabilograms, a significant decrease was revealed in comparison with the norm of the average values of the y/x ratio in both groups, which was manifested by a decrease in the elongation of the ellipse in the sagittal plane. This indicates the presence in both groups of patients with an equally pronounced tendency of an equally probable strategy of PC oscillations both in the sagittal and frontal planes. This strategy of maintaining balance is close to pathological, which may indicate a significant decrease in the adaptive capabilities of the musculoskeletal system in patients with asymmetries in the length of the lower extremities.

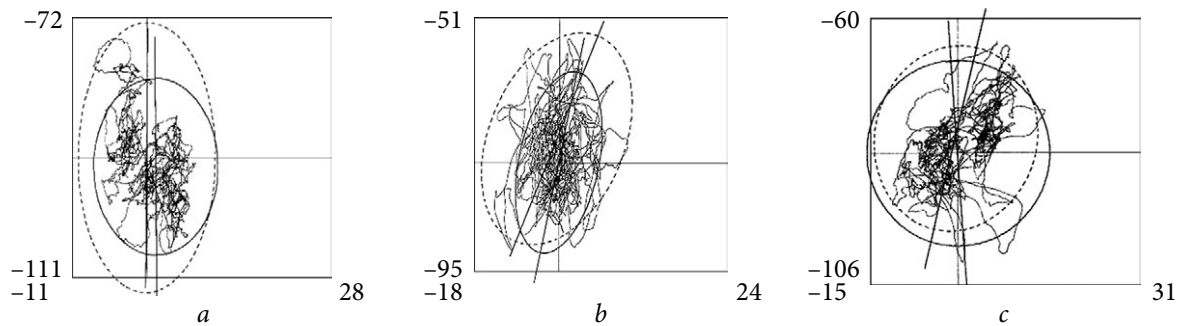


Fig. 2. Signs of the angle of the preferred direction of the pressure center oscillations on the statokinesiograms: *a* — healthy child B., 10 years old, with a symmetrical load on the lower extremities; *b* — patient N., 12 years old, with congenital shortening of the left lower extremity; *c* — patient T., 13 years old, with acquired shortening of the left lower extremity. The long axis of the ellipse is the direction of oscillation, clockwise relative to the sagittal plane is a positive angle, and counterclockwise is a negative angle. The solid line is with eyes open and the dotted line is with eyes closed

The average angle of the oscillation direction, Al , of the PC in pediatric patients with acquired shortening of the lower extremity remained within normal values under the conditions of preserved influence of visual afferentation and only increased significantly when conducting tests with closed eyes (Table 3). According to the considered parameter, the group of patients with congenital unilateral shortening of the lower extremity showed a difference, namely that the average angle of the oscillation direction, Al , significantly exceeded that in healthy children, both with and without visual control.

The magnitude of the change in the angle of the direction of oscillation, ΔAl , between the tests with open and closed eyes significantly exceeded the norm in the group with congenital shortening of the lower extremity. In the group of patients with acquired shortening of the lower extremity, ΔAl indices had significant differences compared with those in healthy children only with eyes closed.

A quantitative picture of the state of the angle of Al oscillation direction is complemented by qualitative analysis.

On the statokinesiograms of healthy children, the angles of the direction of oscillations deviate slightly from the sagittal plane, regardless of the influence of visual control (Fig. 2, *a*). In pediatric patients with congenital shortening of the lower extremities, the direction of the angle of oscillation remains unchanged regardless of the participation of visual control. Furthermore, the direction of the angle of oscillation is related to the side of the lesion, in that it has positive value with the left-sided lesion and negative value with the right-sided lesion (Fig. 2, *b*). In patients with acquired shortening of the lower extremities, the sign of the angle of the PC oscillation direction changes to the opposite, depending on the state of visual afferentation (Fig. 2, *c*).

Regardless of the sign of the oscillation direction in both groups, the value of the angle module, Al ,

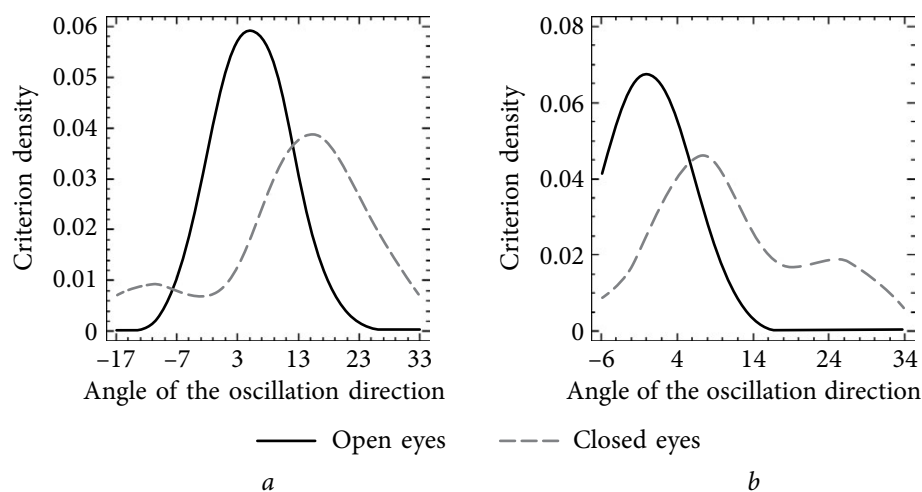


Fig. 3. Density curve of the angle values of the preferred direction of pressure center oscillations on the statokinesiograms of patients with unilateral shortening of the lower extremities: *a* — with congenital shortening of the lower extremity; *b* — with acquired shortening of the lower extremity

was greater with closed eyes than with eyes open (Fig. 3, *a* and *b*), which may indicate a decrease in postural stability without visual afference.

Discussion of the results

It is well known that in healthy people, under normal conditions, body weight is symmetrically distributed between the lower extremities, which are equally involved in creating a moment of force that compensates for the inclination of the body from the equilibrium position. The asymmetric distribution of the load means that a more loaded lower extremity takes a more substantial part in maintaining the orthograde posture than an unloaded one [14]. Imbalance itself triggers adaptive postural motor reactions [15], and with a prolonged asymmetry of the lower extremities, a pathological motor stereotype is generated in a patient [16]. In the present study, pronounced impaired postural stability was revealed in pediatric patients with unilateral shortening of the lower extremity of congenital and acquired genesis. In both groups of patients with an asymmetry of the length of the lower extremities, an increase in stabilometric parameters, such as *S* and *L* of the statokinesiograms, was noted in comparison with healthy children. A pronounced adaptive reaction to unilateral shortening of the lower extremity was an increase in the load on the intact extremity due to a decrease in the support function of the affected lower extremity. Destabilization of the upright position was also registered in the sagittal plane, and depending on the shortening genesis, patients implemented different strategies for maintaining postural stability. Despite the fact that in all patients, the foot support point of the affected side was displaced to the anterior part, in pediatric patients with congenital shortening of the lower extremity, the PC was not only displaced significantly in the front direction, but there was also a tendency to displace the PC posteriorly. However, in patients with acquired shortening, a marked displacement of PC anteriorly was noted, similar to that which occurs in healthy people during artificial creation of a minor instability of a vertical posture by arbitrary partial transfer of body weight to one lower extremity and unloading of the other [17]. Thus, in pediatric patients with acquired shortening of the lower extremity, an additional static moment is

created to maintain a vertical posture in the sagittal plane, which helps to increase the body balance stability. In addition, in this group of patients, with open eyes, the displacement of PC along the *Y*-axis did not depend on the shortening of the extremity, Δl , which testifies in the preservation of the physiological mechanism of maintaining the vertical stability. In patients with congenital shortening of the lower extremity, the PC displacement in the sagittal plane correlated well with shortening of the extremity and did not depend on the flow of visual information, which indicates a pronounced pathological establishing response of the body balance control system and impairment of the postural control stereotype.

It should be noted that patients of the studied groups, despite the uniformity in age and magnitude of the lower extremity shortening, differed in the level of damage to the growth zones of bones. There were also differences in the severity of hypotrophy of the muscles of the lower extremities. Such anatomical aspects must be considered when interpreting patient balance. In the group of pediatric patients with congenital shortening of the lower extremity, the growth zones of the bones that form the knee joint responsible for sagittal balance were more often involved in the pathological process. In patients with lesions of the proximal metaepiphyseal zone of growth of the femoral bone, impairment of the vertical balance with the pathological orientation of the PC oscillations in the frontal plane could be expected. However, it must be considered that in pediatric patients with a chronic unequal length of lower extremities, regardless of the etiology, compensatory changes in the kinematic chains of the musculoskeletal system develop. On the one hand, this is manifested by the lateral distortion of the pelvis and the creation of a spinal curvature arch [18]. On the other hand, all the links of the musculoskeletal system interact diversely, which, in the process of child growth, leads to steady positive changes in locomotion biodynamics [19]. Considering that the muscles of the pelvis and spine make the greatest contribution to human vertical balance regulation, along with the muscles of the lower extremities [20], their complex interaction in patients with different lengths of the lower extremities of various origins likely leads to an averaged balanced adaptive response of the postural control system to abnormally modified

biomechanical conditions. This assumption is supported by the results of the present work on the assessment of the balance strategy (frontal or sagittal) in pediatric patients, namely that the average y/x ratio indicates the sagittal balance strategy in patients of both groups, the severity of which did not differ between the two groups, although it was reduced compared with the norm.

Arbitrary values of the sign of the angle Al of the oscillation direction of PC in patients with acquired shortening of the lower extremity correspond to the principle of the statokinesiogram axial direction distribution typical for healthy children. That is why, according to the results of this study, the partially unloaded lower extremity is actively involved in postural control in patients with acquired shortening, which can be a sign of the formation of an adaptive motor stereotype that is close to the physiological one. This means that in such patients, the system for ensuring the postural balance of the body is stabilized adequately under the new conditions.

In pediatric patients with congenital shortening of the lower extremity without visual control, the sign of the angle Al of the PC oscillation direction remained unchanged. Thus, a decrease in the flow of afferent information in connection with visual deprivation was not accompanied by sensory correction of the PC movements by proprioceptors. This motor strategy, devoid of the advantages of the visual regulation system, is manifested by destabilization of the postural balance system since, in the absence of visual control, the mechanism of maintaining vertical stability does not fully correct the child's body position in the spatial planes. The specified program of motor activity, which is responsible for the effectiveness of postural control, is considered non-optimal or pathological [21]. This suggests the formation of a non-optimal motor stereotype in patients with congenital shortening of the lower extremity.

It should be highlighted that this study only included pediatric patients with an uncomplicated form of asymmetry of the lower extremities, as they had a preserved axis of a shortened extremity. Therefore, the data presented in this study do not reveal all aspects of the problem, require careful interpretation, and cannot be applied to patients with the unevenness of the lower extremities in combination with their deformities.

Conclusion

The stabilometry method enables determination of the state of adaptive postural mechanisms to assess the formation in patients with unilateral shortening of the lower extremity of the degree of the motor stereotype adequacy, depending on the lesion etiology. It has been established that, in patients with acquired shortening of the lower extremity, an adequate adaptive motor stereotype is generated, which is close to physiological. In patients with congenital shortening of the lower extremity, a different strategy for maintaining postural stability is noted, which is characterized by the formation of a non-optimal motor stereotype in the form of a lack of compensatory PC displacement, anteriorly along the sagittal component, as well as the constancy of the angle of the preferred direction of oscillation, independent of the influence of visual afferentation. The pathological postural reaction in such patients can be considered as a criterion for reducing adaptive capabilities of the postural stability. The proposed methodology for diagnosing motor disorders is promising for assessing the efficacy of the formation of a new motor program in patients after surgical elongation of the lower extremity using transosseous distraction osteosynthesis.

Additional information

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Ethical review. The study was performed in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association, as amended by the Ministry of Health of Russia, and was approved by the ethics committee of the Turner Scientific Research Institute for Children's Orthopedics (protocol No. 4 of 27.11.2018). Patients (their representatives) signed a voluntary informed consent for processing and publication of personal data.

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Contribution of the authors

I.E. Nikityuk developed the research methodology, processed the data, wrote all sections of the article, and collected processed literature data.

E.L. Kononova conducted the research and data processing.

Yu.E. Garkavenko edited the text of the article.

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Information about the authors

Igor E. Nikityuk* — MD, PhD, Leading Researcher of the Laboratory of Physiological and Biomechanical Research. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. <https://orcid.org/0000-0001-5546-2729>. E-mail: femtotech@mail.ru.

Elizaveta L. Kononova — MD, PhD, Senior Research Associate of the Laboratory of Physiological and Biomechanical Research. The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. <https://orcid.org/0000-0001-7624-013X>. E-mail: Yelisaveta@yandex.ru.

Yuriy E. Garkavenko — MD, PhD, D.Sc., Professor of the Chair of Pediatric Traumatology and Orthopedics. North-Western State Medical University n.a. I.I. Mechnikov; Leading Research Associate of the Department of Bone Pathology of The Turner Scientific Research Institute for Children's Orthopedics, Saint Petersburg, Russia. <https://orcid.org/0000-0001-9661-8718>. E-mail: yurijgarkavenko@mail.ru.

Игорь Евгеньевич Никитюк* — канд. мед. наук, ведущий научный сотрудник лаборатории физиологических и биомеханических исследований ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России. <https://orcid.org/0000-0001-5546-2729>. E-mail: femtotech@mail.ru.

Елизавета Леонидовна Кононова — канд. мед. наук, старший научный сотрудник лаборатории физиологических и биомеханических исследований ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России. <https://orcid.org/0000-0001-7624-013X>. E-mail: Yelisaveta@yandex.ru.

Юрий Евгеньевич Гаркавенко — д-р мед. наук, профессор кафедры детской травматологии и ортопедии ФГБОУ ВО «СЗГМУ им. И.И. Мечникова» Минздрава России, ведущий научный сотрудник отделения костной патологии ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России. <https://orcid.org/0000-0001-9661-8718>. E-mail: yurijgarkavenko@mail.ru.