

RELATIONSHIP BETWEEN FLEXION CONTRACTURES OF THE JOINTS OF THE LOWER EXTREMITIES AND THE SAGITTAL PROFILE OF THE SPINE IN PATIENTS WITH CEREBRAL PALSY: A PRELIMINARY REPORT

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Background. The considerable incidence of kyphosis in patients with cerebral palsy (CP) causes back pain and aggravates movement disorders. However, few studies have investigated the pathogenesis of this condition.

Aim. To identify the relationship between patient motor abilities, the severity of flexion contractures of the knee and hip joints and spinal sagittal profile changes, and the impact on the latter by surgical correction of flexion contracture of the knee joint.

Material and methods. The study cohort included 17 pediatric CP patients (11 boys and 6 girls) with a mean age of 13.1 ± 1.3 (range, 10–16) years and level 2–4 spastic diplegia according to the Gross Motor Function Classification System. The relationship between radiological indicators of the spine sagittal profile and motor abilities of children, as well as the severity of flexion contractures at the hip and knee, and the degree of insufficiency of the active extension of the knee were investigated. Of these 17 patients, 12 underwent surgery to correct flexion contracture of the knee, which involved lengthening of leg flexors, to analyze the impact of contracture on the sagittal profile of the spine. The following radiological indicators were assessed: angle of thoracic kyphosis (CC), lordosis angle (UL) of the lumbar spine, and sacral inclination angle (SS). The study included patients with a CC of at least 30° .

Results. Results of an X-ray study showed that the severity of kyphosis was $50.7^\circ \pm 2.1^\circ$, lordosis was $30.3^\circ \pm 4.3^\circ$, and SS was $30.5^\circ \pm 3.3^\circ$. There was a significant association between kyphosis and flexion contracture of the knee joint, as well as between lordosis and insufficient active extension of the knee joint. After elimination of the flexion contracture of the knee, the degree of severity of the CC (thoracic kyphosis) was unchanged, while UL (lordosis angle) and SS (sacral inclination angle) increased by approximately 10° .

Conclusion. The severity of kyphosis in patients with CP is mainly dependent on the degree of flexion contracture of the knee joint. Although elimination of contractures does not lead to kyphosis correction, it increases the degree of lumbar lordosis and tilting of the sacrum.

Keywords: cerebral palsy, kyphosis, lordosis, lengthening of leg flexors.

ВЗАИМОСВЯЗЬ СГИБАТЕЛЬНЫХ КОНТРАКТУР В СУСТАВАХ НИЖНИХ КОНЕЧНОСТЕЙ И САГИТТАЛЬНОГО ПРОФИЛЯ ПОЗВОНОЧНИКА У БОЛЬНЫХ ДЕТСКИМ ЦЕРЕБРАЛЬНЫМ ПАРАЛИЧОМ: ПРЕДВАРИТЕЛЬНОЕ СООБЩЕНИЕ

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Актуальность определяется значительной частотой развития кифоза у больных детским церебральным параличом, который вызывает боли в спине и усугубляет двигательные расстройства пациентов. Однако вопросам патогенеза данного состояния посвящено незначительное количество работ.

Цель исследования — выявить взаимосвязь между двигательными возможностями больных, степенью выраженности сгибательных контрактур коленных и тазобедренных суставов и изменениями сагиттального профиля позвоночника, а также влияния на последний хирургической коррекции сгибательной контрактуры коленного сустава.

Материал и методы. Обследованы 17 пациентов, больных детским церебральным параличом (ДЦП), в возрасте от 10 до 16 лет ($13,1 \pm 1,3$), среди которых были 11 мальчиков и 6 девочек. Все больные были с формой спастической диплегии различной степени тяжести. По шкале нарушения глобальных моторных функций GMFCS они соответствовали 2–4-му уровням.

У 17 пациентов выполнено исследование взаимосвязи рентгенологических показателей сагиттального профиля позвоночника с двигательными возможностями детей, а также степенью выраженности у них сгибательных контрактур тазобедренных, коленных суставов и степени недостаточности активного разгибания коленных суставов. Двенадцати больным выполнена операция, направленная на коррекцию сгибательной контрактуры коленного сустава — удлинение сгибателей голени с целью анализа влияния данной контрактуры на сагиттальный профиль позвоночника. Рассмотрены следующие рентгенологические показатели — угол кифоза (УК) грудного отдела, угол лордоза (УЛ) поясничного отдела и угол наклона крестца (SS). В исследование были включены пациенты, имевшие значение УК не менее 30° .

Результаты. Согласно данным рентгенологического исследования степень выраженности кифоза составила $50,7 \pm 2,1^\circ$, лордоза — $30,3 \pm 4,3^\circ$, SS — $30,5 \pm 3,3^\circ$. Выявлена значимая связь между кифозом и сгибательной контрактурой коленного сустава, а также между лордозом и недостаточностью активного разгибания коленного сустава. В то же время после устранения сгибательной контрактуры коленного сустава степень выраженности УК не изменилась, а УЛ и SS увеличилась приблизительно на 10° .

Заключение. Степень выраженности кифоза у больных ДЦП в основном зависит от выраженности сгибательной контрактуры коленного сустава. В то же время устранение этой контрактуры не способствует коррекции кифоза, однако увеличивает степень выраженности поясничного лордоза и наклона крестца.

Ключевые слова: детский церебральный паралич, кифоз, лордоз, удлинение сгибателей голени.

A small number of studies have reported on the influence of the flexion contractures (SC) of the knee joints (KJ) and hip joints (HJ) on the formation of the spinal sagittal profile in patients with infantile cerebral paralysis (ICP). KJ and HJ are the largest human joints. Most of the muscles that provide their movement are diarticular, which predetermines their direct participation in the formation of the pelvis position, and indirectly, in the sagittal profile of the spine [1]. The interaction of these muscles is coordinated by complex neurophysiological processes aimed at maintaining balance of the body when standing or walking. Some authors noted that the flexion contracture of the HJ (tonic or secondary) causes an anterior pelvic slope, leading to a compensatory increase in the severity of the lumbar lordosis. The muscle flexors of the KJ stretch, which increases the power of their action and contributes to the formation of the KJ flexion contracture. This exacerbates the flexion position of the HJ and the pelvic slope, resulting in sagittal imbalance, which usually develops at an early age, and the formation of pathological reflex systems. The researchers found a relationship between the severity of the flexion contracture of the KJ and the flattening of the lumbar lordosis (through the increased kyphosis), which confirms their pathogenic interdependency [2]. Additionally, some authors showed a relationship between the change in the sagittal profile of the spine and the pelvic slope in the formation of kyphosis [3].

In a comprehensive study conducted using the three-dimensional gait analysis, it was found that in patients with flexion contracture of the KJ the anterior pelvic slope was seen both in the upright standing position and while walking [4]. When walking with bent KJs, there is a decrease in the strength of the extensor muscles of the knee and the hip joints due to their points of attachment; therefore, the possibility of their active extension in the support phase is reduced (<50% of normal power when severe). However, it should be considered that this is most often not due to a true decrease in muscle strength but the absence of the conditions necessary for its functioning from the adjacent limb segments. In literature there is no delimiting factor between the impact on the spinal position of the KJ flexion contracture and its pathological flexion apparatus due to the functional weakness of the quadriceps muscle of thigh.

Thus, the imbalance of the spinal sagittal profile in patients with ICP appears to be closely connected with the flexion contractures of the KJ and HJ, so elimination of these contractures may improve the position of the spine. Variants for lengthening the muscle tendons, which are the flexors of the tibia, are commonly used for this purpose [5, 6]. The authors noted a decrease in the severity of kyphosis of the lumbar and thoracic spine, but did not provide data on the extent of these changes. To reduce the slope of the pelvis after lengthening of the lower leg flexors, tenotomy of the straight

head of the quadriceps muscle of thigh is also recommended, based on positive results achieved by performing this intervention. [7]

The aim of this study was to identify correlations between the motor abilities of patients, the severity of flexion contractures of the KJ and the HJ, and changes in the sagittal profile of the spine; in addition we aimed to determine the impact of the correction of the KJ flexion contracture.

Materials and methods

In total, 17 patients (11 boys and 6 girls) with ICP aged 10–16 years (13.1 ± 1.3 years) were enrolled in this study. All patients had a form of spastic diplegia of varying severity. Based on the scale of disorders of global motor functions (GMFCS), 10 patients corresponded to level 3, 4 of them corresponded to level 4, and 3 of them corresponded to the level 2.

All patients reported the presence of non-fixed kyphosis causing discomfort, and had previously caused fatigue, back pain, and difficulty holding up the head and neck while sitting and walking. The patients could partially correct the position of the spine but only for a short period of time because of weakness of the back muscles.

The relationship of the radiological indicators of the spinal sagittal profile with the motor abilities of the 17 pediatric patients was studied, along with the severity of their HJ and KJ flexion contractures, and the degree of failure of active extension of the knee joints. The surgery was performed for 12 patients to correct the KJ flexion contracture by lengthening the tibia flexors. To analyze the effects of this contracture on the spinal sagittal profile, the following clinical parameters were determined:

- level of motor abilities on the scale of global motor functions GMFCS;
- degree of severity of the HJ flexion contracture based on results of Thomas' test;
- degree of severity of the KJ flexion contracture in the prone position; and
- degree of failure of active extension of the knee joint (FAEKJ) in the upright position with the maximum straightened limbs (with full extension 180°).

The X-ray examination was performed in patients in the upright position with the maximum straightened limbs in a body position that was

habitual for the patient. The following parameters were analyzed:

- kyphotic angle (KA) of the thoracic spine, determined between the axes of intervertebral discs in the positions Th_2-Th_3 and $Th_{12}-L_1$;
- angle of lumbar lordosis (LA), determined between the axes of the intervertebral discs in the positions $Th_{12}-L_1$ and L_5-S_1 ; and
- angle of the sacral slope (SS), determined between the horizontal line of the support area and the line passing through the upper edge S.

These values vary considerably between patients [8], which somewhat hinders the interpretation of the data obtained from the patients with ICP. However, in this study, we compared the radiographic values obtained after surgery with the preoperative values rather than normal values. The study included patients who had a KA value of at least 30° .

The coefficient of correlation between the values was evaluated by the Chedoke scale, based on which the relationship between the parameters (the correlation coefficient r) may be weak ($r = 0 \pm 0.299$), average ($r = 0.3 \pm 0.699$) and strong ($r = 0.7 \pm 1$).

The surgery performed in the 12 patients included lengthening the tendons of the semitendinosus muscle and the gracilis muscle, the partial intersection of the tendinosus part with the semimembranosus, and the two heads of the biceps muscle. The limb was fixed with a high plaster cast for 3 weeks. If it was not possible to correct the contracture completely on the operating table, the full extension of the limb was achieved in the postoperative period by using the cast. A control X-ray of the spine was performed 1–5 months after the surgery and the course of motor rehabilitation, when the stable active fixation of the torso and full extension of the knee joints had been achieved.

All patients were examined after a voluntary consent of their parents.

Study results

The average score on the GMFCS system corresponded to level 3 motor defects. The flexion contracture of the HJ was equal to $172.2 \pm 2.7^\circ$, while that of the KJ was $160.8 \pm 3.2^\circ$; failure of the active extension of the KJ was $52.1 \pm 3.1^\circ$.

Based on X-ray examination, the severity of kyphosis was $50.7 \pm 2.1^\circ$ (ranging 34° – 70°), the severity of lordosis was $30.3 \pm 4.3^\circ$ (ranging 0° – 56°), and the severity of SS was $30.5 \pm 3.3^\circ$ (ranging 8° – 58°). Variants of the sagittal profile of the spine in the patients with ICP participating in this study are presented in Fig. 1.

We performed a correlation analysis on data from the clinical and the radiological studies. The results are presented in the Table 1.

Based on the data presented in the table, there is a correlation between kyphosis and the flexion contracture of the KJ, as well as between lordosis and FAEKJ; the correlation between other indicators is either absent or is weakly expressed in this study.

We examined the sagittal profile of the spine before and after surgery in all 12 patients and analyzed the differences. The data are presented in the Table 2.

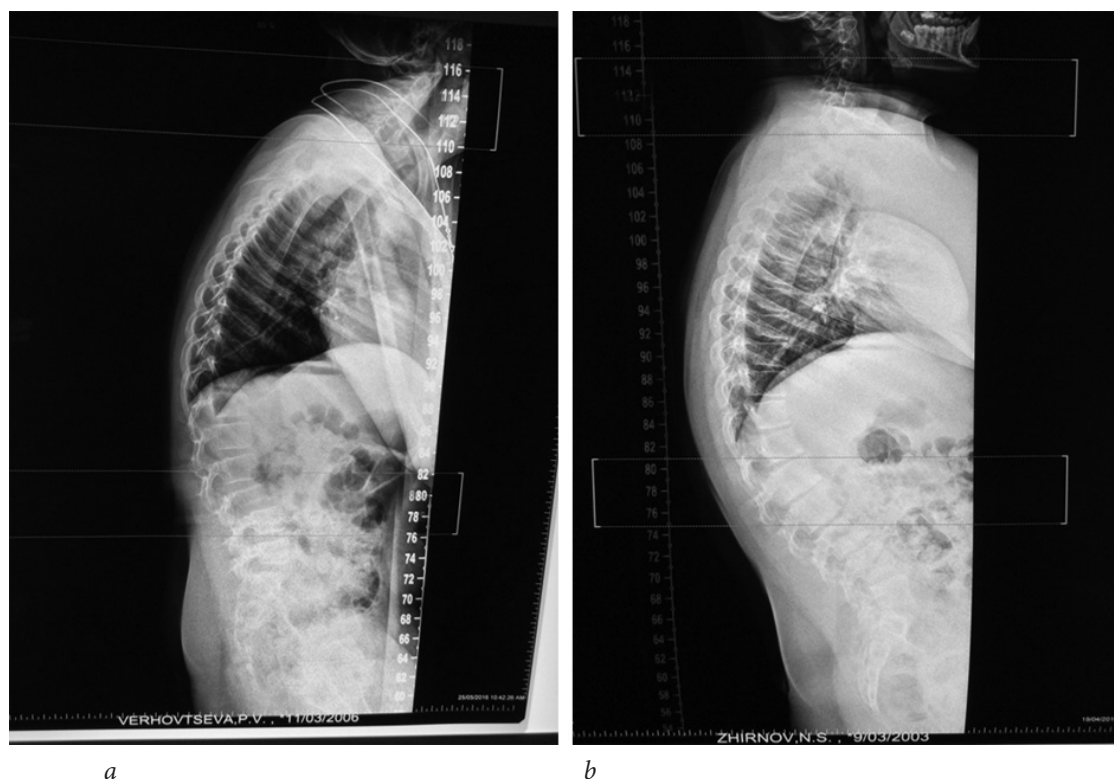


Fig. 1. X-ray variants of the sagittal profile of the spine in patients with ICP with kyphosis: a) B-a V., 10 years: kyphosis, 50° ; lordosis, 10° ; SS, 8° ; b) B-y G., 13 years old: kyphosis, 70° ; lordosis, 38° ; SS, 18° .

Table 1

Correlations between the clinical and radiological parameters (correlation coefficient r)

	GMFCS	Flexion contractures of the hip joint	Flexion contractures of the knee joint	Failure of active extension of the knee joint
Kyphosis	-0.14	+0.05	-0.54	-0.17
Lordosis	-0.12	-0.22	-0.17	+0.35
SS	-0.06	-0.01	+0.14	+0.08

Table 2

Preoperative and postoperative radiological indicators of the spinal sagittal profile

	Kyphosis, $^\circ$	Lordosis, $^\circ$	SS, $^\circ$
Before the surgery	50.7 ± 2.1	30.3 ± 4.3	30.5 ± 3.3
After the surgery	49.2 ± 3.4	40.2 ± 4.3	40.8 ± 3.6

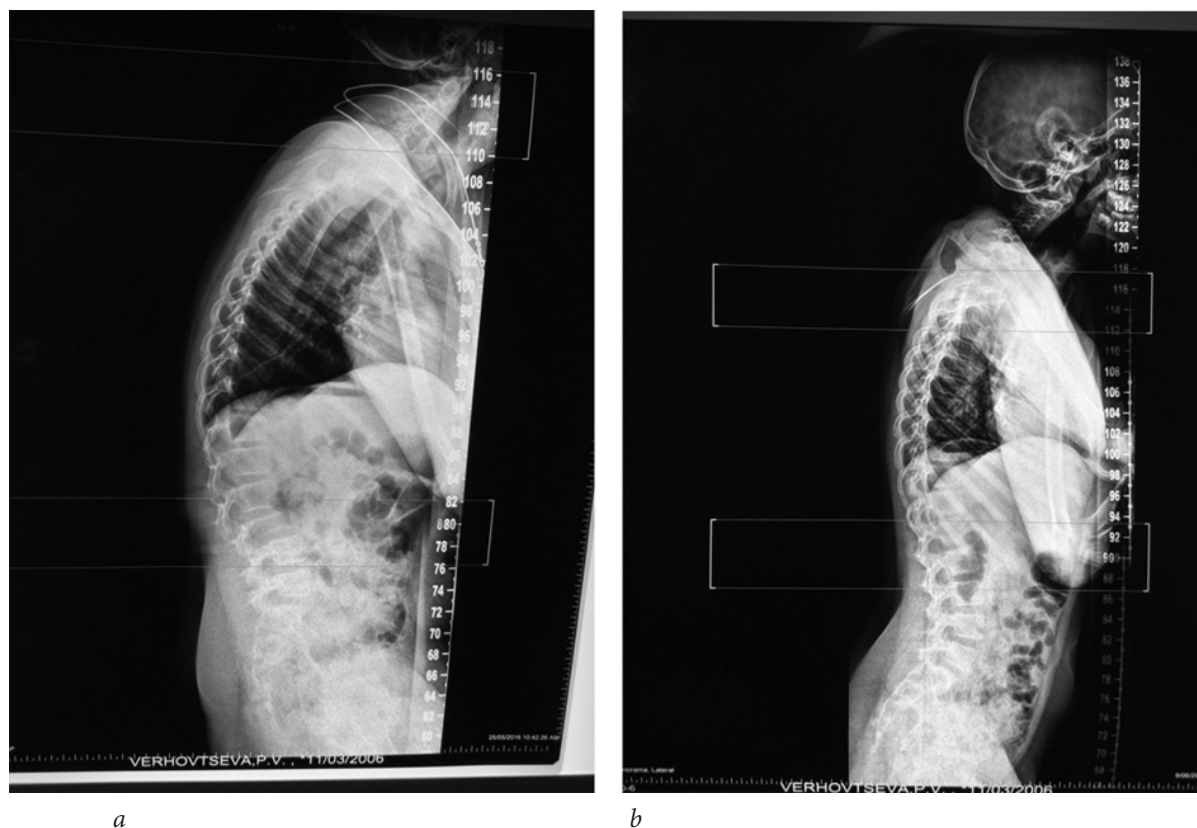


Fig. 2. The spinal sagittal profile before and after surgery a) B-a, 10 years: kyphosis, 50°; lordosis, 10°; SS, 8° (before the surgery); b) B-a, 10 years: kyphosis, 42°; lordosis, 42°; SS, 40° (after the surgery)

The data revealed an increased in the degree of LA and SS after extension of the lower leg flexors, while the degree of severity of the KA changed little, if at all.

The correlation analysis between the severity of kyphosis and lordosis revealed a weak correlation between these indicators, both before and after the surgery ($r = 0.2$ and $(-).0.2$, respectively).

The nature of the changes of the spinal sagittal profile after lengthening of the tibia flexors is shown in Fig. 2.

Discussion

The considerable variability of the radiological indicators in spinal sagittal profiles of the patients with ICP is noteworthy. However, this is consistent with the data presented by J. M. Mac-Thiong et al. [8], who observed great variability in these parameters in healthy pediatric patients aged 3–18 years. This indicates that there is an absence of a clear boundary between normality and pathology for these indicators.

We observed an correlation of moderate strength between the severity of kyphosis and the

flexion contracture of the KJ, which may indicate that kyphosis in ICP patients is dependent, not on the flexion position of the KJ and the associated change in the patient's posture, but on the degree of shortening of the tibia flexors and the associated posterior pelvic slope. The correlation observed between lordosis and FAEKJ may indicate that the lumbar spine is the main balancing point for the changing position in the KJ and is less dependent on the retraction of the muscles. The primary dependencies of kyphosis and lordosis on various factors in patients with ICP is explained by the significant difference between FAEKJ and the degree of KJ flexion contracture (an average of about 33°), which allows enough space for “fine-balancing” of the hip segment. Firstly, the lumbar spine responds to the change of the limb sagittal profile, which is natural, and only on achievement of the amplitude of motion in the joints depending on the retraction of muscles, it responds to the change in the flexors of the lower leg (much smaller than at FAEKJ); the severity of kyphosis begins to change. The lack of effect of the HJ flexion contracture on the sagittal profile of the spine may indicate that the presence of the flexion position of

the KJs may neutralize the pelvic slope anteriorly, and the points of fixation of muscle-flexors of hips converge. This causes a significant reduction in muscle retraction and their impact on the pelvic position.

The presence of the weak correlation between the degree of kyphosis and lordosis ($r = 0.2$) only confirms the clinical and radiographic correlation ratio. This correlation remains weak after the lengthening of the tibia flexors ($r = -0.2$).

Lengthening of the tibia flexors significantly changes the severity of lordosis and the sacral slope, but has almost no influence on the curvature of the thoracic spine, thereby confirming the predominant relationship of this particular segment of the spine with the position of the joints of the limbs.

Conclusions

1. The severity of kyphosis of the thoracic spine and lordosis of the lumbar spine in patients with ICP is associated with the ability to form a balance with the sagittal profile of the lower limbs to hold the torso upright.

2. Kyphosis is mostly dependent on the degree severity of the KJ flexion contracture.

3. Correction of the KJ flexion contracture by lengthening the tibia flexor affects the curvature of the lumbar spine and the degree of sacral slope, almost without changing the severity degree of kyphosis.

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