FIOR & GENTZ
ORTHOPÄDIETECHNIK MIT SYSTEM

CP Guide

A Concept for the Orthotic Treatment of the Lower Extremity in Cerebral Palsy

6th edition

Introduction

Thanks to its wide range of adjustment possibilities in combination with the high spring forces, the NEURO SWING system ankle joint has now become the standard solution for the orthotic treatment of CP patients.

The continuous further development of the system joint has made it possible to considerably increase the treatment success for the patient with each new orthosis. This positive trend is especially visible in the large number of successfully completed treatments. In addition, the advantages of the NEURO SWING system ankle joint in the orthotic treatment of CP patients have also been confirmed by a wide range of international studies (see p. 42f).

Thanks to its dynamic properties, the NEURO SWING system ankle joint is meeting with better and better acceptance among physiotherapists and doctors alike, since its use as a complement to qualified therapy has now proven itself. This trend is a clear indication that a change in thinking was triggered by the introduction of the NEURO SWING system ankle joint and the publication of the CP Guide.

But, unfortunately, there are still different strategies being pursued in the field of CP treatments between the individual countries. The conservative treatment of CP patients is often held back from unfurling its true potential. With its simple classification of the pathological gait using the Amsterdam Gait Classification [Gru] and the treatment suggestions based on it, the CP Guide lays important foundations for optimal collaboration in the orthotic treatment of CP patients.

We want to stay on the ball so as to provide you with the latest study findings and up-to-date information. This guide is the first of its kind to list all the available studies on the subject of cerebral palsy and paediatric neurology in which the NEURO SWING system ankle joint is employed or studied.

We would like to thank all the readers who have contributed to the further development of the CP guide with their suggestions and constructive criticisms since the first edition was published.

Your FIOR & GENTZ team

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Content

Treatment Objective

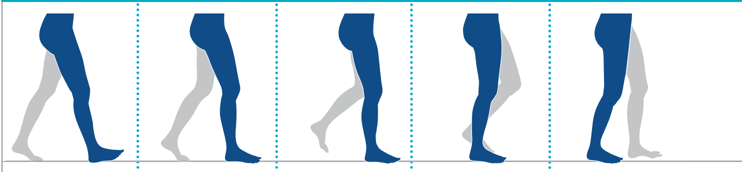
What is Cerebral Palsy?

Cerebral palsy is a movement disorder in which the brain communicates erroneous signals to the affected muscles, with the result that the muscles are activated excessively, insufficiently or at the wrong time. This abnormal activation often leads to dysfunctions of some muscle groups, which normally result in a pathological gait [Gag1, p. 65]. Additionally, these muscular dysfunctions may be accompanied by spasticity [Pea, p. 89], which, in turn, changes the muscle tone in such a way that it may either worsen or improve gait.

Treating CP in an Interdisciplinary Team

It is important that the interdisciplinary team consisting of doctor, physiotherapist, gait instructor, orthotist and biomechanic pursue the same treatment concept and work closely with each other [Doe, p. 113ff].

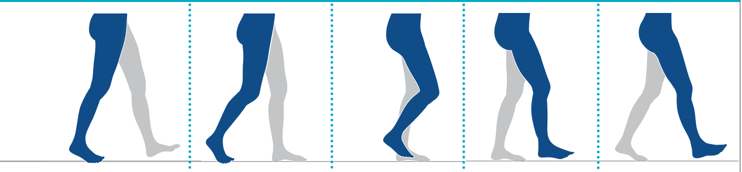
Division of Physiological Gait into Individual Phases following



Description (Abbreviation)				
initial contact (IC)	loading response (LR)	early mid stance (MSt)	mid stance (MSt)	late mid stance (MSt)
Percentage Share of Stride				
0%	0-12%	12-31%		
Hip Angle				
20° flexion	20° flexion	10° flexion	5° extension	5° extension
Knee Angle				
5° flexion	15° flexion	10° flexion	5° flexion	5° flexion
Ankle Angle				
neutral	5° plantar flexion	neutral	5° dorsiflexion	5° dorsiflexion

The first step in the treatment concept should be immediate initiation of physiotherapy [Kra, p. 188]. The goal of this therapy is to treat insufficient muscle groups by establishing the right cerebral connections via motor impulses [Hor, p. 5-26] as well as strengthening individual muscle groups by means of targeted muscle training. Both procedures should help bring the patient closer to a physiological gait.
In addition to physiotherapy, some CP patients also require treatment with drugs such as antispasmodics, e.g. botulinum toxin, [Mol p. 363] and orthopaedic surgery to correct deformities [Gag2].
The illustration shows the individual physiological gait phases of a healthy person. These phases refer to the right leg (reference leg). This physiological gait pattern serves as a reference for the interdisciplinary team in the treatment of CP patients and helps them to achieve the treatment goal [Per, p. 9ff].

the Model of Jacquelin Perry and Kirsten Götz-Neumann



terminal stance (TSt)	pre swing (PSw)	initial swing (ISw)	mid swing (MSw)	terminal swing (TSw)
31-50%	50-62%	62-75%	75-87%	87-100%
20° extension	10° extension	15° flexion	25° flexion	20° flexion
10° flexion	40° flexion	60° flexion	25° flexion	5° flexion
10° dorsiflexion	15° plantar flexion	5° plantar flexion	neutral	neutral

Requirements on Orthoses

Effective orthoses are essential in supporting physiotherapy as well as surgical treatment. In some cases, the orthotic fitting needs to be complemented by orthopaedic shoes or shoe modifications or adjustments [Gru, p. 30].
Depending on the patient's pathological gait, the doctor's requirements and the goal of physiotherapy, the orthotist must produce an orthosis that provides the required lever effect [Nov2, p. 488ff; Owe, p. 262].

Additionally, the result of surgery should be sustained with an orthosis that ensures correct alignment and an adjustable range of motion without interfering with physiotherapy. This is the point when the orthotist faces problems because, until now, it has been difficult in practice to produce an effective orthosis due to the lack of adjustment possibilities.

Difficulties of Orthotic Treatment to Date

Depending on the severity and the characteristics of the disease pattern, CP patients can be treated using a variety of devices. They range from simple orthotic devices such as supramalleolar orthoses (SMOs) or sensorimotor inserts up to ankle-foot orthoses (AFOs) with or without an ankle joint. Since all currently available orthotic treatments have advantages and disadvantages, treating CP can have both positive and negative effects [Rom, p. 473].

"One orthosis may not be optimal to address all of the goals." [Nov1, p. 330]

One easy and common way of treating CP patients is orthopaedic inserts with a sensorimotor insole. This type of sensorimotor insole can also be integrated into SMOs. SMO stands for supramalleolar orthosis. SMOs slightly correct the foot position and activate the muscles. If the Achilles tendon area is not covered, they also possess dynamic features. In comparison to AFOs, however, they do not have any dorsiflexion-assist effect.

SMO

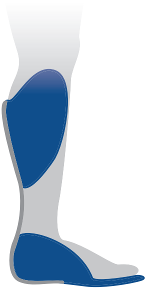
AFOs are mostly produced without an ankle joint. They are divided into dynamic AFOs (DAFOs) and rigid/static AFOs (SAFOs) [Nov1, p. 330ff]. However, DAFOs allow movement in the anatomical ankle joint, for example, without a defined pivot point or range of motion.
SAFOs made of polypropylene do not allow any movement in the ankle.

DAFO SAFO

AFOs with an ankle joint (hinged AFOs), which allow movement in the anatomical ankle joint with a defined pivot point and range of motion, are used less commonly. However, in most cases, hinged AFOs only possess elastomer spring joints or ordinary joints with coil springs. The weak or non-existent spring effect of these joints as well as the lack of dorsiflexion stop can lead to the development of crouch gait [Nov1, p. 345]. Therefore, hinged AFOs are barely used in the orthotic treatment of CP patients.


hinged AFO

For some time now, AFOs with a spring effect such as a posterior-leaf-spring AFO (PLS-AFO) have been used. However, they do not have a defined pivot point or a defined or adjustable range of motion. AFOs with a ventral shell are generally referred to as floor reaction AFOs (FRAFOs). For example, these orthoses can block the movement in the anatomical pivot point and its rigid sole with flexible toe area facilitates push off from the ground.


PLS-AFO


FRAFO

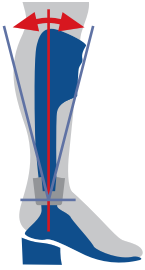
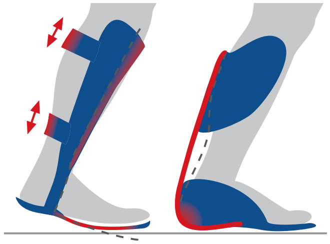
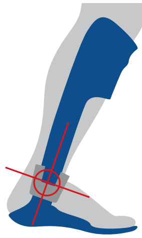
Almost all of the listed AFOs limit the physiological plantar flexion and make it difficult to achieve the best possible compromise of dorsiflexion-assist effect, energy storage for the push off and heel rocker. A qualified physiotherapist uses the very important heel lever. The right cerebral connections are established via motor impulses [Hor, p. 5-26] and single muscle groups are strengthened with targeted muscle training. Additionally, all mentioned orthotic treatments cannot be optimally adjusted to the pathological gait of the patient and, therefore, reduce the effect of the orthosis.

New Orthotic Treatment Possibilities Thanks to the Adjustable NEURO SWING System Ankle Joint

Optimal adjustment to the patient's needs is expected of a modern orthotic concept. This is the only way to ensure the realisation of all goals required for an AFO in Novacheck [Nov1, p. 330]. And that is exactly what the adjustable NEURO SWING system ankle joint was developed for.

Both dynamic and static AFOs should be produced with an adjustable ankle joint to meet the patient's pathological gait as well as the required range of motion. It is necessary to adjust the orthosis to the gait pattern since the position of the patient's foot during plastering differs from the position when putting weight on the leg wearing the orthosis. The adjustable range of motion makes it possible to react with minimal effort to changes in the gait that can occur during treatment.

The NEURO SWING in a Dynamic AFO

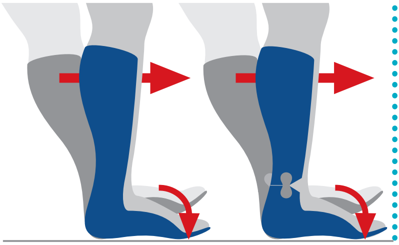
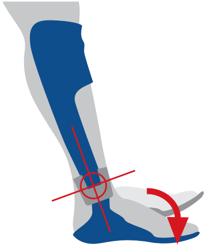
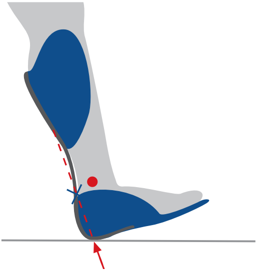
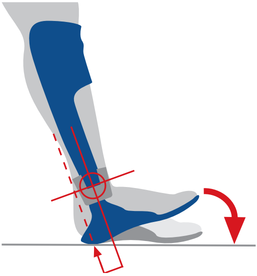
Disadvantages of Existing AFOs	Properties of the NEURO SWING
 no adjustable alignment	 adjustable alignment
 no defined pivot point	 defined pivot point

Description

Since the orthosis must be produced in such a way that it provides the required lever effect [Nov2, p. 488ff], it is necessary to use an adjustable ankle joint. This is the only means of ensuring the orthosis can be precisely adjusted to the CP patient's pathological gait and changes can be reacted to flexibly.
In rigid AFOs without an ankle joint, the structure can only be adjusted by inserting wedges, also known as tuning [Owe, p. 257]. However, increasing the pitch also enlarges the dorsiflexion, the lower leg incline, the hip and knee flexion and the knee flexion moment in mid stance (see p. 20ff). In the NEURO SWING system ankle joint, the design of the orthosis can be altered independently of the pitch.

Some orthoses allow movement between the foot and lower leg even without an ankle joint. However, these orthoses only allow insufficient movement in the anatomical ankle joint which can result in muscular atrophies [Goe, p. 98f.].
Furthermore, the shells of the orthoses can move undesirably on the patient's leg and cause skin irritations. The defined pivot point supports qualified physiotherapy in treating insufficient muscle groups by establishing the right cerebral connections using motor impulses [Hor, p. 5-26] and strengthening single muscle groups with specific muscle training.

The NEURO SWING in a Dynamic AFO

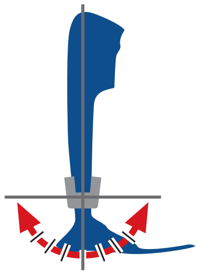
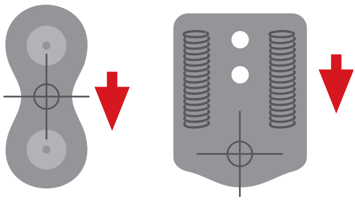
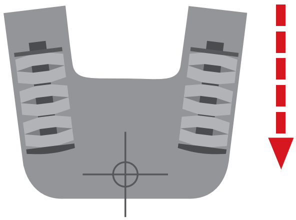
Disadvantages of Existing AFOs	Properties of the NEURO SWING
 plantar flexion locked	 plantar flexion possible
 no heel rocker	 heel rocker

Description

Due to the locked plantar flexion, an increased knee flexion moment is generated. This puts high demand on the m. quadriceps (e.g. walking with a ski boot), although CP patients mostly have an insufficient m. quadriceps [Goe, p. 134ff; Per, p. 195].
A qualified physiotherapist uses the physiological plantar flexion to treat insufficient muscles. The right cerebral connections are established via motor impulses [Hor, p. 5-26] and single muscle groups are strengthened with targeted muscle training. This makes it possible to counteract the advancing muscle atrophy [Goe, p. 98ff].

Because of the anatomical pivot point, there is a lever arm at the hindfoot which leads from the point of heel strike through the calcaneus to the ankle. On initial contact, the body weight triggers a passive plantar flexion through this lever which is controlled by the eccentric work of the m. tibialis anterior.
Other orthoses such as the posterior-leaf-spring AFO do not allow this lever. These orthoses only ensure plantar flexion through active muscle work, but this does not correspond to the physiological movement. The NEURO SWING system ankle joint enables the passive plantar flexion through the defined pivot point and the adjustable range of motion in plantar flexion. This movement is controlled by the dorsal spring unit.

The NEURO SWING in a Dynamic AFO

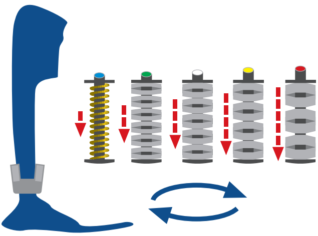
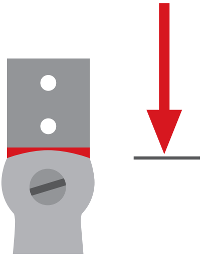
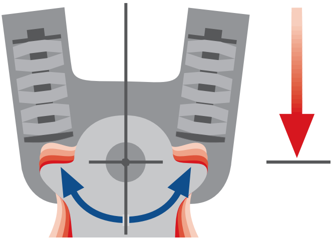
Disadvantages of Existing AFOs	Properties of the NEURO SWING
	
no adjustable range of motion	adjustable range of motion
elastomer spring and coil spring joint	disc spring
	
low spring force	high spring force

Description

After surgery, it may be necessary to lock the range of motion of an orthosis partially or completely and only allow it again later during the course of the therapy. Thus, an ankle joint with an individually adjustable range of motion must be mounted in the AFO.
Using an adjustable ankle joint in a static AFO: Some CP patients are treated with antispasmodics such as botulinum toxin. The muscles are paralysed temporarily. If administered too frequently, the muscle strength may alter. In this case, a static AFO can provide the greatest possible lever effect [Nov2, p. 488ff]. It also makes sense to treat CP patients with a static AFO when physiotherapeutic success cannot generally be expected or the foot is severely deformed.

The pathological gait of some CP patients requires very high spring forces. With the NEURO SWING system ankle joint, these spring forces are achieved with disc springs layered into compact spring units. The spring units store the energy brought in by the body weight. If this energy is released again in pre swing, it supports the push off [Nov1, p. 333]. An AFO with NEURO SWING system ankle joint achieves this effect at least as well as a posterior-leaf-spring AFO. In CP patients with excessive knee flexion in mid stance, the high spring forces of the red and yellow spring unit improve the joint angle and the energy return when walking (see p. 20ff).
Common constructions such as elastomer spring or coil spring joints do not come anywhere close to achieving this effect.

The NEURO SWING in a Dynamic AFO

Disadvantages of Existing AFOs	Properties of the NEURO SWING
 no variable spring force	interchangeable spring units  variable spring force
 hard stops	 soft stops

Description

The spring force in plantar flexion and dorsiflexion can be individually adjusted to the patient's pathological gait with minimal effort by using spring units of different strength. This makes it possible to determine the optimal spring force with which CP patients can reduce the energy required for walking (see p. 20ff).
In AFOs without an ankle joint, the spring force can only be changed to a limited extent.

The integrated disc springs guarantee a soft stop that counteracts the development or worsening of spasticity.

Patient Classification

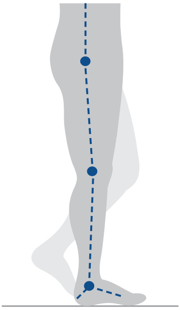
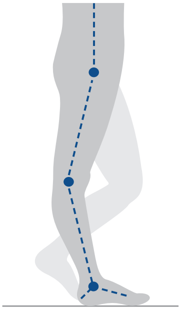
To achieve the desired treatment goal, the interdisciplinary team needs the same basis to assess the different characteristics of CP. The basis can be created by grouping CP patients according to certain criteria, a so-called classification.

Gross Motor Skills and Mobility

The Gross Motor Function Classification System (GMFCS) helps to assess gross motor skills of CP patients in everyday situations and to make a prognosis of their further development [Rus]. It gives priority to locomotion, taking required assistance into account and classifies patients according to their age into five levels [Õun, p. 151ff].

The Functional Mobility Scale (FMS) divides CP patients into six groups, according to their mobility. The devices used for the locomotion and the distance covered with them are included in the assessment [Gra, p. 515].

Gait Types According to the Amsterdam Gait Classificatio

GAIT TYPES	TYPE 1	TYPE 2
		
KNEE	normal	hyperextended
FOOT CONTACT	complete	complete
TREATMENT	see p. 20-23	see p. 24-27

Pathological Gait

In 2001, Rodda and Graham analysed and divided patients with spastic hemiplegia and diplegia into four gait types using video recording and taking gait pattern and posture into account [Rod, p. 98ff]. Currently, this classification is the most used in clinical practice.
Alongside this classification, the Amsterdam Gait Classification was developed especially for CP patients at the VU University Medical Center in Amsterdam. It classifies five types of gait according to their knee position and foot-floor contact in mid stance (see illustration below). A description of the physiological mid stance is given on pages 4 and 5. The Amsterdam Gait Classification is equally suitable for patients that are affected either unilaterally or bilaterally [Gru, p. 30]. Therefore, it can be used optimally as classification for a standardised orthotic treatment.
The Amsterdam Gait Classification makes it possible to classify CP patients quickly according to their gait pattern. This facilitates interdisciplinary communication as well as selection of the right treatment. Furthermore, it contributes to standardising orthotic treatments and controlling their quality.
The books by Perry and Götz-Neumann present an easy-to-understand overview about the clinical gait analysis [Per; Goe].

n

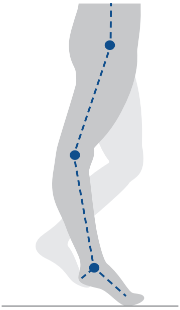
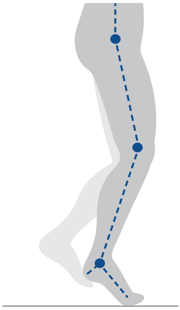
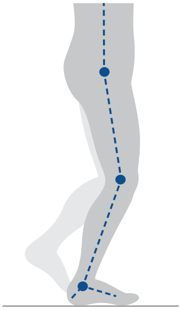
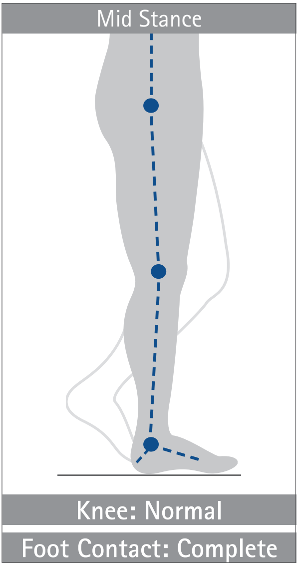
TYPE 3	TYPE 4	TYPE 5
		
hyperextended	flexed	flexed
incomplete	incomplete	complete
see p. 28-31	see p. 32-35	see p. 36-39

illustration of gait types in mid stance

Treatment Suggestion for Gait Type 1

Pathological Gait

An insufficient m. tibialis anterior and a mostly shortened m. gastrocnemius are typical of gait type 1. This muscular deficiency causes a weakness of foot dorsiflexion which, in turn, causes a dysfunctional foot lift in swing phase.
In mid stance, the heel does not rise and the knee is in a physiological position [Bec, p. 1, p. 5f].



Recommended Orthosis

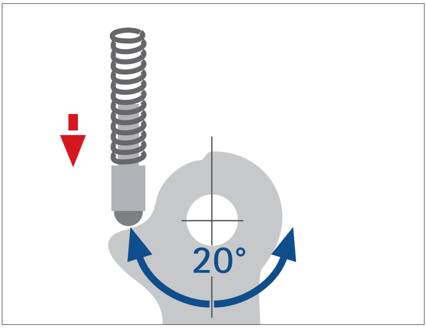
Dynamic AFO with ventral shell, long and partially flexible foot piece (rigid sole with flexible toe area) and the NEURO SPRING system ankle joint.

NEURO SPRING System Ankle Joint Adjustment Possibilities

Adjustment to the pathological gait by:

- the range of motion in dorsiflexion being established by filing the system stirrup.

The NEURO SPRING can be converted into a NEURO CLASSIC-SWING system ankle joint.



range of motion spring force

Effect on Foot Deformities

There are a number of different methods which can be applied to improve the patient's foot deformity and which can be combined with an orthosis:
Both a ring-shaped foot holder and an inner shoe can be integrated in the orthosis and thus additionally offer positive support for its function.
Sensorimotor elements can be added to the foot bed of the orthosis, inner shoe or modelled during the production of the positive cast represent another alternative.

Treatment Suggestion for Gait Type 1

Current Orthotic Treatment Possibilities

Due to the small difference in comparison to the physiological gait, CP patients of this gait type have been treated almost only with simple devices up to now. This includes ankle-high shoes, supramalleolar orthoses (SMOs) or sensorimotor inserts [Gru, p. 33; Nov1, p. 331]. Nevertheless, the dorsiflexion-assist effect of these devices, which is only minimal, must be considered critically. Moreover, maintained physiological movements can be restricted.

Effect of the Orthosis

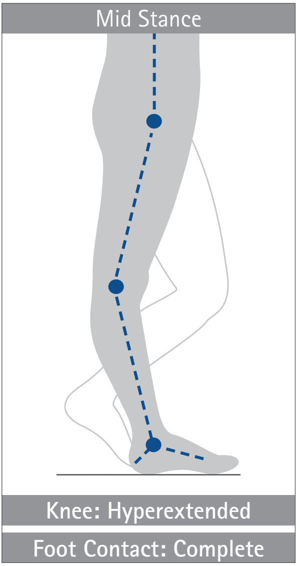
- Initial contact and loading response: The integrated spring unit of the NEURO SPRING system ankle joint is strong enough to keep the foot in neutral position during swing phase and hence ensure that the heel touches the floor first during initial contact. At the same time, this dorsiflexion-assist enables physiological plantar flexion, since it replaces the eccentric work of the pretibial muscles and thus allows the heel rocker. From initial contact to loading response, the foot is lowered in a controlled manner against the spring force.
- Mid stance and terminal stance: Physiological knee extension is not influenced thanks to the free dorsiflexion stop of the NEURO SPRING system ankle joint.
- Pre swing and mid swing: The dorsal spring unit brings the foot from pre swing to mid swing in neutral position. The CP patient can walk without stumbling and, therefore, trunk and hip are relieved.

Treatment supports and above-mentioned simple orthotic devices such as sensorimotor insoles can also be integrated in the recommended orthosis.

Treatment Suggestion for Gait Type 2

Pathological Gait

An insufficient m. tibialis anterior and, additionally, wrong activation of the m. triceps surae are typical of gait type 2.
In mid stance, the heel does not rise and the knee remains hyperextended. [Bec, p. 146].



Recommended Orthosis

Dynamic AFO with high ventral shell, long and semi-flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint.
Why a ventral shell? Please read the last section on page 27.

Spring units to be used:

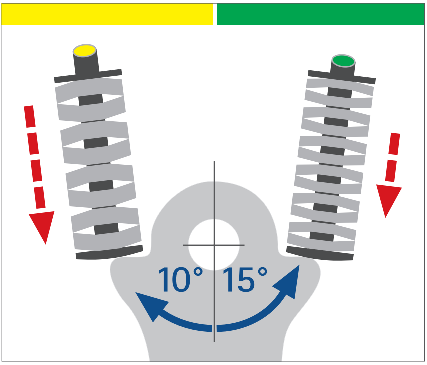
- dorsal: yellow marking (very strong spring force, max. 10° range of motion);
- ventral: green marking (medium spring force, max. 15° range of motion).

NEURO SWING System Ankle Joint Adjustment Possibilities

Individual adjustment to the pathological gait by:

- interchangeable spring units,
- adjustable alignment,
- adjustable range of motion.

All three adjustments can be changed separately and do not influence each other.



range of motion spring force

Effect on Foot Deformities

There are a number of different methods which can be applied to improve the patient's foot deformity and which can be combined with an orthosis:
Both a ring-shaped foot holder and an inner shoe can be integrated in the orthosis and thus additionally offer positive support for its function.
Sensorimotor elements added to the foot bed of the orthosis, inner shoe or modelled during the production of the positive cast represent another alternative.

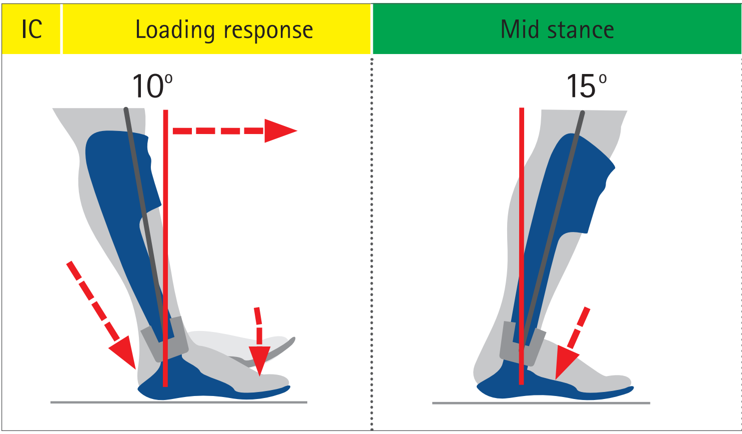
Treatment Suggestion for Gait Type 2

Current Orthotic Treatment Possibilities

Until now, hinged AFOs have been used to treat CP patients of this gait type. Their design allows free dorsiflexion and locks plantar flexion. Therefore, the foot is kept in neutral position or in slight dorsiflexion and the physiological plantar flexion is restricted [Gru, p. 33]. Between initial contact and loading response, an increased knee flexion moment is generated. This puts high demand on the m. quadriceps (e.g. walking with a ski boot) [Goe, p. 134ff; Per, p. 195].

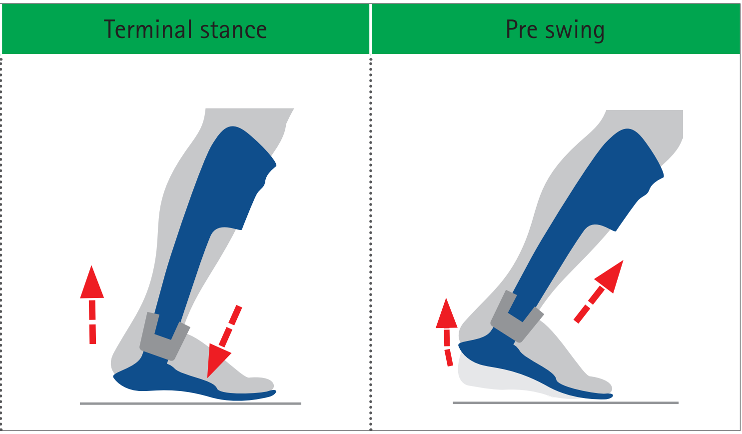
Effect of the Orthosis (see illustration below)

- Initial contact and loading response: The dorsal spring unit of the NEURO SWING system ankle joint is strong enough to keep the foot in neutral position and hence ensure that the heel touches the floor first during initial contact. It enables a physiological plantar flexion since it allows the eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no increased knee flexion moment is generated. From initial contact to loading response, the foot is lowered in a controlled manner against the spring force. This physiological plantar flexion should prevent the m. gastrocnemius being activated too early. If the recommended, very strong dorsal spring unit (yellow marking) severely restricts the heel rocker, it must be exchanged for the medium spring unit (green marking).



- Mid stance: The dorsal spring unit in the NEURO SWING system ankle joint prevents the hyperextension of the knee.
- Terminal stance: The very strong dorsal spring unit provides a physiological lifting of the heel.
- Pre swing: The ventral spring unit brings the foot from pre swing to mid swing in neutral position. The CP patient can walk without stumbling and, therefore, trunk and hip are relieved.

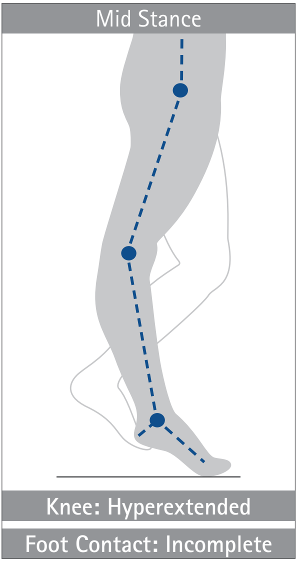
An orthosis with high ventral shell can be produced in this case due to the very high spring forces of the applied spring units. The ventral shell adapts the CP patient's reflex to support himself in such a way that he now pushes his body weight against the ventral shell via the tibia and is hence stable in his stance. This prevents increasing knee hyperextension and the development of contractures in the anatomical ankle joint.



Treatment Suggestion for Gait Type 3

Pathological Gait

An insufficient m. tibialis anterior and, additionally, premature or premature and excessive activation of the m. triceps surae are typical of gait type 3.
In mid stance, the load remains on the forefoot and the heel rises. The knee is hyperextended [Bec, p. 146].



Recommended Orthosis

Dynamic AFO with high ventral shell, long and semi-flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint.
Why a ventral shell? Please read the last section on page 31.
Spring units to be used:

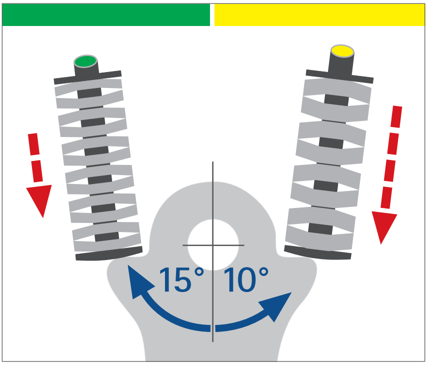
- dorsal: green marking (medium spring force, max. 15° range of motion);
- ventral: yellow marking (very strong spring force, max. 10° range of motion).

NEURO SWING System Ankle Joint Adjustment Possibilities

Individual adjustment to the pathological gait by:

- interchangeable spring units,
- adjustable alignment,
- adjustable range of motion.

All three adjustments can be changed separately and do not influence each other.



range of motion spring force

Effect on Foot Deformities

There are a number of different methods which can be applied to improve the patient's foot deformity and which can be combined with an orthosis:
Both a ring-shaped foot holder and an inner shoe can be integrated in the orthosis and thus additionally offer positive support for its function.
Sensorimotor elements can be added to the foot bed of the orthosis, inner shoe or modelled during the production of the positive cast represent another alternative.

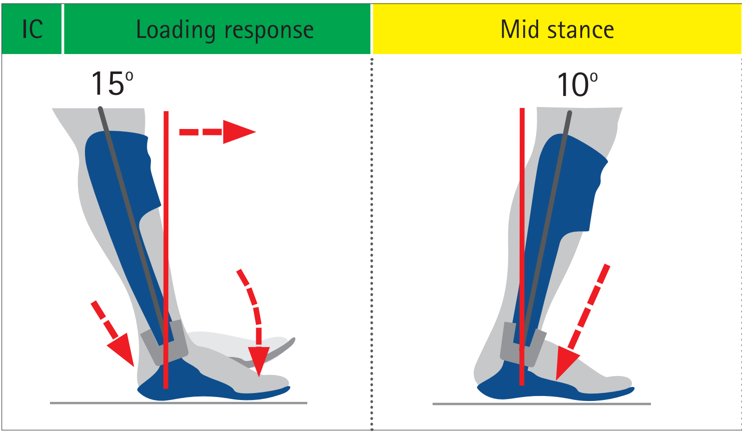
Treatment Suggestion for Gait Type 3

Current Orthotic Treatment Possibilities

Until now, SAFOs with a dorsal shell have been used to treat CP patients of this gait type. They keep the foot in neutral position or in slight dorsiflexion [Gru, p. 33]. However, this rigid construction restricts the physiological plantar flexion. Between initial contact and loading response, an increased knee flexion moment is generated. This puts high demand on the m. quadriceps (e.g. walking with a ski boot) [Goe, p. 134ff; Per, p. 195]. Additionally, due to the unfavourable construction with a dorsal shell, the CP patient's reflex to support himself with the calf on the shell is enhanced in order to gain stance stability. This provokes the hyperextension of the knee.

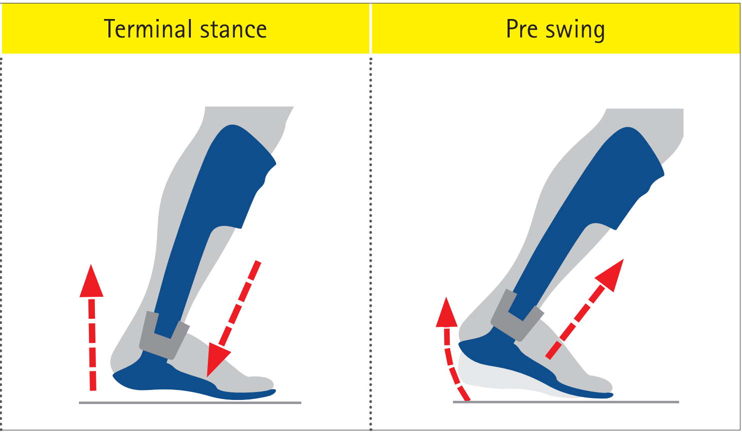
Effect of the Orthosis (see illustration below)

- Initial contact and loading response: The dorsal spring unit of the NEURO SWING system ankle joint is strong enough to keep the foot in neutral position and hence ensure that the heel touches the floor first during initial contact. It enables a physiological plantar flexion since it allows the eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no increased knee flexion moment is generated. From initial contact to loading response, the foot is lowered in a controlled manner against the spring force. This physiological plantar flexion should prevent the m. gastrocnemius being activated too early.



- Mid stance: The tibial progression causes dorsiflexion in the ankle which, in turn, preloads the ventral spring unit.
- Terminal stance: The spring unit is preloaded up to the adjusted range of motion. The energy brought in by the body weight is stored in the ventral spring unit.
- Pre swing: From terminal stance to pre swing, the ventral spring unit releases the stored energy that assists the push off.

An orthosis with high ventral shell can be produced in this case due to the very high spring forces of the applied spring units. The ventral shell adapts the CP patient's reflex to support himself in such a way that he now pushes his body weight against the ventral shell via the tibia and is hence stable in his stance. In contrast to the dorsal shell, this prevents increasing knee hyperextension and the development of contractures in the anatomical ankle joint.

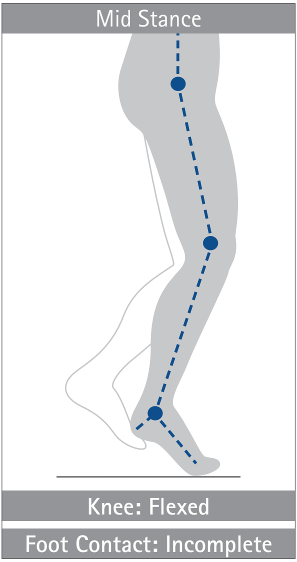


Treatment Suggestion for Gait Type 4

Pathological Gait

Excessive activation of the ischiocrural muscles accompanied by incorrect activation of the m. gastrocnemius or m. psoas major are typical of gait type 4.
In mid stance, the load remains on the forefoot and the heel rises. In addition, the knee and hip flexion persist [Bec, p. 146].

The patient also expends a lot of energy when walking [Bre, p. 102].



Recommended Orthosis

Dynamic AFO with high ventral shell, long and rigid foot piece and NEURO SWING system ankle joint.
Spring units to be used:

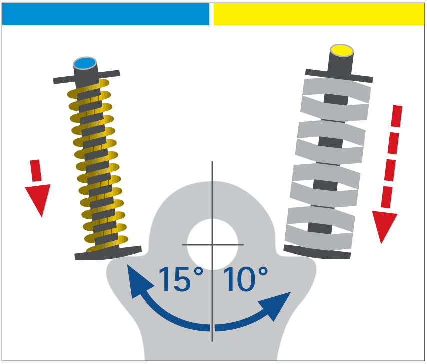
- dorsal: blue marking (normal spring force, max. 15° range of motion);
- ventral: yellow marking (very strong spring force, max. 10° range of motion).

NEURO SWING System Ankle Joint Adjustment Possibilities

Individual adjustment to the pathological gait by:

- interchangeable spring units,
- adjustable alignment,
- adjustable range of motion.

All three adjustments can be changed separately and do not influence each other.



range of motion spring force

Effect on Foot Deformities

There are a number of different methods which can be applied to improve the patient's foot deformity and which can be combined with an orthosis:
Both a ring-shaped foot holder and an inner shoe can be integrated in the orthosis and thus additionally offer positive support for its function.
Sensorimotor elements can be added to the foot bed of the orthosis, inner shoe or modelled during the production of the positive cast represent another alternative.

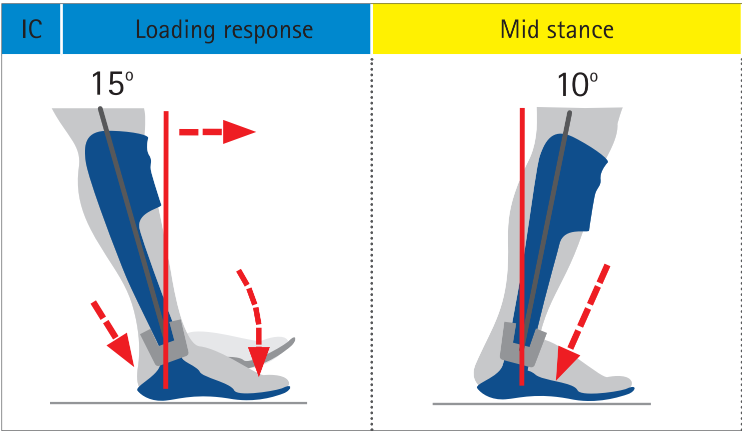
Treatment Suggestion for Gait Type 4

Current Orthotic Treatment Possibilities

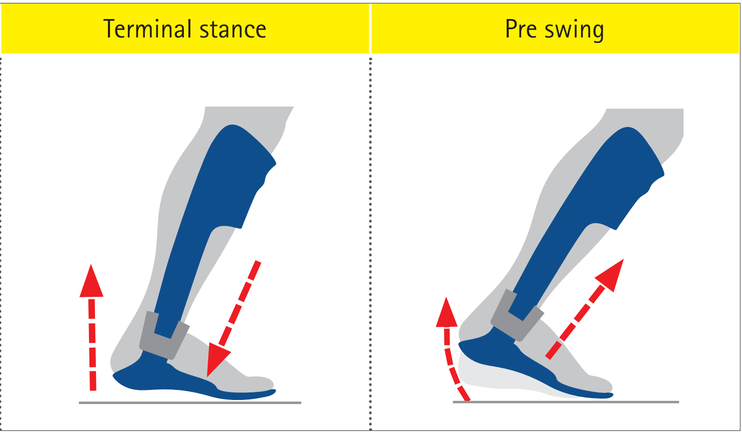
Until now, SAFOs with a dorsal shell and rigid sole have been used to treat CP patients of this gait type. They keep the foot in a neutral position or in slight dorsiflexion. However, this rigid construction restricts the physiological plantar flexion. Between initial contact and loading response, an increased knee flexion moment is generated. This puts high demand on the m. quadriceps (e.g. walking with a ski boot) [Goe, p. 134ff; Per, p. 195].

Effect of the Orthosis (see illustration below)

- Initial contact and loading response: If the CP patient has no plantar flexion contracture, the dorsal spring unit of the NEURO SWING system ankle joint is strong enough to keep the foot in neutral position and hence ensure that the heel touches the floor first during initial contact. It enables a physiological plantar flexion since it allows the eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no increased knee flexion moment is generated. From initial contact to loading response, the foot is lowered in a controlled manner against the spring force. If the recommended, normal spring unit (blue marking) is too weak to keep the foot in neutral position in terminal swing because of an existing plantar flexion contracture, it must be exchanged for the very strong spring unit (yellow marking).



- Mid stance: The ventral spring unit in combination with the long and rigid foot piece and the ventral shell creates a knee extension moment. This straightens the CP patient up and significantly improves the excessive knee flexion and lower leg incline (see p. 24f). Furthermore, the patient gains stance stability. If the very strong spring unit (yellow marking) is not strong enough, it can be exchanged for the extra strong spring unit (red marking).
- Terminal stance: From mid stance to terminal stance, the ventral spring unit is preloaded up to the adjusted range of motion and stores the energy brought in by the body weight.
- Pre swing: From terminal stance to pre swing, the ventral spring unit releases the stored energy that assists the push off. Due to the construction of the orthosis and the supportive effect of the spring units, the CP patient expends less energy when walking (see p. 24f).

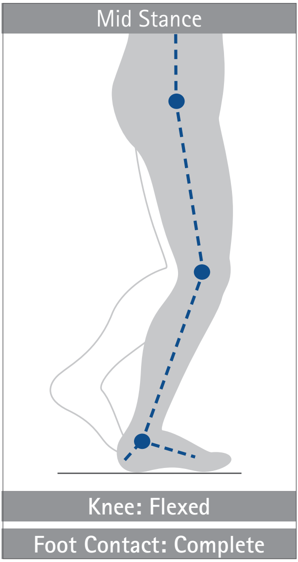


Treatment Suggestion for Gait Type 5

Pathological Gait

Excessive activation of the ischiocrural muscles accompanied by insufficient activation of the m. gastrocnemius or incorrect activation of the m. psoas major are typical of gait type 5.
This leads to increased knee and hip flexion in mid stance. Furthermore, the heel does not rise [Bec, p. 146].

The patient also expends a lot of energy when walking [Bre, p. 102].



Recommended Orthosis

Dynamic AFO with high ventral shell, long and rigid foot piece and NEURO SWING system ankle joint.
Spring units to be used:

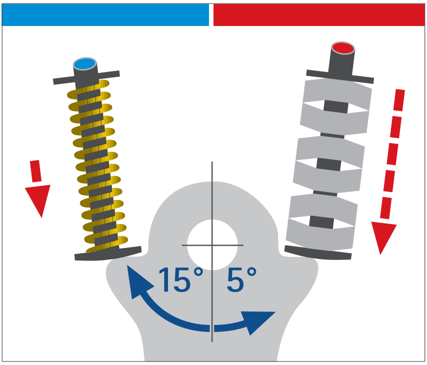
- dorsal: blue marking (normal spring force, max. 15° range of motion);
- ventral: red marking (extra strong spring force, max. 5° range of motion).

NEURO SWING System Ankle Joint Adjustment Possibilities

Individual adjustment to the pathological gait by:

- interchangeable spring units,
- adjustable alignment,
- adjustable range of motion.

All three adjustments can be changed separately and do not influence each other.



range of motion spring force

Effect on Foot Deformities

There are a number of different methods which can be applied to improve the patient's foot deformity and which can be combined with an orthosis:
Both a ring-shaped foot holder and an inner shoe can be integrated in the orthosis and thus additionally offer positive support for its function.
Sensorimotor elements can be added to the foot bed of the orthosis, inner shoe or modelled during the production of the positive cast represent another alternative.

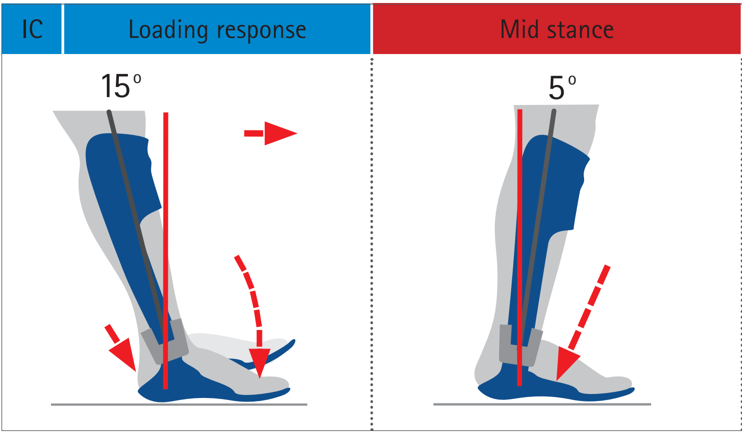
Treatment Suggestion for Gait Type 5

Current Orthotic Treatment Possibilities

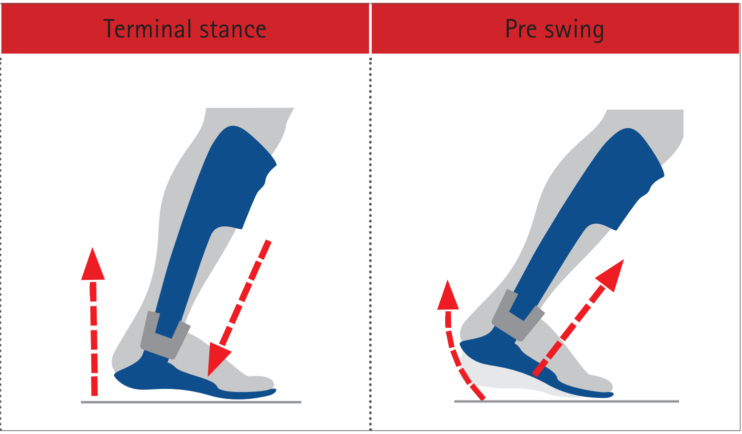
Until now, FRAFOs with a ventral shell and rigid sole have been used to treat CP patients of this gait type. They keep the foot in a neutral position or in slight dorsiflexion. The ventral shell and the rigid sole are supposed to extend the knee in mid stance. However, the construction of the orthosis restricts the physiological plantar flexion. Between initial contact and loading response, an increased knee flexion moment is generated. This puts high demand on the m. quadriceps (e.g. walking with a ski boot) [Goe, p. 134ff; Per, p. 195].

Effect of the Orthosis (see illustration below)

- Initial contact and loading response: The defined pivot point and the adjustable range of motion enable a physiological plantar flexion since they allow the eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no increased knee flexion moment is generated. The foot is lowered in a controlled manner against the force of the dorsal spring unit.



- Mid stance: The ventral spring unit in combination with the long and rigid foot piece and the ventral shell creates a knee extension moment. This straightens the CP patient up and significantly improves the excessive knee flexion and lower leg incline (see p. 24f). This is only possible if the knee flexion is still not strong enough for the load line to run behind the anatomical pivot point. Furthermore, the patient gains stance stability.
- Terminal stance: From mid stance to terminal stance, the ventral spring unit is preloaded up to the adjusted range of motion and stores the energy brought in by the body weight. The lever effect of the foot piece and the optimally adjusted dorsiflexion stop cause the heel to rise at the right moment.
- Pre swing: From terminal stance to pre swing, the ventral spring unit releases the stored energy that assists the push off. Due to the construction of the orthosis as well as the support of the spring units, the CP patient expends less energy when walking.



Dissertation: Maximizing the efficacy of ankle foot orthoses in children with cerebral palsy

In her dissertation "Maximizing the efficacy of ankle foot orthoses in children with cerebral palsy", Yvette L. Kerkum treated 32 children with spastic cerebral palsy orthotically with the NEURO SWING system ankle joint within the scope of a large-scale Dutch study. The children's gaits were analysed and assessed based on a number of questions. The results of the study support the perspectives presented in this guide and are summarised here:

Increasing of lower leg incline and joint angle in mid stance via increasing of pitch

The insertion of wedges under a rigid AFO (tuning) leads to a significant increase in the lower leg incline and the knee and hip flexion in mid stance [Ker, p. 49ff].

Increasing of joint moments in mid stance via increasing of pitch

The insertion of wedges under a rigid AFO (tuning) leads to a significant increase in the knee flexion moment in mid stance [Ker, p. 49ff].

Increasing of joint moments in mid stance via increasing of foot piece rigidity

Increasing the rigidity of the foot piece leads to a significant reduction in the knee flexion moment in mid stance [Ker, p. 49ff].

The mechanical properties of the NEURO SWING system ankle joint

As the spring units of the NEURO SWING system ankle joint are interchangeable, the AFO can be adapted to reflect the patient's individual gait. Their design gives the spring units a threshold value below which there is no movement in the mechanical ankle joint (compaction of spring units) when there are only small moments in the anatomical ankle joint. This threshold value supports knee extension at the beginning of the stance phase [Ker, p. 67ff].

The optimal spring force for CP patients with increased knee flexion in mid stance

The red and yellow spring units of the NEURO SWING system ankle joint are best suited of children with CP who present with increased knee flexion in mid stance (gait type 4 and 5). The yellow spring unit offers an optimal balance of spring force and freedom of movement and makes the best contribution to improving the push off with the resulting high energy return. The red spring unit standardises the joint angle the most efficiently with its relatively high spring unit and low freedom of movement [Ker, p. 67ff].

Reduced energy consumption when walking with the yellow spring unit

The improvement in energy consumption when walking with the yellow spring unit is due to the improvement of the joint angle and moments in the stance phase rather than the supporting of the push off [Ker, p. 79ff].

Reduced energy consumption when walking with an AFO and optimal spring force

Thanks to the optimal spring force, the patient can significantly reduce his energy consumption when walking with an AFO compared with walking wearing just shoes [Ker, p. 109ff].

Improved knee angle when walking with an AFO and optimal spring force

The optimal spring force makes it possible to reduce the CP patients' excessive knee flexion in mid stance significantly when walking with an AFO [Ker, p. 109ff].

Improved lower leg incline when walking with an AFO and optimal spring force

Thanks to the optimal spring force, the lower leg incline is significantly reduced when walking with an AFO compared with walking wearing just shoes [Ker, p. 109ff].

No time needed to get used to the new AFO

Even after a time of getting used to the AFO, no further improvement is noted in the important gait parameters (time-distance parameter, joint angles, joint moments). As such, no time for getting used to the device needs to be provided in routine clinical practice [Ker, p. 129ff].

Further Studies on NEURO SWING

In addition to the dissertation described above, the NEURO SWING system ankle joint has been employed in a wide range of studies since 2012, primarily for the indication of cerebral palsy. The results of these studies were presented as posters or presentations at a wide range of national and international conferences and/or published in renowned journals.

Block J, Heitzmann D, Alimusaj M et al. (2014): Effects of an ankle foot orthosis with a dynamic hinge joint compared to a conventional orthosis – a case study. OTWorld 2014. Leipzig, Germany, May 2014.

Gentz R, Friebus F (2012): Das Neuro Swing Systemknöchelgelenk. Seine Verwendung in der Orthesenversorgung für Patienten mit Cerebralparese. Orthopädie Technik 63(8): 35-41.

Kerkum YL, Harlaar J, Buizer AI et al. (2013): Optimising Ankle Foot Orthoses for children with Cerebral Palsy walking with excessive knee flexion to improve their mobility and participation; protocol of the AFO-CP study. BMC Pediatrics 13(1): 17.

Kerkum YL, Brehm MA, Buizer AI et al. (2014): Defining the mechanical properties of a spring-hinged ankle foot orthosis to assess its potential use in children with spastic cerebral palsy. Journal of applied biomechanics 30(6): 728-731.

Kerkum YL, Brehm MA, Hutten K et al. (2015): Acclimatization of the gait pattern to wearing an ankle-foot orthosis in children with spastic cerebral palsy. Clinical biomechanics 30(6): 617-622.

Kerkum YL, Buizer AI, Noort JC et al. (2015): The Effects of Varying Ankle Foot Orthosis Stiffness on Gait in Children with Spastic Cerebral Palsy Who Walk with Excessive Knee Flexion. PloS one 10(11): e0142878.

Kerkum YL, Houdijk H, Brehm MA et al. (2015): The Shank-to-Vertical-Angle as a parameter to evaluate tuning of Ankle-Foot Orthoses. Gait & Posture 42(3): 269-274.

Kerkum YL, Harlaar J, Buizer AI et al. (2016): An individual approach for optimizing ankle-foot orthoses to improve mobility in children with spastic cerebral palsy walking with excessive knee flexion. Gait & Posture 46: 104-111.

Sabbagh D, Fior J, Gentz R (2016): Long-term effects of a dynamic ankle foot orthosis on a patient with cerebral palsy following ischemic perinatal stroke – A case study. Gait & Posture 49(Suppl. 2): 224.

Sabbagh D, Fior J, Gentz R (2014): The observance of biomechanical effects on the estimation of common ankle foot orthoses in cerebral palsy. Gait & Posture 39 (Suppl. 1): S95-S96.

Sabbagh D, Fior J, Gentz R (2013): A Critical Consideration on Common Orthotic Treatment Concepts for Gait Problems in Cerebral Palsy. Journal of Children's Orthopaedics 7(4): 331.

Skaaret I (2012): Evaluation of Ankle Joint Stiffness on Gait Function in Neuromuscular Diagnoses: a Case Study. 9. Nordiske Ortopeditekniske Kongress. Lillestrøm, Norway, November 2012.

Wolf S, Block J, Heitzmann D et al. (2013): Kinetics of an ankle foot orthosis with a dynamic hinge joint for children with neuromuscular disorders. Journal of Children's Orthopaedics 7(4): 331.

AFO
(ankle-foot orthosis): lower leg orthosis.

Amsterdam Gait Classification
Classification of ↑pathological gait patterns of CP patients into five gait types. It evaluates the position of the knee and contact of the foot with the floor in mid stance. The Amsterdam Gait Classification was developed at the VU University Medical Center in Amsterdam assisted by Prof Dr Jules Becher.

Antispasmodics
(from Greek *spasmos* = spasm): relaxant drug. It decreases the tone of the smooth muscles or reduces muscle tension.

Botulinum Toxin
Trade names include Botox®. Botulinum toxin is one of the most powerful neurotoxins known. The toxic proteins inhibit the signal transmission of the nerve cells to the muscle.

Cerebral Connection
(from Latin *cerebrum* = [in broadest sense] brain): The brain saves control programmes for complex movement patterns. Repetitions of ↑physiological movement patterns lead to corrections of these in the brain. In turn, each environmental disturbance can result in a repeated program error and thus in a ↑pathological movement pattern.

Cerebral Palsy
(CP): disorder of the muscle tone and muscle coordination caused by damage to the central nervous system before, during or after birth. Depending on the type of damage, paralyses can occur as ↑hemiplegia, ↑diplegia or ↑paraplegia. For many patients, these paralyses may be accompanied by ↑spasticity.

Concentric
(from Latin *con* = with; *centrum* = centre): moving towards a centre; having a common centre. Mechanical: Force starts precisely in the centre. Physiological: Concentric muscle work is the work done by a muscle when shortening.

Contracture
(from Latin *contrahere* = to tighten): involuntary permanent tissue shortening or shrinking, e.g. of certain muscles or tendons. It leads to a reversible or irreversible restriction of mobility or fixed deformity of the adjoining joints. There are elastic and rigid contractures.

Crouch Gait
Gait pattern with permanently flexed hips and knees.

DAFO
(dynamic ankle-foot orthosis): dynamic lower leg orthosis.
The term DAFO is used internationally for both ↑supramalleolar orthoses (↑SMOs) and partially flexible ↑polypropylene ↑AFOs. The current use of this term is ambiguous since ↑AFOs with joint should also be named ↑dynamic ↑AFOs.

Diplegia
(from Greek *dis* = twice, double; *plege* = stroke, paralysis): bilateral paralysis; in diplegia, two parts of the body (e.g. both arms or both legs) are affected.

Disc Spring
A conical shell which can be loaded along its axis either statically or dynamically. Either a single spring or a stack of springs can be used. In a column, a spring stack can consist of either single disc springs or parallel spring sets. The geometric form of the disc spring leads to a ↑concentric force absorption and hence to an almost linear spring characteristic curve.

Dorsal
(from Latin *dorsum* = back): pertaining to the back or to any dorsum; e.g. for an ↑AFO this means the shell is on the calf.

Dorsiflexion
Lifting of the foot. Countermovement: dropping of the foot (↑plantar flexion). Called dorsal flexion as it actually involves ↑flexion of a body part. From a functional perspective though, the movement could be more precisely described as ↑extension.

Dorsiflexion Stop
Constructional element of an orthosis which limits the degree of the ↑dorsiflexion. The dorsiflexion stop activates the forefoot lever resulting in an increase of the area of support. Furthermore, the dorsiflexion stop causes a knee extension moment and in mid stance a heel lift.

Dynamic
(from Greek *dynamikos* = active, strong): showing a movement, characterised by momentum and energy; i.e., a dynamic ↑AFO allows a defined movement in the anatomical ankle joint.

Eccentric Muscle Work
(from Latin *ex centro* = outside the centre): work done by the muscle by actively extending and controlling a slowing down joint movement such as a weightlifter who lifts a dumbbell above his head and slowly lowers it again.

Extension
(from Latin *extendere* = to extend): active or passive straightening of a joint. Straightening is the countermovement of bending (↑flexion) and characteristically increases the joint angle.

Flexion
(from Latin *flectere* = to bend): active or passive bending of a joint. Bending is the countermovement of straightening (↑extension) and characteristically reduces the joint angle.

FRAFO
(floor reaction AFO): solid orthosis with a ↑ventral shell which provides a knee or hip extension moment from terminal stance. FRAFOs can be made of ↑polypropylene as well as carbon fibre and they either have a rigid or a partially flexible foot piece. However, the name FRAFO is misleading since there are other ↑AFOs which also interact with the ↑ground reaction force.

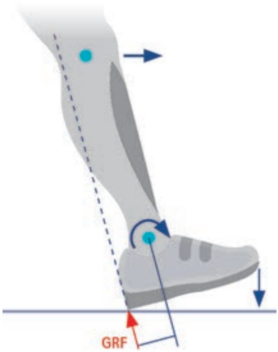
Ground Reaction Force
(GRF): a force exerted by the ground in response to the forces a body exerts on it.

Heel Lever

Is a lever whose pivot point is the ↑point of heel strike and whose lever arm is the distance of this point to the pivot point of the anatomical ankle joint. During initial contact, the ↑ground reaction force which moves ↑dorsally from the ankle causes a rotation around the ↑point of heel strike.

Heel Rocker

Means the whole rotation of the foot around the ↑point of heel strike and in the anatomical ankle joint between initial contact and loading response: From terminal swing to initial contact, the swing leg "drops" to the ground from a height of about 1cm. The ↑ground reaction force starts at the ↑point of heel strike and its force vector (broken line) moves ↑dorsally from the ankle. With the resulting ↑heel lever, a plantar flexion moment is created in the ankle which lowers the foot. The ↑m. tibialis anterior muscle works ↑eccentrically against this movement, thus allowing a controlled foot lowering.



Hemiplegia

(from Greek *hemi* = half; *plege* = stroke, paralysis): unilateral paralysis. A hemiplegia is the paralysis on one full side of the body.

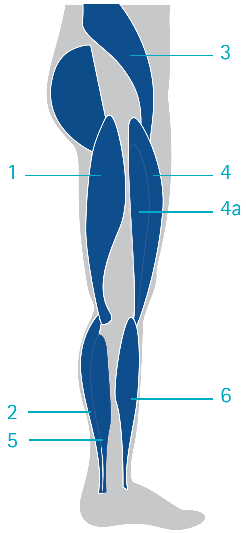
Hinged AFO

The classic hinged ↑AFO is an orthosis with a dorsal shell made of ↑polypropylene with an elastomer spring joint or a simple coil spring joint. Hinged ↑AFOs allow ↑dorsiflexion in the anatomical ankle joint. The elastomer spring joints used are mostly not strong enough to allow ↑plantar flexion and, at the same time, keep the foot in ↑neutral position during swing phase. That is why the ↑plantar flexion in hinged ↑AFOs is locked in such cases.

Insufficiency

Insufficient function or inadequate performance of an organ or organ system (e.g. the muscular system).

Interdisciplinary
(from Latin *inter* = between two or more): the cooperation between various disciplines.



Ischiocrural Muscles (1)
(hamstrings): are on the back of the thigh; cause ↑extension in the hip and ↑flexion in the knee.

M. Gastrocnemius (2)
Musculus gastrocnemius: two-headed calf muscle that causes ↑plantar flexion of the foot. Part of the ↑m. triceps surae.

M. Psoas Major (3)
Musculus psoas major: "greater lumbar muscle", an internal hip muscle starting in the lumbar vertebrae that flexes the thigh at the hip joint and rotates outwards.

M. Quadriceps Femoris (4)
Musculus quadriceps femoris: four-headed muscle of the femur. Mainly permits ↑extension of the lower leg in the knee joint.

M. Soleus (5)
Musculus soleus: lower leg muscle, its tendon and the one of the ↑m. gastrocnemius together form the Achilles tendon. It is involved in ↑plantar flexion of the foot. Part of the ↑m. triceps surae.

M. Tibialis Anterior (6)
Musculus tibialis anterior: anterior tibial muscle, from tibia to medial foot edge pulling muscle that causes ↑dorsiflexion of the foot.

M. Triceps Surae (2 and 5)
Musculus triceps surae: three-headed calf muscle, a combination of the two-headed ↑m. gastrocnemius and the ↑m. soleus.

M. Vastus Lateralis (4a)
Musculus vastus lateralis: lateral aspect of femur, from back of the thigh to the patella pulling part of the ↑m. quadriceps. It is involved in the ↑extension of the lower leg in the knee joint.

Muscle Atrophy
(from Greek *atrophia* = emaciation): visible skeletal muscle volume loss due to reduced stress.

Neutral Position
A neutral position is characterised by an upright posture with feet nearly shoulder width apart. The joint's range of motion can be determined from the neutral position.

Paraplegia
(from Greek *para* = beside, near; *plege* = to impact, to strike): complete paralysis of two symmetrical extremities.

Pathological
(from Greek *pathos* = pain; disease): altered by disease.

Physiological
(from Greek *physis* = nature; *logos* = science): concerning natural life processes.

Plantar
(from Latin *planta* = sole of the foot): concerning the sole of the foot.

Plantar Flexion
Dropping of the foot. Countermovement: lifting of the foot (↑dorsiflexion).

Point of Heel Strike
Point where the heel touches the floor first in initial contact.

Polypropylene
(PP): group of thermoformable and weldable plastics. Often used for the production of simple orthoses. Economical manufacturing technique. The considerably higher weight is a disadvantage over materials of a higher quality, such as carbon fibre, offering the same rigidity.

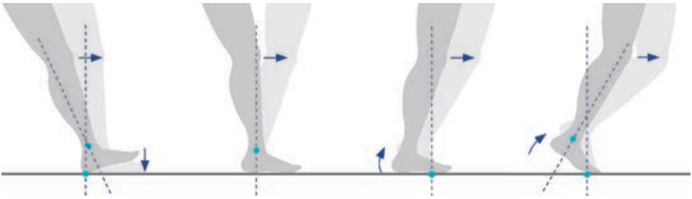
Posterior-Leaf-Spring AFO (PLS-AFO)
(from Latin *posterior* = back): lower leg orthosis with leaf-spring attached behind the Achilles tendon, mostly made of carbon fibre.

Pretibial
(from Latin *prae* = before; *tibia* = shinbone): situated before the tibia.

Glossary

Push Off
Rapid toe-off in pre swing assists the ankle's push off and advances the leg into swing.

Rockers
Rotations around three different points of the foot in stance phase. 1^{st} rocker (heel rocker) = rotation of the foot around the heel and of the lower leg around the anatomical ankle joint during initial contact and loading response, 2^{nd} rocker (ankle rocker) = rotation of the lower leg around the ankle in mid stance, 3^{rd} rocker (toe rocker) = rotation of the hindfoot around the metatarsophalangeal joints in terminal stance, 4^{th} rocker = combined rotation around the ankle the metatarsophalangeal joints in pre swing.



1^{st} rocker | 2^{nd} rocker | 3^{rd} rocker | 4^{th} rocker

SAFO
(solid ankle-foot orthosis): rigid lower leg orthosis.
The term SAFO is used internationally for rigid ↑AFOs made of ↑polypropylene. The present use of this term is ambiguous since static ↑AFOs are also rigid.

Sensorimotor
Refers to the combination of sensory and motor parts of the nervous system. For example, the sensory impressions of the foot sole affect the function of certain muscles. Sensorimotor elements can be produced, for instance, as inserts or also be integrated in ↑SMOs as insoles.

SMO
(supramalleolar orthosis): supramalleolar orthoses made of reinforced leather or ↑polypropylene. If the Achilles tendon area is not covered, movement in the anatomical ankle joint is possible. That is why SMOs can possess ↑dynamic properties. If the Achilles tendon is covered, the ↑plantar flexion is limited.

Spasticity
(from Greek *spasmos* = spasm): an intermittent or sustained, involuntary muscle activity caused by a lesion of the upper motor neuron responsible for the sensorimotor system [Pan, p. 2ff.].

Static
(from Greek *statikos* = standing, causing to stand): concerning the balance of power and statics, being in balance and idle state, stagnant; i.e. a static ↑AFO allows no movement in the anatomical ankle joint.

Tibial Progression
(from Latin *procedere* = proceed, increase): movement of the tibia (shinbone) in direction of movement around the anatomical ankle joint in mid stance. Also known as ankle rockers (rockers).

Ventral
(from Latin *venter* = belly, body): denoting a position toward the belly surface, abdominal; e.g. for an ↑AFO, this means the shell is on the front side of the lower leg.

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