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O. A. Danylov, O. V. Shulga, V. V. Gorelik, J. Abdalbari
P. L. Shupyk National Medical Academy of Postgraduate Education, Kyiv

THE MECHANISM OF FORMATION AND CLINICAL COURSE OF PRONATION FOOT DEFORMITY IN CHILDREN WITH THE CEREBRAL PALSY

The aim — definition of the main mechanisms of formation and clinical course of pronation foot deformity in different age groups at the children with a cerebral palsy.

Materials and methods. The data obtained from treatment of 68 patients aged from 2 till 16 years were analyzed. In all cases deformation of foot was noted bilateral pronation foot deformity. Clinical methods included definition of a position of a calcaneal bone (valgus, an equines deformity in degrees), the pronation of foot and forefoot abduction, a condition of the longitudinal arch at loading and in a prone position. Degree of mobility of foot was determined by coefficient.

Results and discussion. Depending on nature of changes of foot shape has been allocated three variants of pronation foot deformity. Equines plano-valgus deformity — a combination of an equines deformity of a calcaneal bone (displacement of its rear in a proximal direction) with the pronation of foot and forefoot abduction. Plano-valgus deformity — the pronation of foot is combined with forefoot abduction and a valgus abduction of a calcaneal bone. At the third variant the main component of deformation is the pronation of foot in talocrural and subtalar joints. Abduction of the forefoot is not present or poorly expressed at loading.

Conclusions. Plano-valgus deformity of foot is a heavy complication of cerebral spastic infantile paralysis that causes violation of a statics and locomotion walk, increases motive insufficiency. Depending on the character of a muscular imbalance, a condition of the ligaments, speed of progressing of deformation allocate three variants of its development. Clinical course pronation foot deformity is caused by the age of patients, body weight and physical activity.

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Key words: pronation foot deformity, children, cerebral palsy, plano-valgus deformity.

One of the reasons of heavy motive insufficiency at the children having a cerebral palsy (cerebral spastic infantile paralysis) is deformation of foot. The main factor, which influences the formation of the deformation, is the muscular imbalance which is coursed by the dominance of certain muscle groups, for example, dominance flexors of foot and toes over extensors or supinators (arch supports) of foot over a pronator [2, 5].

Considering multifactorial disease nature, it is heavy to determine the initial stages by what variant there will be a formation of deformation of foot. So, in one case at prevalence of function of flexor muscles of foot its equines deformity is formed. Further, in the process of increase in load of the ligaments of foot, such deformation can be reformed in equines plano-valgus (at weakness of the ligaments), varus (at prevalence of function of muscles instep supports) or to remain invariable (at the sufficient durability of the ligaments). Irrespective of the nature of deformations, a necessary condition of its formation is preservation of tonic tension of muscles synergists and muscles antagonists according to existing changes of a reciprocal innervation. The least favorable in functional sense is the combined deformation which includes the pronation of foot, forefoot abduction, an equines deformity in talocrural and subtalar joints, flattening of the longitudinal arch of foot. In most cases authors unite the specified changes by the general term «plano-valgus deformity of foot» [1, 2, 5, 6].

However, supervision over patients specifies that changes in joints of foot have versatile character. So, in one case there is a transformation of an equines deformity of foot in equines plano-valgus, in others — the main component is valgus foot deviations in talocrural and subtalar joints.

Irrespective of nature of deformations of foot at patients with the main thing and their constant compo-

Данилов Олександр Андрійович, д. мед. н., проф., зав. кафедри дитячої хірургії
04209, м. Київ, вул. Богатирська, 30. E-mail: pedsurgery_ua@ukr.net

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nent the pronation is including an inclination of foot outwards and forefoot abduction. Longitudinal arch of the foot thus can be kept, and in certain cases — increased (for example, at the calcaneal foot arising owing to an plastic surgery achilles tendon or, so-called, fiberotomy Ulzibat's by method).The calcaneal bone can be inclined outside or take a neutral position. Therefore the term «plano-valgus deformity» in our opinion not always, unlike definition «pronation foot deformity» (further correctly reflects the pronation foot deformity as PFD). Now the age periods in which various variants of deformation most often develop are not defined, is their clinical course is not studied. It does not allow to carry out adequate preventive measures for prevention of progressing of deformation. Also there is no analysis of mechanisms of formation of this or that option of change of foot shape, does not allow to carry out a right choice of a method of treatment (both quick, and conservative).

So, all aforesaid defines relevance of a problem and allows to define the specific objectives promoting its decision.

The aim — definition of the main mechanisms of formation and clinical course of pronation foot deformity in different age groups at the children with a cerebral palsy.

MATERIALS AND METHODS

The data obtained at treatment of 68 patients aged from 2 till 16 years were analyzed. In all cases bilateral PFD was noted (table 1).

Clinical methods included definition of a position of a calcaneal bone (valgus, an equines deformity in degrees), the pronation of foot and forefoot abduction, a condition of the longitudinal arch at loading and in a prone position. Degree of mobility of foot was determined by coefficient.

The area of an entrance to sinus tarsi was for this purpose measured in the provision of the maximum varus position of foot and, respectively, its pronation. As reference points for determining its slopes were following bone: in the horizontal plane — area talus-navicular and calcaneal-cuboid joints, edge of a calcaneal bone at the level of a back shoot of a talus bone in the sagittal plane — bottom edge of a talus bone and the upper edge of a calcaneal bone in a zone of the widest part of sinus tarsi. Bone reference points were marked at the neutral provision of foot (between the pronation and a supination).The data obtained in the provision of a supination shared on the similar, received *in situ*ation pronations. The received values were defined as mobility coefficient.

Previously conducted research in group of children without PFD showed that average value of coefficient of mobility is equal 1,5. The increase in coefficient testified about hyper mobility of foot, decrease — about a rigidity.

Radiological research included definition of a talus angle at children under 4—7 years. The vertex of angle settled down on the middle of an articulate surface of a talus bone which was connected to a head of I metatarsal bone and the center of a calcaneal tubercle. At children of advanced age the navicular angle — similar indicators were defined, but the top was middle of a navicular bone. At not changed foot the angle makes depending on age in compliance 145—155°. Calcaneus-tibia and talus-tibia angle were determined by the section of axial lines of tibia, talus and calcaneal bones. In frontal pictures were defined talus-medial and other angles, by creation of the axial lines drawn through talus and I—II and IV—V metatarsal bones.

Radiological research of foot was conducted with loading standing and without loading lying. For the purpose of determination of complexity of deformation 3 its stages were defined (table 2).

When determining extent of deformation considered 2 and more indicators were taken (considered). So, in case of lack of an equines or valgus deformity of a calcaneal bone the data characterizing longitudinal arch of foot, forefoot abduction and other indicators were taken into account.

RESULTS AND DISCUSSION

Depending on nature of changes of foot shape three variants of PFD are allocated.

1. Equines plano-valgus deformity — a combination of an equines deformity of a calcaneal bone (displacement of its hindfoot in the proximal direction) from the pronation of foot and forefoot abduction. At the III stage of deformation stop gets the blotter form. In certain cases in this category of patients Hallux valgus is formed. Valgus deviations the calcaneal bones, as rule, it is not observed.

2. Plano-valgus deformity — the pronation of foot and forefoot abduction. Takes place valgus deviations of a calcaneal bone. Hyper mobility in talocrural and subtalar joints is noted. Longitudinal arch is absent at loading. All patients have Hallux valgus.

3. At the third variant the main component of deformation is pronation of foot in talocrural and subtalar joints. Forefoot abduction is absent or has a weak branch on loading. Hallux valgus is absent or poorly expressed, it is combined with the bending part of I toe of interphalangeal joint. The longitudinal arch on loading it is kept, and in extreme cases calcaneal foot is formed.

Table 1

Distribution of patients according to the age and the form of cerebral palsy

Cerebral palsy form	Age of patients, years				Total
	2—4	5—7	8—12	13—16	
Spastic diplegiya	17	16	8	10	51
Spastic tetraparesis	3	5	1	2	11
Hyperkinetic form	1	–	2	3	6
Total	21	21	11	15	68

Table 2
Angles of pronation foot deformity

Deformation indicator		Extent of deformation		
		I	II	III
Arch of foot, °	With loading	15—10	No	Negative value or none
	Without loading	20—25	5—10	
Valgus deviations of a calcaneal bone, °	With loading	5—7	8—10	>15
	Without loading	0—5	5—8	14—8
Mobility coefficient		1,5—1,45 or 1,55	1,4—1,35 or 1,6	<1,3 or >1,6
Navicular or talus angles, °	With loading	150	160—170	>170
	Without loading	<150	170—180	>180
Talocrural angle, °	With loading	<165	170—175	>175
Talus-calcaneal angle, °	With loading	<35	45—50	>50
Talus-medial angle, °	With loading	<10	10—15	>15

The clinical and radiological analysis of each of variants showed that the mechanism of their development has a number of differences.

Formation of an equines flat or equines plano-valgus deformity (1 variant) included displace of a calcaneal tubercle under the influence of triceps surae muscles up. According to the front part of a calcaneal bone containing articular facets on its front and medial surface (front and medial) for the corresponding articulate surfaces of the talus bone, it is displaced the medial side. By means of transfer of effort through interosseous talus-calcaneal and medial talus-calcaneal ligaments the front part of a talus bone is also displaced down and deviates in medial the party. The talus bone adopts the vertical provision. Ligaments on a rear surface talocrural and subtalar joints reduce owing to rapprochement of points of fixing. The talus bone through talus-navicular ligament displaces a navicular bone in plantar the direction and carries out its rotation to the middle. Owing to lig.bifurcatum tension the front part of a calcaneal bone displaces a cubical bone down and carries out its rotation in the medial direction. These processes are resulted by the pronation of foot and decrease in its longitudinal arch. The calcaneal bone at this type of deformation does not deviate in lateral the party. Owing to pathological influence of muscles of a extensor hallucis longus and extensor digitorum the forefoot is taken away. So, the main indicators of deformation are:

1) the vertical position of the talus;

2) displacement to plantar direction of navicular and cuboid bone, owing to what there is a reduction of longitudinal arch of the foot;

3) pronation of the foot.

The starting moment of deformation is a pathological action of triceps surae muscle on a calcaneal bone and extensor digitorum longus and extensor hallucis longus on phalanxes and, indirectly, on metatarsal bones of foot. Necessary condition of development of this deformation is weakness of the ligaments of foot which does not maintain loading on its plantar surface.

Plano-valgus deformity of foot (the 2nd variant) is formed as a result of the dominating influence of peroneal muscles. A long peroneal muscle, being attached to a tuberosity of I and a basis of II metatarsal bones, provides pronation of the foot, reducing at loading it longitudinal arch. The short peroneal muscle except the pronation takes away forefoot, but by the main force, causes taking away influence, is extensors of I toe and toes of foot. The specified muscles, indirectly, through Lisfrank's joint and wedge-shaped bones carry out rotation of a talus bone in and by means of pressure upon a calcaneal bone reject it outside. Thus the distance between articulate surfaces of talus-navicular, subtalar and talocrural joints on a medial surface of foot increases, stretching ligaments and reducing their on a lateral surface, is increases. Thanks to expressed pathological influences of muscles of foot Hallux valgus. As a result, key elements of deformation is pronation and forefoot abduction, the formation of Hallux valgus combined with high mobility in the joints of the foot.

At pronation installation of foot (the 3rd variant of deformation) main pathological action is muscles pronators, and force of a long peroneal muscle prevails. Weakening of the ligaments on a medial surface of talocrural and subtalar joints is caused by the extreme fixed of pronation of foot. The Longitudinal arch it is kept, it is in certain cases increased due to displace of rear of a calcaneal bone in the distal direction. Position of a talus bone in these cases the horizontal. The expressed retraction of the ligaments on a lateral surface of foot causes its rigidity. Hallux valgus is not noted. Flexion deformity of toes in interphalangeal joints is often observed. Forefoot abduction is moderate. Most

often this type of deformation is noted at patients with the hyperkinetic form of cerebral palsy or other forms which are followed by a high spasticity.

The analysis of a clinical course of separate variants of PFD showed that extent of deformation depended both on age of patients, and on nature of changes in joints and bones of foot. Fast progressing at 1 variant of PFD was noted. Thus the greatest number of cases of the II—III degree is noted aged from 2 till 6 years. At the 2nd variant of progressing of PFD was slower and the greatest number of cases was defined at the age of 9—12 years. For 3 variants it is characteristic quite quick start of its formation and the greatest number of cases from the II—III extent of deformation is noted at teenagers (fig. 1).

A certain sequence in increase of manifestations of separate elements of deformation during the different age periods was shown.

For the first variant of PFD initial manifestation of deformation was forefoot abduction in attempts of verticalization of patients, that is since 12—14 months of life. In process of increase in load of foot the equines deformity joined. Longitudinal arch of foot without loading it is lowered, and in vertical position of the patient — is absent. With a growth of body weight of patients increased an equines deformity of foot and change of a position of calcaneal and talus bones. Quite intensively — within 2—3 years, the volume of movements in joints of foot was reduced and its rigidity grew (fig. 2). During the first period of formation of this variant of PFD variability of changes of a angle of forefoot abduction was noted. So, when walking at some patients the angle of branch decreased, but in process of growth of patients it accrued and was stabilized irrespective of position of a body of the patient in space. The short interval of time (8—12 months) from the moment of verticalization of the patient to transition of PFD to the II—III degree with formation of negative value of the longitudinal arch of foot was characteristic of 1 variant of deformation.

Initial elemantamy by the PFD 2 variant were defined moderate decrease in height of the longitudinal arch of foot and valgus deviations of a calcaneal bone at loading. In process of growth of body weight there was a pronation of foot, valgus deviations of a calcaneal bone increased, and not only due to easing ligaments on a medial surface of an ankle joint, but also talocrural. Longitudinal arch of the foot without loading it is kept. Hyper mobility in talocrural, subtalar, talus-navicular and talus-cuboid joints was formed. Reached forefoot abduction at the II—III degree of PFD 20—30°. During the same period Hallux valgus was formed. That is, unlike 1 variant of PFD in this category of patients with primary element there was a pronation of foot, then adjoined forefoot abduction and Hallux valgus against weakness of the ligaments on a medial surface. A position of a calcaneal bone and talus bones in the sagittal plane without changes.

So, for this variant of PFD manifestation of the first elements of deformation at children after 4—5-year age was a distinctive sign, its increase occurred in process of growth of load of foot. The pronation of foot, forefoot abduction and valgus deviations of a calcaneal bone was the main component. There was a pronation of foot as in talocrural, and subtalar joints, Hallux valgus was formed.

The third variant of PFD was characterized by variability of elements of deformation. It was formed at patients aged after 6—7 years with high degree of a spasticity and at the cerebral spastic infantile paralysis hyperkinetic form, and also after carrying out an plastic surgery achilles tendon and a fiberotomy Ulzibat's by method. Existence of the kept or increased longitudinal arch as a result of an inclination of rear of a calcaneal bone in the distal direction was a distinctive sign. Formed calcaneal foot as a result of weakness of triceps surae muscle; extensor digitorum longus muscle and extensor hallux longus muscle has been reduce. As a result of this mechanism extensor contracture occurred in the ankle joint and flexor contracture — the I—III

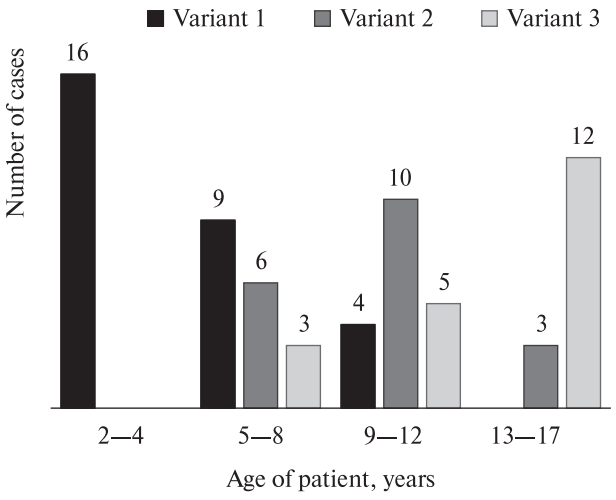

Fig. 1. ***Distribution of patients from the II—III extent of deformation depending on age and variant of PFD***

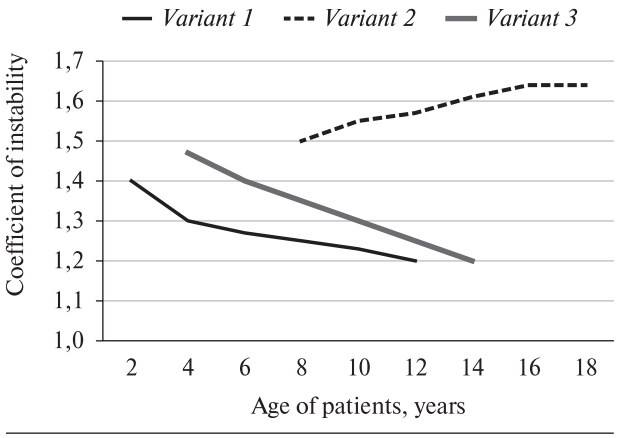

Fig. 2. ***Dependence of coefficient of instability on age of patients and variant of PFD***

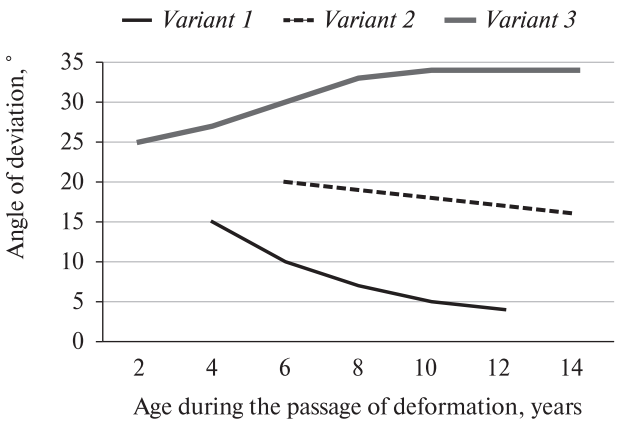

Fig. 3. ***A angle ratio between front part and rear of a calcaneal bone depending on variant of deformation and duration of a course of PFD***

toes. Rather slowly weight of deformation increased but the high rigidity foot was defined (fig. 3). In all cases 3 variants of deformation the external torsion of bones of a shin was noted.

The comparative characteristic of radiological indicators of the first variant of PFD showed existence increase talus and navicular angles depending on extent of deformation. Both with loading, and without it the vertical position of a talus bone was noted. With duration of a course of this deformation more than 3 years the shape of bones changed. The angle between front part and rear of a calcaneal bone to zero value was reduced. A navicular bone got the triangular shape with the basis turned in plantar and medial the parties. The size of a cubical bone after plantar and medial surfaces increased.

At the second variant of deformation the talus and navicular angle, and also an instep — a phalanx angle increased. Changes of a shape of a calcaneal bone the horizontal position of a talus bone was not noted, remained. Observed deviation of a calcaneal bone outside to 10—15°. At the same time the shape of bones of a tarsus even changed at the III extent of deformation a little.

The third variant of deformation was characterized by increase in a angle between front part and rear of a calcaneal bone, and also a plantar-calcaneal angle. The talus bone at the III extent of deformation took a horizontal position due to shift of its back surface in the proximal direction. The shape of navicular and cubical bones changed a little. An metatarsus-phalanx angle was neutral.

Extent of deformation of bones of a tarsus was directly proportional to duration of a course of PFD and depended on its variant and age of the patient. So, at 1 variant of PFD change of a shape of bones of a tarsus it was noted at the age of 4—5 years and at the II extent of deformation. On the contrary, at the 3rd variant of change of a shape of bones of a tarsus occurred during later period, at the age of 14—17 years and lasting deformation more than 7—8 years (fig. 3).

Thus PFD is multicomponent and multifactorial deformation. Its form is influenced by character of a muscular imbalance, a condition of the ligaments, speed of increase of weight of deformation and change of a shape of bones. A clinical course of PFD it is caused by age of patients, body weight and physical activity.

It should be noted that the described changes are important in respect of the forecast of a course of deformation and a choice of a method of treatment. For example, at the shape of bones moderated change perhaps conservative treatment or restrictions of surgery only elimination of a muscular imbalance and strengthening of the ligaments. At profound changes of the bone device operation needs to be added with intervention on bones and joints.

CONCLUSIONS

The main causes pronation foot deformity are muscular imbalance, changing the shape of bones during growth and weak ligaments. Depending on their displays strain of deformation occurs in three main variants, the characteristics of which are condition of the longitudinal arch of the foot, the degree of pronation and forefoot abduction.

Deformation of the foot bones was changing their shape, position talus and calcaneus bone in the sagittal and horizontal planes and the formation of Hallux valgus. The nature and severity of bone changes affect the degree of violation of muscle tone, option and duration of flow strain of deformity and age of the patient.

Volatility factor of the foot can objectively assess the condition of ligaments, nature of muscle imbalance and level of violation muscle tone. This indicator primarily depends on the variant of the PFD, the patient's age and form of cerebral palsy.

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О. А. Данилов, О. В. Шульга, В. В. Горелік, Дж. Абдалбарі
Національна медична академія післядипломної освіти імені П. Л. Шупика, Київ

МЕХАНІЗМ ФОРМУВАННЯ І КЛІНІЧНИЙ ПЕРЕБІГ ПРОНАЦІЙНОЇ ДЕФОРМАЦІЇ СТОП У ДІТЕЙ З ЦЕРЕБРАЛЬНИМ ПАРАЛІЧЕМ

Мета роботи — визначити основні механізми формування та клінічного перебігу пронаційної деформації стоп у дітей різних вікових груп, хворих на церебральний параліч.

Матеріали і методи. Проаналізовані дані, отримані при лікуванні 68 хворих віком від 2 до 16 років. У всіх випадках відзначено двобічну пронаційну деформацію стоп. Клінічні методи передбачали визначення позиції п'яткової кістки (вальгусна, еквінусна установка в градусах), пронацію стопи і відведення її переднього відділу, стан поздовжнього склепіння при навантаженні та в положенні лежачи. Ступінь мобільності стопи визначали за коефіцієнтом.

Результати та обговорення. Залежно від характеру змін форми стопи виділено три варіанти пронаційної деформації стоп. Еквіноплосковальгусна деформація — поєднання еквінусної установки п'яткової кістки (зміщення її заднього відділу в проксимальному напрямку) з пронацією стопи і відведенням її переднього відділу. Плосковальгусна деформація — пронація стопи поєднується з відведенням її переднього відділу та вальгусним відхиленням п'яткової кістки. При третьому варіанті основним компонентом деформації є пронація стопи в надтаранному і підтаранному суглобах. Відведення переднього відділу немає або слабко виражене при навантаженні.

Висновки. Пронаційна деформація стоп — це тяжке ускладнення дитячого церебрального паралічу, що обумовлює порушення статики і локомоції ходьби, посилює рухову недостатність. Залежно від характеру м'язового дисбалансу, стану зв'язкового апарату, швидкості прогресування деформації вирізняють три варіанти її розвитку. Клінічний перебіг пронаційної деформації стоп обумовлений віком хворих, масою тіла і руховою активністю.

Ключові слова: пронаційна деформація стоп, діти, церебральний параліч, плосковальгусна деформація.

А. А. Данилов, А. В. Шульга, В. В. Горелик, Дж. Абдалбари
Национальная медицинская академия последипломного образования имени П. Л. Шупика, Киев

МЕХАНИЗМ ФОРМИРОВАНИЯ И КЛИНИЧЕСКОЕ ТЕЧЕНИЕ ПРОНАЦИОННОЙ ДЕФОРМАЦИИ СТОП У ДЕТЕЙ С ЦЕРЕБРАЛЬНЫМ ПАРАЛИЧОМ

Цель работы — определить основные механизмы формирования и клинического течения пронационной деформации стоп в разных возрастных группах у детей, больных церебральным параличом.

Материалы и методы. Проанализированы данные, полученные при лечении 68 больных в возрасте от 2 до 16 лет. Во всех случаях отмечалась двусторонняя пронационная деформация стоп. Клинические методы включали определение позиции пяточной кости, пронацию стопы и отведение ее переднего отдела, состояние продольного свода при нагрузке и в положении лежа. Степень мобильности стопы определяли по коэффициенту.

Результаты и обсуждение. В зависимости от характера изменений формы стопы выделено три варианта пронационной деформации стоп. Эквиноплосковальгусная деформация — сочетание эквинусной установки пяточной кости (смещение ее заднего отдела в проксимальном направлении) с пронацией стопы и отведением ее переднего отдела. Плосковальгусная деформация — пронация стопы сочетается с отведением ее переднего отдела и вальгусным отклонением пяточной кости. При третьем варианте основным компонентом деформации является пронация стопы в надтаранном и подтаранном суставах. Отведения переднего отдела нет или слабо выраженное при нагрузке.

Выводы. Пронационная деформация стоп является тяжелым осложнением детского церебрального паралича, что обусловливает нарушение статики и локомоции ходьбы, усиливает двигательную недостаточность. В зависимости от характера мышечного дисбаланса, состояния связочного аппарата, скорости прогрессирования деформации выделяют три варианта ее развития. Клиническое течение пронационной деформации стоп обусловлено возрастом больных, массой тела и двигательной активностью.

Ключевые слова: пронационная деформация стоп, дети, церебральный паралич, плосковальгусная деформация.