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STUDY OF THE ANATOMY, PATHOLOGY AND RECOVERY OF THE ADDUCTED EQUINOVARUS FOOT

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Abstract: *The equinovarus foot is a deformity of the foot sole that can be described as an imperfect contact to soil in both shape and position. It appears as a static and dynamic disorder caused by genetic modifications of human organism. The incidence of vicious positions, malformations of lower limbs is reduced but the lack of information and of appropriate amelioration and recovery programmes can determine painful reactions and discomfort possibly leading to visible physical deficiencies which could result in patient inferiority complex. Correction of deformities in the affected foot will be accomplished by means of adequate programmes which include procedures using gypsum devices along with adequately devised, dosed and correctly applied recovery exercises.*

Keywords: *physical deficiency, talocrural joint, equinovarus, forefoot, hindfoot.*

1. Topicality

The equinovarus foot is described as the presence of vicious foot positions representing the most frequent malformations of lower limbs. The absence of information leads to a delayed screening of this congenital deformity, whose frequency is about 80%. The absence of adequate programmes for physical deficiencies recovery can produce imbalances in the organism. Social and professional integration of the affected subjects is difficult when considering the absence of many useful capacities during an affected person's life.

2. Assumption

By early screening of the equinovarus foot – of the physical deficiencies in general – adequate rehabilitation and amelioration programmes can be devised which will also contribute to a more accelerated social and professional integration of affected subjects.

3. Research goals:

- determining the pathogenesis of the adducted equinovarus foot;
- evaluation of the impact of early diagnosis and recovery programmes on the progresses accomplished in the amelioration of this deficiency;

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- evaluation of the impact of amelioration and recovery of this type of deficiency on the affected person's social and professional integration.

4. Description of equinovarus foot

The equinovarus foot implies a deformity of the foot sole including shape and position alterations resulting in an imperfect ground contact. In this case support is accomplished on the lateral and forward border of the foot (forefoot), "the longitudinal axis of the foot being rotated outwards". It can be: congenital or therapeutic and has the aspect of a foot with inward turned front and outward turned heel. The interior muscles of the lower leg are shortened, while the exterior muscles are weakened and stretched" [3].

The talocrural joint (ankle) is equine and the sole (foot) is in supination (varus) and adduction. The navicular is displaced medially, like the cuboid, and soft tissue contractures can be felt on the medial side of the sole. The calcaneus is in equine position, its frontal face is rotated medially while its posterior face is turned laterally. The heel is small and hollow. The heel feels soft when palpated. With the treatment in progress, it develops and feels harder. The neck of the talus is easy to palpate since it is laterally free. Normally it is covered by the navicular bone. The medical malleolus is difficult to palpate, and is often in contact with the navicular. The normal spacing between navicular and malleolus is diminished.

5. The anatomy of the normal foot:

The foot skeleton consists of 26 bones grouped in three distinct groups: tarsus – 7 bones, metatarsus – 5 bones and 14 phalanxes – the hallux has 2 and the remaining toes 3 each.

The tarsus:

- the *posterior tarsus* composed of talus and calcaneus
- the *anterior tarsus* composed of navicular, 3 cuneiforms and cuboid.

Important joints:

- the talocalcanean joint
- the mediotarsian joint (Chopart join).

Concerning the normal foot position and the position of its bones, we can identify:

The medial / tibial radius

- talus
- navicular
- 3 cuneiforms
- I, II, III metatarsians.

The lateral / fibular:

- Calcaneus
- cuboid
- IV, V metatarsians.

The medial radius forms the arch of the foot which is supported by 3 extrinsic muscles: anterior tibial, posterior tibial and peroneal (thigh) long" [14].

The pathological anatomy of the equinovarus foot:

- the tibia – possibly shorter

The tarsian bones:

- equine adducted talus, talus body in external rotation and palpable, neck of the talus is medially rotated and in plantar flexion.
- The calcaneus – in adduction, laterally rotated and equine
- The navicular – dorsal subluxation and flattened
- The cuneiforms (3) – in adduction
- The cuboid – laterally rotated and adducted
- The metatarsian bones (5) – in adduction and supination; in grave cases presenting a hollow foot with the first metatarsus dropped.

Between talus and calcaneus there is normally an angle of 20 to 40 degrees while talus and first metatarsian normally form a 15^0 angle.

The muscles are atrophied, especially the peroneal muscle. The number of muscle fibers is normal but these are of smaller size. The muscles: sural triceps, posterior tibial, toes long flexor and long flexor hallucis are contracted. The sural triceps and plantar muscles are smaller in size and will remain unchanged for the rest of the life. The ligaments: calcaneofibular, anterior and posterior talofibular, medial collateral (deltoid) are contracted. Also, the plantar fascia is contracted.

- The <VAR> component presupposes:
  - adduction of forefoot over the hindfoot
  - adduction of the hindfoot
  - the plantar plane and the ground plane form a medially open angle.
- The <EQUINE> component presupposes: the lower leg axis and the forefoot axis form a ventrally open angle.[14]

6. Incidence

In Caucasian populations the equinovarus foot has an 1:10.000 incidence in newborn babies, "in case of first degree relatives of around 2%, in case of second degree around 0,6% while in monozygotic twins if one the twins has this deficiency the other will have it too with a 32% probability". Its occurrence is higher in male subjects and in 40% of cases it is bilateral [10].

7. Clinical forms

- the *equinovarus attitude* occurs, in general, in newborns, in form of congenital clubfoot
- the partially reducible equinovarus foot occurs in suckling infants and toddlers (1 – 3 years).
- the inveterate equinovarus foot occurs in school children and teenagers

In suckling infants, the equinovarus foot is not painful "but gradually, during growth, it causes discomfort and becomes a visible physical deficiency which induces a psychical inferiority complex in patients. In the absence of treatment the affected limbs may become permanently deformed, which leads to limb inequality. Therefore, early treatment, increases the chances of amelioration and reduction of deformities that are threatening balance and coordination of walking" [12].

"If in family is born an infant with an equine spastic foot, there are high chances for a second-born to develop this affection. The neurological equine foot may indicate other health problems, as it can be associated with spina bifida.

Occasionally, echographies during intrauterine life can diagnose the presence of equinovarus foot. Among other imagistic techniques employed in ascertaining the existence of equinovarus foot, radiography is unsuitable for correct diagnosis, since some of the foot bones or foot joints are incompletely ossified". [12]

The true etiology of the congenital clubfoot is idiopathic."Histological studies of the terminal medullar lumbar segment conducted on fetuses with unilateral congenital clubfoot have shown delayed closure of the neural canal between 16^{th} and 24^{th} gestation weeks, at level L5. Also, it indicates immaturity at the L5/S1 level, which consists in the persistence of rich capillaries, corresponding with a dorsally open aspect, neuroblasts and neuroepithelial cells, in comparison with the motor ventral side with inflammatory

cells. The deformity side is characterized by a marked reduction of motoneurons and shows advanced chromatolysis. The modifications involve the anterior motoneurons afferent to the lower leg and foot muscles. Some authors imply an intrauterine viral infection in the etiology of the disease as an explanation to medullar modifications and secondarily, the orthopedic ones.

Currently, the evidences are in favour of an inervation imbalance, as primary factor. A muscular imbalance can produce large deformities, especially in case of early uterine development. Most patients exhibit abnormal electrophysiological test results, which are considered an excellent prognosis factor therefore in grave cases thorough medical testing will be conducted. The peroneal nerve affection requires a subsequent therapy planning for the transfer of the anterior tibial tendon to the anterior – external level of the foot." [13]

8. Pathogenesis

"The equinovarus foot presents a static and dynamics disorder of the organism. It occurs as a consequence to genetic modifications of the DNA structure during the stage of intrauterine life or alternatively it is subsequent to a muscular imbalance between agonic and antagonic muscles" [14]

Further causes

- **Fibular** defects during intrauterine life
- **Cartilage** defects of the talus during intrauterine growth
- **Neurogenetic factors** – during intrauterine life the fetus can suffer a cerebral vascular accident which can lead to light hemiparesis or paraparesis. Therefore, the equinovarus foot can be associated with spina bifida in 35% of the cases; "disorders of neuromuscular junctions or the connection of the peripheral motor neuron with the extrapyramidal system" [7];
- **Myofibrosis** – the pressure of the fibrous tissue in muscles and ligaments. During his fetal and studies on corpses, Ponseti found collagen in all tendinous and ligamentous structures (except for the Achilles tendon), these were very soft and loosely wound so they could be stretched. On the other hand, the Achilles tendon, was presenting tightly wound collagen and was resistant to stretch.
- **Abnormal tendon insertions** – while it is more probably that the clubfoot anatomy will make these seem abnormal tendon insertions.

9. The treatment

In order to achieve reducing of equinovarus foot deformity, various procedures are applied on the muscle groups including: the use of gypsum devices – the Ponseti method, use of special shoes, use of Denis Browne, abduction splints in cases of paralysis, alcohol infiltrations and botulinic toxin Dysport A can be used. "Long-term kinetotherapy is particularly important in young children equinovarus foot treatment since it can be applied from the newborn's first week of life in order to take advantage of the elasticity of the issues forming the capsules, ligaments and tendons. These tissues can be stretched by gentle

manipulations. Subsequent to manipulations, a plaster cast is always applied extending above the knee in order to preserve the correction achieved through manipulation. Thus, the displaced bones are gradually brought in the correct position." [12]

"The arthroses of the foot are in most cases secondary to static disorders such as: hollow foot, flat foot, talus valgus foot, talus varus foot, genu varum foot, congenital malformations (synostoses, condrodysplasia) and poliomyelitis sequels. [15]

The nonoperative treatment should begin preferably 2 – 3 days after birth "to take advantage of the elasticity of the tissue forming the ligament, capsule and tendons. These tissues can be stretched by gentle manipulation. Subsequent to manipulations a plaster cast is always applied extending over the knee in order to preserve the correction achieved through manipulation. Thus the displaced bones are gradually brought in the correct position."

This aims at the following:

- Correction of forefoot adduction
- Correction of hind foot adduction
- Correction of varus – will be carried out at maximum limit
- Correction of equine – will be achieved slowly and gradually, avoiding ischemia
- Stabilization is achieved through kinetotherapy and passive immobilization. [14]

10. The Ponseti method

i. The internal rotation of the calcaneus (adduction) and the plantar flexion are the key deformities of the adducted foot. The goal is to achieve foot abduction and dorsiflex it which allows the calcaneum to freely rotate under the talus. This correction is accomplished under the normal arc of the subtalar joint and is carried out as follows: the index finger of the operator is placed on the medial malleolus is order to stabilize the joint while placing the thumb on the lateral side of the talus head thus abducting the forefoot.

ii. The foot cavus growth when the forefort is pronated; if cavus is present, the first step is to supinate the forefoot by lifting the first metatarsal.

iii. Pronation prevents rotation of the calcaneum under the talus and it stays in varus.

The plaster cast is applied on the whole length of the lower leg to preserve the correct position. For better adherence, tincture of benzoin is applied. The lateral aspect of the talus is molded with plaster.

Between five to six plaster casts should be sufficient for the correction of a normal equinovarus foot. Even the most rigid cases will require no more than 8 or 9 casts. Before applying the last cast, percutaneous transaction of Achilles tendon must be performed in order to complete foot correction. After the surgical intervention, the foot is immobilized between 3 and 4 weeks to allow for complete regeneration of the tendon at its optimum length.

"The treatment is intended for achieving normal foot aspect and functionalities" [12]

The forcible correction of cavus and equinovarus foot through dorsiflexion opposing the contraction of Achilles'

tendon results in a compensated reduction of the hindfoot which produces a deformity known as "vertical talus".

Foot adduction correction requires 6-7 casts. After achieving maximum abduction a final cast is applied to keep the foot in maximum dorsiflexion for 2-3 weeks.

11. The Denis Browne abduction splints

Subsequent to manipulation and plaster casts application, the Denis Browne splints are employed to keep the affected foot in 70° abduction while the healthy foot is kept in 45° abduction. The device is used 23 hrs/day for 3 months and afterwards only during sleep for a period of 3 years.

Between 10 – 30% of the cases, a tibialis anterior tendon transfer to the posterior lodge is achieved around 3 years of age to prevent metatarsus adduction. This procedure is recommended in children aged 2 – 2.5 years presenting dynamic supination of the foot.

12. The Ilizarov correction technique

It is employed in congenital adducted equinovarus foot in association with special conditions such as arthrogryposis. The calcaneum is supported by two opposing pins. The developed forces must be directed rearwards in order to avoid anterior talus subluxation.

13. The surgical treatment

A very important therapy method is orthopedic surgery, which is indispensable for certain cases. However, in children with major deficiencies, this type of treatment can entail new risks. A first step envisages soft tissue interventions (muscles, ligaments) while in a second phase modification of osseous structures is considered since these require resections-arthrodeses.

1. Types of approach

- Dorsal
  - elongation of the Achilles tendon- is performed only in cases of spastic retraction of the former

Achilles tendon elongation should not be performed if the tricipital spasm can be contained through kinetotherapy If the equinovarus foot degree remains unchanged, the Scholder technique appears more appropriate. For a 7 -15 degrees equine with little variations depending on knee flexion, Achilles tendon insertion aponeurosis transection should be applied. The transection is performed on the muscular insertion fibrous elements forming the Achilles tendon end. For all cases, immobilization should be continued 4-6 weeks depending on age and evolutions. In cases of genu flexum, especially in young children, the knee should be immobilized in extension. The equinovarus foot should be resolved at younger ages through simultaneous elongation of the posterior tibial tendon. (17).

  - arthrotomy/talocalcanean syndesmolysis.
- Dorsomedially
  - Medial radius syndesmolysis, deltoid ligament transection
- Dorsolaterally
  - Plantar disinsertion
  - Longitudinal mediotarsal syndesmolysis

✸ Lateromedially
- Protarsal syndesmolysis
- Plantar disinsertion (14)

Surgical treatment should be applied only if non-surgical methods have failed.

2. Therapy treatment

Different methods can be used:

The Bobath method
- is applied in patients with cerebral, central neuromotor injuries
- is intended for combatting spasticity; e.g. "the distal lower limb extension spasticity is combatted by applying external rotation hip and knee abduction along with ankle and toes dorsiflexion and hallux abduction"[8]

The Kabat method
- uses proprioceptive techniques for neuromuscular facilitation
- uses global motion patterns for proprioceptive facilitation

The Kabat facilitation patterns are:
- passive
- active
- active-passive
- active, with resistance.

"It is intended for muscular function facilitation and achievement of stronger muscular contractions compared to those obtained through voluntary effort, by using various proprioceptive stimuli and voluntary contraction with maximum effort against maximum resistance" [20]

Other methods applied in physical deficiencies recovery using a range of devices or special physical training complexes are: mechano-therapy, pulley therapy, suspension therapy, hydrokinesis, aerobics, sports therapy, shiatsu, stretching etc.

Sport therapy is aimed at "increase of motor coordination and control as well as dosed effort training". [8] Some of the most applied sports therapies are: swimming, skating, cross-country skiing, golf, tennis (field & table) etc.

Frequently used devices and equipments:
- treadmill
- stepper
- ergometric bicycle
- elastic bands
- wall ladder.

16. Recovery exercises

These can be: active, passive, active-passive, passive-active.

✸ **Static exercises**

i. Sit on the floor with spread flexed knees (between the lower legs), with the sole medially resting on the floor and the plantar face rearwards, hands on thighs – maintain position.
ii. Lie face down, perpendicular to wall ladder (feet on ladder), with support on forearms, grab a ladder step (40 cm high) with the big toes – maintain position
iii. Lie face down, legs spread, inner edge of sole resting on floor – maintain position
iv. Lie sideways, with forearm support, hold a medicine ball at the level of plantar medial edge – maintain position (the affected foot is underneath to achieve abduction)
v. Balance on a knee, with support on hands, affected foot extended rearwards to grab with toe tip a ladder step – maintain position.
vi. Sit with affected leg laterally flexed, sole on the floor, resting on its

interior edge, torso bent forward – maintain position

vii. Kneel and sit on heels, arms extended upward resting on wall or ladder – maintain position

viii. With back to wall, lie face down with hands on a stool and unaffected leg on wall – maintain position (affected leg should have floor contact with most of plant)

ix. Stand sideways to the wall ladder at about 1 m distance, the affected leg extended and resting on the inner edge of the sole on the ladder, at pelvic height, the arm on the corresponding side rests on wall ladder – maintain position (affected leg in abduction)

x. Stand in side lunge, hands on hips, healthy leg with knee flexed, affected leg extended, ground contact on inner sole edge (foot in abduction) – maintain position (hands can rest on wall or on ladder)

xi. Sit on stool or on floor, affected foot flexed and resting on the healthy knee; hand on the side of affected foot rests on the knee of the latter, the other hand grabs the foot and pulls it in forward direction – maintain position for 5 – 10 s and repeat 3 times

xii. From the same position, extend and twist foot outwards – maintain position for 5 – 10 s and repeat 3 times.

✸ **Dynamic exercises**

i. Normal walking (plantar face with maximum contact to floor) – use adequate shoes and support (walk near to wall, use a rail for support etc.)

ii. Walking on inner edge of foot

iii. Sit on knees, legs spread, arms laterally extended, move back and forth while sitting between lower legs with support on elbows

iv. Lie sideways, with forearm support, affected leg above, perform triple extension of lower limb and touch ground with toe tip

v. Lie face down, arms extended upward, lift affected foot in flexion, grab tip of foot with opposite hand, opposite arm stays extended

vi. Lie on backside, with support on forearms, perform alternate leg lifts, 45° leg lift.

vii. Lie on backside, form "bridge" position with floor contact on shoulder blades, keep most of sole in ground contact, hands are grabbing the ankles, return

viii. From squat position, forward lunge, unaffected leg extended rearwards, affected leg with most of sole in ground contact, return

ix. Lie on backside, perpendicular to wall ladder at 1m distance (head faces the ladder), transition to "shoulder blades on the floor" with flexed knees, roll rearwards and grab a ladder step (40 cm high) with tips of feet, return

x. Sit on your knees, move affected leg sideways, resting on the interior edge of the foot, arching and return (arms can rest on the thigh of the performing leg, for balance)

xi. Laying on your back, perform passive and active leg flexions / extensions

xii. From ventral decubitus, lower leg flexion over thigh (burdened) with orthopedic shoes.

Exercises adopted from various sports

i. Roller skating
ii. Alpine skiing – legs apart, propped on sticks, knee flexing while exerting, pressure with the affected leg on the inner ski edge, return
iii. Cross – country skiing – slide walking (ski sticks can be used)
iv. Swimming – in a shallow pool, the patient seated on a stool or pool step with the sole in good contact with ground perform gentle abductions
v. Swimming – walking through water on the inner edge of foot
vi. Soccer – standing beside a ball, push the ball with the exterior edge of the foot about 1 – 2 m.

17. Conclusions

i. The incidence of congenital equinovarus addus foot is very high in development countries – 1 : 1000 live newborns
ii. Impossibility of early screening of this affection, during intrauterine life unless fetal ecographs are performed
iii. The non-surgical recovery treatment – through therapy – includes following steps: forefoot adduction, forefoot supination and equine will be corrected slowly and gradually.

Recommendations

1. Performing fetal echographies during pregnancy for early screening of physical deficiency
2. Starting non-surgical treatment using plaster casts 2-3 days after birth
3. Surgical treatment must be always associated with therapy.

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