Neurological foot deformities: is surgery the only way?

NÉJIB KHOURI
Pediatric Orthopedic Surgery department
Necker-Enfant Malades university hospital 75015
Responsible for the gait analysis unit
CRF Ellen Poidatz foundation 77310 Saint Fargeau – Ponthierry
nejib.khouri@gmail.com

Introduction

Every foot deformity should be studied and assessed relative to the overarching aspect of the entire lower limb and the patient's global functional and mental capacities. Deformities and malpositioning of the limbs are secondary to muscular disequilibrium induced by the central neurological disorder (weakness in certain muscle groups, excessive or anarchic contractions, spasticity). Postural collapse in the standing position and inapt positioning compound this deforming effect. In children during growth, constant muscular imbalance leads to structural osteoarticular deformities.

The orthopedic or surgical treatment of a neurological foot deformity relies on assessing muscular imbalances and the reducibility of the deformity. In ambulating children, two biomechanical parameters should also be evaluated: knowledge of the foot's rockers during gait and the foot-flexion/knee extension couple. In children with limited ambulation or those who are wheelchair-dependent, the patient's ability to tolerate the deformity while bearing weight will guide treatment.

Furthermore, surgical treatment is not optimal until it is accompanied by an adapted orthosis and, inversely, an orthosis may not be tolerated until the foot's deformity is surgically corrected. In this chapter, foot deformities that are primarily related to cerebral palsy and other related deformities will be discussed.

Emphasis: Understanding the plantar flexion/ knee extension couple (fig.1)

In the middle of stance phase, ground reaction forces are in front of the ankle and knee. While knee stability is a passive phenomenon, it is dependent on the foot's orientation in the sagittal and transverse planes relative to the axis of knee flexion/extension. If the foot is in the axis of the body's progression, the knee extension vector will be maximal. Inversely, if the foot is in external rotation relative to the knee, the extension vector will be impeded.

The foot's position in external rotation may be due to an intrinsic valgus deformity of the foot, hindfoot valgus, or an external tibial torsion. These deformities may be concomitant, and the physician should be able to determine their respective roles.

This schematic stability of the knee is adjusted by the actions of surrounding muscles. The soleus is not a plantar flexor of the ankle. When the foot is plantigrade during the second rocker, the soleus actively works off-center to hold the tibia back and prevent its forward inclination, thus functioning as a knee extensor. This is known as the plantar flexion/ knee extension couple. This normal coupling requires a foot with normal functioning, structure, and alignment and a normal gastrocnemius-soleus complex. These pathological situations may affect one or all of these conditions thus leading to either excessive or insufficient coupling; In the case of triceps spasticity or contractures, the knee may hyperextend during midstance over a well-aligned foot. The plantar flexion/ knee extension couple may also be insufficient and contribute to ambulate in crouch gait.

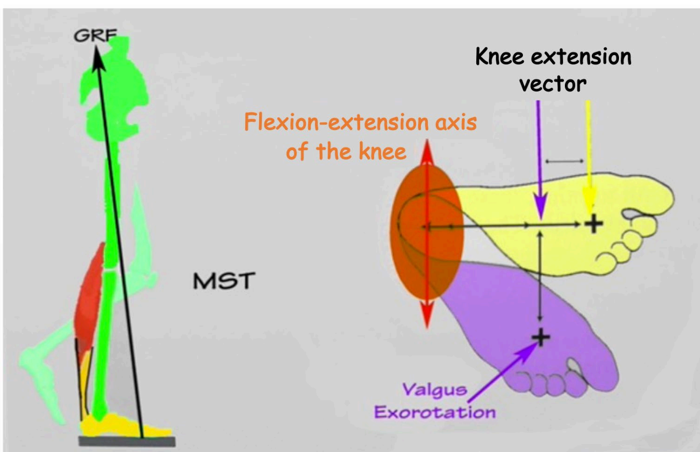


Figure 1. The plantar flexion/knee extension couple. By J. Perry 2010, J. Gage 2004, F. Miller 2004

2. The role of devices

"Short walking" orthoses play an increasingly important role, thus replacing orthopedic shoes. Every orthopedic surgeon treating a pathological foot deformity should have deep knowledge in the mechanical concepts, manufacturing process, and care of orthoses. For years, rigid orthoses were more frequently employed. However, this type of orthosis could not be used in all patients. As a result, over the years, a large selection of new types of orthoses have been developed. Conversely, the terminology and the indications of some of these types of orthoses have muddled the picture.

2.1 Terminology

In France, orthoses are defined either by their superior and inferior anatomical limits or by the bony segments that these limits envelop: e.g., an orthosis may be called a sural-pedal or calf-foot orthosis. The internationally adopted terminology includes the joints that are supported by this orthosis, such as an Ankle-Foot orthosis.

2.2 Quality-assessment criteria

Respecting "useful" mobility. The walking ankle-foot orthosis should, to the extent possible, respect the mobility of the ankle during stance phase, either completely or partially. In the latter, the 3 rockers may serve as a guide.

The search for a functional aid represents the surgeon's second goal. The principle of plantar flexion/ knee extension couple should be applied. Patients with a plantar flexor deficit limiting the ability to reduce tibial forward inclination will have a hyperflexed ipsilateral knee. Ankle foot orthoses controlling this inclination will thus reduce knee flexion and improve quadriceps function and knee stability.

2.3 Different types of orthoses

The rigid or soft nature of the orthosis and the presence of an anterior or posterior window or ground reaction moment should be specified. It should be noted that most orthoses have similar indications:

- Allow proper heel strike
- Stabilize the ankle and leg
- Limit drop foot

Rigid ankle foot orthoses

Most common types

The advantages:

- Prevents the activation of the triceps surae stretching reflex due to the second rocker
- Initiates knee extension during stance phase (due to the plantar flexion/ knee extension couple).

The disadvantages:

- All 3 rockers are blocked

Flexible Orthosis

Leaf Spring flexible orthosis (fig. 2)

The advantages:

- Allows all 3 rockers due to its relative softness, although they remain somewhat limited.

The disadvantages:

These are the opposite of its primary qualities:

- Hindfoot is not strictly maintained
- Insufficient control over triceps tightness
- Absence of Plantar flexion/ knee extension couple

The articulated ankle foot orthosis (fig. 3)

The type of hinge used varies:

the Gillette type is too soft; the most-frequently used Tamarak type opposes medio-lateral foot instability.

Adjusting the flexion-extension angle is achieved via a posterior tuning device.

The advantages:

- The second rocker is possible, and third rocker is partial
- The plantar flexion/ knee extension couple can be more precisely adjusted

The disadvantages:

- It is not indicated for patients with a spastic triceps
- The plantar flexion/ knee extension couple remains insufficient to counteract crouch gait

Figure 2. Leaf Spring flexible orthosis
Figure 3. Articulated ankle foot orthosis

Ground reaction ankle foot orthoses (fig. 4)

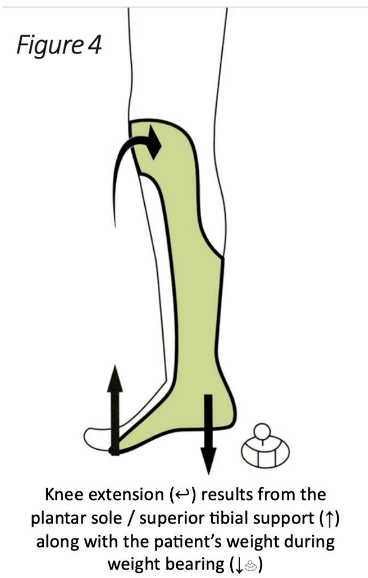
There are two subtypes: rigid or articulated

The advantages:

- The effects of the plantar flexion/ knee extension couple are pushed to the extreme: It is the primary orthosis used to counteract crouch gait deformity.

The articulated ground reaction ankle foot orthosis (Rear Entry) (fig. 5) is the most original but most limited in its indications. It allows plantar flexion, thus a proper first rocker. Its use is conditioned by adequate control over the ankle dorsiflexors.

The rigid ground reaction ankle foot orthosis (fig. 6) helps with function but at the price of a complete loss of ankle mobility.



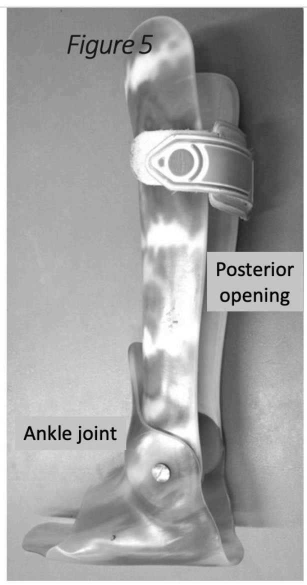


Figure 4. Principle of ground reaction moment
Figure 5. Articulated ground reaction ankle foot orthosis (Rear Entry)

The evolutive hinged ground reaction ankle foot orthosis (fig. 7)

This orthosis assists with knee extension while allowing evolving and precisely adjustable ankle mobility due to a posterior device.

This mobility of a liberated ankle allows a proper first rocker of the foot (downward motion of the food at initial contact) and a third rocker (propulsion of the triceps). The use of an anterior tibial shield along with the ankle angular adjustment apparatus will transmit the force vector toward the knee in an effective and consistent manner.

This orthosis may be used in CP patients with or without drop foot during the swing phase, with stiff or flexible feet, and with or without a correctly motorized foot. It assists in knee extension during single support phase (plantigrade foot), while respecting a possible extension deficit at the level of the knee or the hip, with the adjustments for a proper plantar flexion or dorsiflexion being made precisely and independently.

The materials with which these orthoses and hinges are fabricated are constantly evolving. Although dialogue with the prosthetist is invaluable, it falls on the orthopedic surgeon to specify the mechanical orientation that would be most suitable for the orthosis.

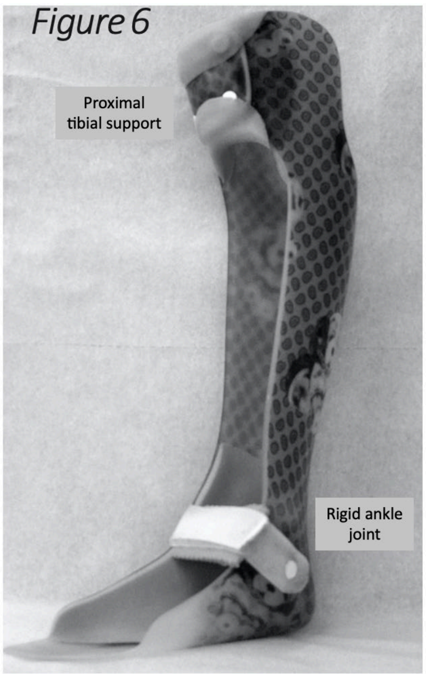


Figure 6. Rigid ground reaction ankle foot orthosis
Figure 7. Evolutive hinged ground reaction ankle foot orthosis

2.4. Summary of indications

A rigid orthosis is useful especially if there is triceps contracture with a foot that is globally inappropriately motorized. A flexible orthosis is indicated in case of drop foot with or without stiffness.

A hinged orthosis is especially useful if the plantar flexors are both flexible and active. A ground reaction orthosis counteracts crouch gait: A rigid orthosis if there is drop foot during the swing phase, hinged orthosis if not.

The evolutive hinged ground reaction orthosis adapts to different types of gait with a hyperflexed knee during midstance.

3. Medical and surgical debate around PES VALGUS

There is not one but many types of pes valgus. The deformity may be either simple or complex affecting each segment and joint of the foot:

- Subtalar reducible or fixed valgus
- Midtarsal soft or deformed
- Forefoot in abduction and supination
- Ankle soft and in equinus

They are often due to an imbalance between a hyperactive and contracted triceps with a weak posterior tibialis muscle and spastic peroneus muscles. These deformities are often associated with rotational deformities of the lower limbs. They decrease the foot's mechanical effectiveness during push-off when in stance and during gait and may cause skin impingement and pain while bearing weight. Management depends on muscle balance, functional level (ambulating or not), patient maturity, and global mechanics of the lower limbs. Soft deformities in valgus in children can initially be treated by orthoses (molded, plastic ankle foot orthoses). Botulinic toxin injections at the level of the fibularis longus may decrease its everting action. However, as the patient ages, valgus foot deformities are less well tolerated and usually fail conservative management.

Two therapeutic options could thus be considered depending on the patient's active mobility.

Limited active mobility (inadequate or lack of selectivity, weakness, co-contractions):

- Mature stiff foot: reconstruction, triple arthrodesis
- Soft foot: subtalar fixation and talonavicular arthrodesis

Proper active mobility and reducibility:

Osteotomies adapted to the deformity: calcaneal lengthening, calcaneal translation with osteotomies of the medial cuneiform, midfoot tarsectomies…

Surgical procedures on the triceps and peroneus brevis muscles and tendons are often associated. The peroneus longus is never lengthened. A spastic triceps muscle should be previously treated by botulinic toxin injections. Treatment success depends on:

- Correction of other associated deformities which hinder gait if the subject is ambulating.
- The choice of appropriate orthosis depends on the mechanics of the foot and the subjacent joints. It should be noted that these interventions do not replace a properly indicated diurnal orthosis due to the muscular imbalance.

These treatment strategies in the growing child ensure that the foot develops properly and removes cutaneous impingement at the level of the weight bearing foot. Furthermore, the proper correction of the foot and use of device is mechanically very effective.

4. Medical surgical confrontation around crouch gait (Fi. 8-9)

This pattern is typical in patients with spastic diplegia.

The knee is flexed during weight-bearing, the hip is only partially extended, and the ankle is in excessive dorsiflexion. The knee is often stiff in the swing phase.

Most musculo-tendinous groups are elongated. This is true for all monoarticular muscles, such as the soleus, quadriceps, and the gluteus maximus, and sometimes for the biarticular muscles, such as the hamstrings. The latter are shortened only in patients presenting with pelvic retroversion. When the pelvis is in neutral position, the hamstrings usually are of normal length, and when the pelvis is anteverted, the hamstrings are too long. Without instrumented gait analysis and assessment of functional muscule length during gait, it is difficult to ascertain the true length of the muscle. As such, inappropriately or excessively lengthening the hamstrings may lead to anterior pelvic tilt leading in the long term to low back pain. There is sometimes associated insufficiency of the quadriceps. This is translated by a knee extensor lag and patella alta.

Excessive ankle dorsiflexion during weight bearing disrupts the plantar flexion/ knee extension couple and further exacerbates the gait. Insufficiency of the hip extensors and imbalance in favor of the hip flexors accentuate crouch gait.

Rotational disturbances or axial anomalies of the lower limbs contribute to crouch gait. In fact, the plantar flexion/ knee extension couple manifests not only in the sagittal plain, but also the axial plane by a deficient lever arm, thus an inability to stabilize the knee into extension. A fixed knee and/or hip flexion contracture perpetuate this abnormal gait that is initially due to Musculo-tendinous imbalances secondary to the original neurological insult.

The surgical treatment is associated with different procedures:

- Intramuscular lengthening of the medial hamstrings if their functional length is too short.
- Improved knee extension during midstance in case of an inefficient quadriceps by patellar lowering in case of patella alta with a too-long patellar ligament.
- A rectus femoris transfer if the knee is stiff during swing phase. Note: The more the knee is flexed during stance phase, the more it will be altered during swing phase. This might erroneously give the appearance of a stiff knee independently of all harmful effects of the rectus femoris.
- Psoas lengthening if there is significant hip flexion contracture (internal rotation of the hips – external rotation of the tibia – collapse of the foot during weight-bearing)

Post-operative device-wear should aid in mastering the plantar flexion/ knee extension couple by associating, if required, a ground reaction moment in order to properly shift the leg posteriorly.

Figure 8. Spastic diplegia presenting with progressive deformity of the lower limbs in crouch gait with a progressive loss of ambulation and an intolerance to orthoses. The knees are in flexion contracture and stiff with short hamstrings and a high riding patella. The feet are not well motorized and collapse in valgus when bearing weight.

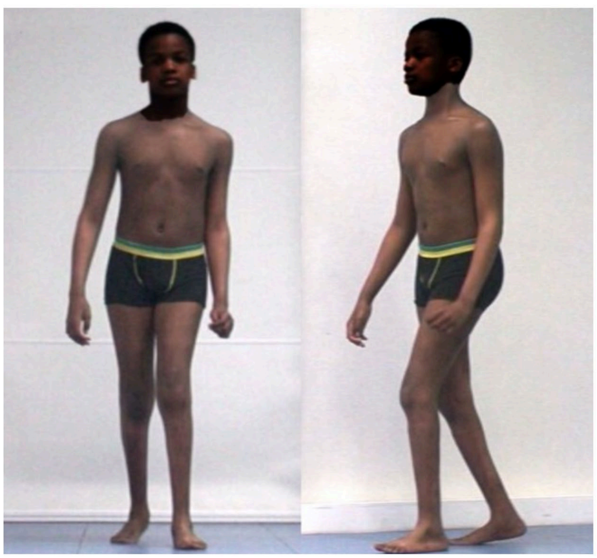


Figure 9. Surgical treatment corrects knee flexion contracture through hamstring lengthening, patellar lowering, patellar ligament shortening, and a rectus femoris transfer. Deformities of the feet will be corrected by reconstruction and arthrodesis. Painless ambulation is expected with short orthoses and the help of a cane.

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