FIOR & GENTZ
ORTHOPÄDIETECHNIK MIT SYSTEM

Stroke Guide

A Concept for the Orthotic Treatment of the Lower Extremity following a Cerebral Vascular Accident

4th edition

Introduction

According to the WHO, nearly 15 million people worldwide suffer a stroke each year. One third of the affected people remain impaired afterwards [Mac, p. 50]. In Germany, the number of impaired people every year is around 196,000 [Did, p. 592]. In most cases, the affected cerebral areas are the ones containing the programs to control the musculoskeletal system [Cor, p. 11]. Acting fast is important because the sooner a stroke is recognised and treated, the better the secondary damages can be controlled. Furthermore, numerous clinical studies confirm the high value of orthoses in stroke rehabilitation [Bow, p. 87ff.]
However, there is still a lot of unused potential in the orthotic treatment of stroke patients. The NEURO SWING system ankle joint offers new opportunities. As a result, many of the previously applied insufficient orthotic concepts can be reconsidered.

We would like to bring more attention to standing as the first step in stroke therapy. In this context, orthoses can be an important aid for practising independently. This Stroke Guide was created to facilitate the communication on the orthotic treatment of stroke patients between physicians, physiotherapists, orthotists and biomechanics. Furthermore, the patients' partner or carer and, of course, the patients themselves should be involved in the communication process to decide on the optimal orthosis.

An important basis for the present treatment concept is the N.A.P.® Gait Classification, which has been developed in collaboration with physiotherapist Renata Horst. This classification helps to easily determine the pathological gait. We are especially grateful to Beate Hesse, who volunteered as a stroke patient for test tfittings and photos.

Our Stroke Guide does not claim to be perfect. Rather, it is intended to be the impetus to rethink in the orthotic treatment of stroke patients. We rely on your comments and suggestions to continually improve its quality.

Your FIOR & GENTZ team

Content

What is a Stroke?

A stroke is a sudden decrease in blood flow in the brain due to vascular causes and it can lead to death or be accompanied by secondary symptoms that last more than 24 hours. The sooner it is recognised and treated, the better the chance of avoiding long-term damages. Mainly, about 80% of all strokes are caused by an acute circulatory disorder (ischaemic stroke) and about 15% by a cerebral haemorrhage (haemorrhagic stroke) [Did, p. 592]. A persistent undersupply of certain cerebral areas causes impairments of various bodily functions.

Movement Restrictions

The undersupply can affect cerebral areas that control the motor function of the musculoskeletal system. As a consequence, the muscles connected to these nerve cells are innervated too early, too late or not at all, thus impairing the muscular stabilisation of the knee and ankle joint.

Compensation Mechanisms

The biomechanical situation of the musculoskeletal system changes due to the dysfunctions, leading to instability in the ankle and/or knee joint when gait and stance. The patient tries to compensate for this instability with other bodily functions. However, these consciously or unconsciously performed compensation mechanisms damage the musculoskeletal system.

Spastic Pareses

If the pyramidal tract of the first motor neuron is damaged after a stroke, the movement restrictions and compensation mechanisms can be accompanied by spastic pareses. If, additionally, the extrapyramidal nerve tracts are damaged, the regulation of the affected muscles' own reflexes is disturbed. This results in an increased muscle tone [Thi, p. 1102]. Spastic pareses can develop or intensify due to perceived insecurities.

Treating a Stroke in an Interdisciplinary Team

After a stroke, an immediate treatment with medical devices is crucial [Hes, p. 1105]. In order to re-establish the motor function in the best possible way and to avoid secondary symptoms caused by the dysfunctions, physician, physiotherapist and occupational therapist as well as orthotist and biomechanic must pursue a common treatment concept. One of the first steps should be an early start of physiotherapy [Die, p. 34].

Stance Training

Before walking comes standing. Even though standing still is perceived as a simple motor task, it involves the same muscle groups as walking. Many small movements keep the body's centre of gravity above the supportive area, thus creating a stable dynamic balance. These small movements show as minimal swaying of the upper body, the so-called postural sway. A study shows that an early and intensive stance training can shorten the time to regain independent walking [Cum, p. 157].

Dynamic orthoses are a valuable support for a safe stance after a stroke and can prevent or reduce the appearance of spastic pareses. Although the patient might not be able to put the orthosis on themself, stance training should already begin in the acute phase. For that purpose, the orthosis must be worn as often as possible. In this way, supported stance can also be trained independently of therapy sessions and already in early rehabilitation at the patient's bed alone or with assistance of another person. This early stance training offers the following advantages:

- Regaining the sense of balance is supported.
- Bringing the body into an upright position (verticalisation) has a variety of positive effects on the human organism [Kne, p. 603].
- The controlled load on the muscles can shorten the time to regain independent walking [Cum, p. 157].
- Standing in the acute phase can establish the correct cerebral connections through motor impulses.

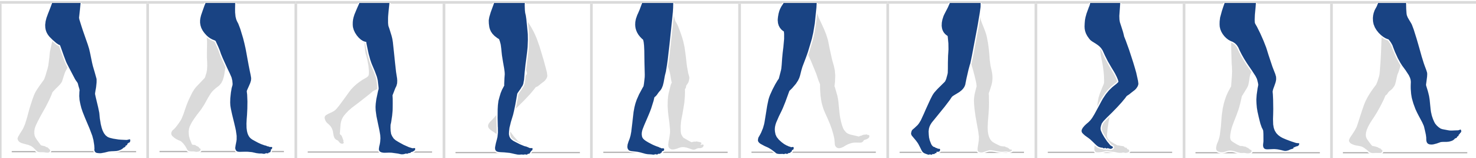
Furthermore, a stance training in this early phase of rehabilitation supports the prevention of pes equinus as the muscles are stretched and loaded dynamically. The orthosis also avoids that the foot is in a permanent pes equinus position when lying in bed.

Gait Training

The goal of modern physiotherapy is to treat the insufficient muscle groups during gait training by establishing the right cerebral connections through motor impulses [Hor, p. 5-26]. Depending on the therapeutic approach chosen, this goal is achieved in different ways. In the N.A.P.® concept, for example, the therapist creates the correct biomechanical situation for the patient. The exercises are integrated into targeted movements.

The combination of physiotherapy and a dynamic orthosis can support an approximation to the physiological gait and reduce spastic pareses during walking. In this context, a comparatively early fitting with an orthosis is beneficial for the patient's independence and safety [Nik, p. 1623]. To improve the gait of stroke patients, the interdisciplinary team uses the physiological gait as a guide, shown below in its individual phases [Per, pp. 70ff., 92ff., 111ff.; Goe, pp. 14ff., 44ff.].

Division of Physiological Gait into Different Phases According to Jacquelin Perry



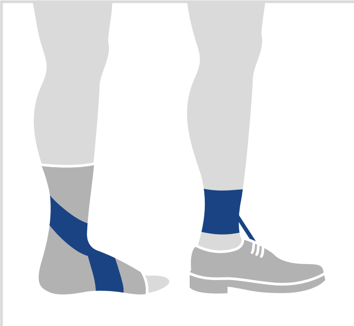
Term (Abbreviation)									
initial contact (IC)	loading response (LR)	early mid stance (MSt)	mid stance (MSt)	late mid stance (MSt)	terminal stance (TSt)	pre swing (PSw)	initial swing (ISw)	mid swing (MSw)	terminal swing (TSw)
Percentage of Stride									
0 %	0–12 %		12–31 %		31–50 %	50–62 %	62–75 %	75–87 %	87–100 %
Hip Angle									
20° flexion	20° flexion	10° flexion	5° extension	5° extension	20° extension	10° extension	15° flexion	25° flexion	20° flexion
Knee Angle									
5° flexion	15° flexion	10° flexion	5° flexion	5° flexion	10° flexion	40° flexion	60° flexion	25° flexion	5° flexion
Ankle Angle									
neutral position	5° plantar flexion	neutral position	5° dorsiflexion	5° dorsiflexion	10° dorsiflexion	15° plantar flexion	5° plantar flexion	neutral position	neutral position

Depending on the severity and the characteristics of the disease pattern, the treatment of stroke patients can be performed with a multitude of devices. They range from simple orthotic devices such as bandages and special orthopaedic inserts to ankle-foot orthoses (AFOs) with or without an ankle joint. In severe cases, these treatments can be supplemented with crutches and walkers.

Effective orthoses are essential to support physiotherapy. In some cases, the orthosis needs to be complemented by orthopaedic shoes or shoe modifications or adjustments [Gru, p. 523]. This page summarises the most common orthoses for stroke patients used today, which should, however, be viewed critically due to new developments in orthopaedic technology.

Bandages

The simplest way to treat an stroke patient is a supramalleolar, dorsiflexion-assist bandage. These bandages stabilise the anatomical ankle joint by using elastic straps and hook and loop fasteners to keep the foot in neutral position during swing phase. In comparison to AFOs, however, they only have a small dorsiflexion-assist effect.



Bandages

Solid Orthoses

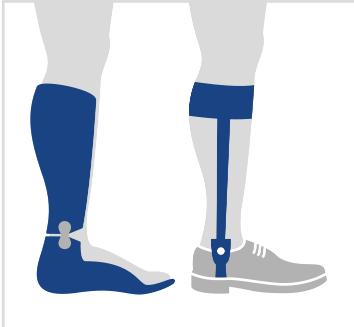
Solid AFOs (SAFOs) made of polypropylene or carbon do not allow any movement in the ankle. SAFOs are commonly used for patients with severe spasticity [Con, p. 437].

The so-called floor reaction AFO (FRAFO) with an anterior shell also blocks any movement of the anatomical ankle joint. A FRAFO is either made of polypropylene or carbon. The anterior shell enables a knee extension in terminal stance. However, this is contraindicated in patients with a hyperextended knee [Fat, p. 527].

SAFO FRAFO

Orthoses with Ankle Joint

Classical hinged AFOs block any plantar flexion and enable a dorsiflexion with a defined pivot point in the anatomical ankle joint. They are commonly designed with elastomer spring joints without any spring effect or dorsiflexion stop. That is why hinged AFOs are not suitable for every stroke patient [Con, p. 437].



hinged AFO metal AFO

A metal AFO integrated into the shoe also has a defined pivot point and a defined range of motion. However, these metal AFOs are usually fitted with simple joints with pressure springs, which have only a slight spring effect.

Orthoses with Posterior Leaf Spring

For some time now, AFOs with a spring effect, so-called posterior-leaf-spring AFOs, have been used. The strong spring effect is achieved using carbon springs, whereas this effect is minimal with similar AFOs made of polypropylene. The disadvantage is that these orthoses have no defined pivot point, no defined or adjustable range of motion and no adaptable alignment. A passive plantar flexion is completly prevented.

posterior-leaf-spring AFO

Conventional Orthoses

Disadvantages of Conventional Orthoses

All currently available treatments can result in a successful therapy, but they can also have a negative effect on it, as each design not only has advantages, but also disadvantages.

1. Lack of Adjustment Options

Depending on the patient's pathological gait, the physician's requirements and the goal of physiotherapy, the orthotist must produce an orthosis that provides the required lever effect [Fat, S. 516; Owe, S. 262]. However, the construction of an effective orthosis has not been possible until now due to a lack of adjustment options. An optimal adaptation to the pathological gait of the patient therefore is only possible to a limited extent with the mentioned orthoses.

2. Limited Plantar Flexion

Almost all of the listed constructions restrict the physiological plantar flexion. Thus, no ideal compromise between dorsiflexion-assist effect and heel rocker can be found. A qualified physiotherapist uses the very important heel lever. By doing so, the right cerebral connections are established through motor impulses [Hor, p. 5-26] and individual muscle groups are strengthened with specific muscle training.

Requirements for an Orthosis

A modern orthosis concept is expected to be optimally adaptable to the patient's needs and the course of therapy. It should also allow for a dynamic stability while both standing and walking. Only then can the overall goal of an orthosis be achieved: a physiological gait.

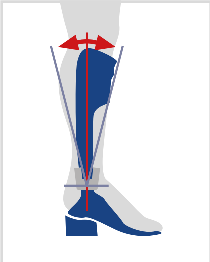
Therefore, all orthoses for stroke patients should be constructed with an adjustable ankle joint. It is absolutely necessary to be able to adjust the orthosis alignment, since the position of the patient's foot when producing the cast model differs from its position under load with the orthosis. Thanks to an adjustable range of motion and a variable spring force, the orthotist can react to changes in the gait that may occur during the course of therapy without much difficulty.

The adjustable NEURO SWING system ankle joint has been developed for that exact reason.

To adapt the orthosis optimally to the patient's requirements, the NEURO SWING system ankle joint has three adjustment options. All adjustments can be made separately. They do not influence each other:

1. **Adjustable Alignment**

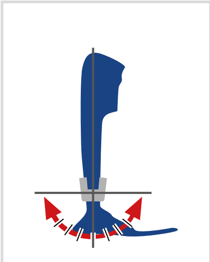
Thanks to the adjustable alignment of the NEURO SWING system ankle joint, the orthosis can be individually adjusted to the patient's pathological gait. If the gait changes, a quick response can easily be made by adjusting and tuning the settings.



adjustable alignment

2. **Adjustable Range of Motion**

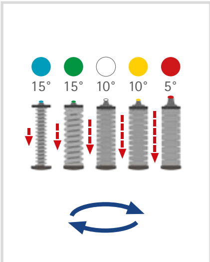
In the early rehabilitation stages following a surgery, it may be necessary to partially or completely disable the range of motion of an orthosis and to only enable it at a later stage of therapy. Thanks to the motion limiting screw, which is integrated in the NEURO SWING system ankle joint, the predefined range of motion in plantar flexion and dorsiflexion can be completely blocked and gradually released again.



adjustable range of motion

3. **Variable Spring Force**

The spring force in plantar flexion and dorsiflexion can be individually adjusted to the patient's needs thanks to the interchangeable, precompressed spring units. A total of five different spring units is available for the NEURO SWING system ankle joint, ranging in strength from normal to extra strong and with a range of motion from 15° to 5°.



variable spring force

The NEURO SWING system ankle joint is available in four models, each in up to five system widths. In order to be able to select the suitable system width according to the determined patient data, please use the FIOR & GENTZ Orthosis Configurator.

Orthosis Configurator

www.orthosis-configurator.com

NEURO SWING

With its adjustable alignment, adjustable range of motion and the interchangeable, precompressed spring units, the NEURO SWING is the ideal system joint for a flexible treatment. Another advantage is the plug + go modularity, which allows a conversion to any other system joint in the plug + go series in just a few simple steps.

NEURO SWING 2

With the NEURO SWING 2, the alignment, range of motion and spring force are also adjustable. In addition, it has an integrated noise reduction and is therefore the ideal choice for people who appreciate silent locomotion. Like the NEURO SWING, it is part of the plug + go series and can be converted if required.

NEURO SWING Carbon

The NEURO SWING Carbon is the waterproof NEURO SWING model. With its adjustable alignment and interchangeable, precompressed spring units it offers the same advantages as the NEURO SWING, but can also be used in wet and outdoor areas thanks to the carbon fibre-reinforced joint case. The range of motion of the NEURO SWING Carbon is not adjustable.

NEURO HiSWING

With the NEURO HiSWING, the first hydraulic ankle joint has been developed. The ankle joint angle can be adjusted by the patient themselves using the hydraulic mechanism, which makes it possible to climb stairs and hike in uneven terrain with less effort. The orthosis can be easily adapted to different heel heights and offers more comfort when sitting.

NEURO SWING NEURO SWING 2 NEURO HiSWING

Precompressed Spring Units

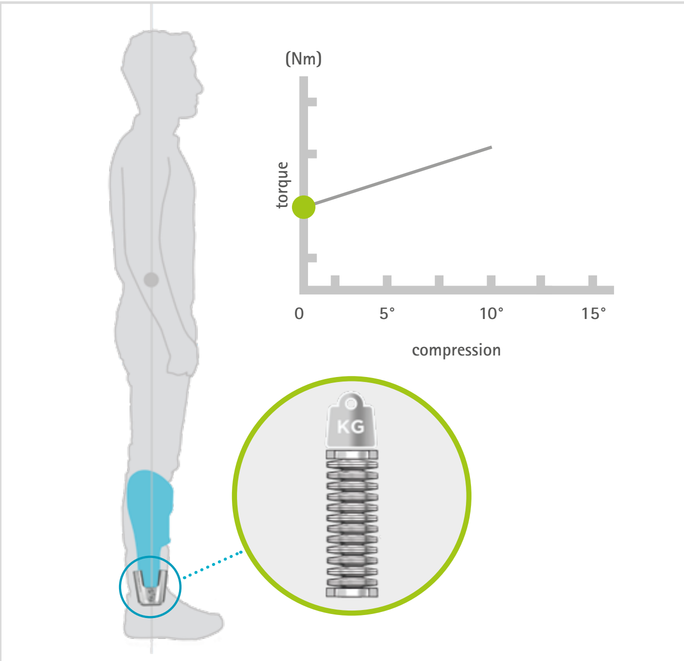
In order to bring a body into a stable balance, the forefoot lever must be activated. In case of a weakness of the plantar flexors, the dynamic activation of the forefoot lever enables a knee-extending moment and guarantees knee stability.

Effects on Stance

Precompressed spring units with a high basic resistance with the NEURO SWING system ankle joint provide dynamic balance and stability. This allows for a secure stance. Since no medical devices other than the orthosis are required, the hands are free for everyday tasks.

Effect on Gait in Terminal Stance

- heel lift
- body's centre of gravity at physiological height
- normal knee flexion on the contralateral side
- improved energy consumption during walking



Non-Precompressed Spring Units

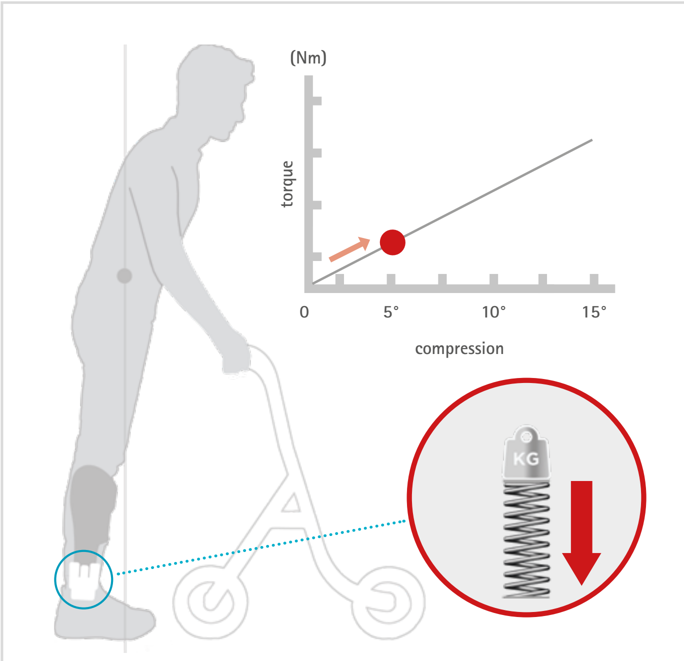
Commonly used coil springs of conventional ankle joints must be heavily compressed to generate resistance. In case of a weakness of the plantar flexors, the activation of the forefoot lever is not possible causing the absence of a knee-extending moment and a reduced knee stability.

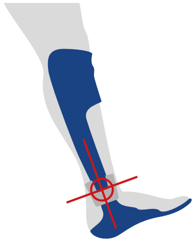
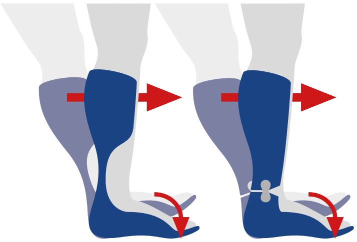
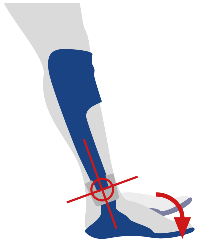
Effects on Stance

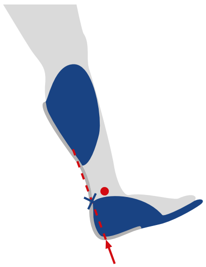
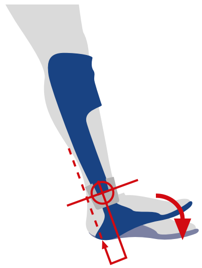
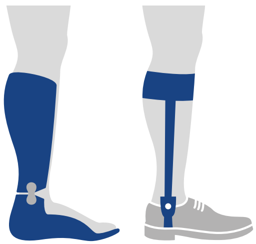
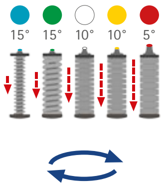
The nonexistent basic resistance due to the lack of precompression leads to a yielding of the spring when loaded during stance and, due to the missing security, to an unstable stance. This requires the use of medical devices such as crutches or walkers. The hands are therefore needed for support.

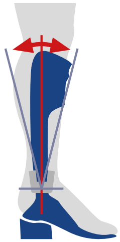
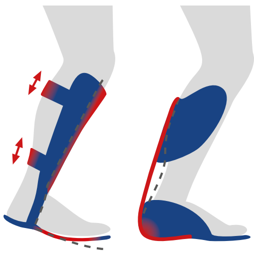
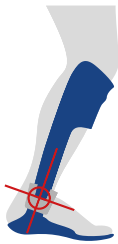
Effect on Gait inTermibal Stance

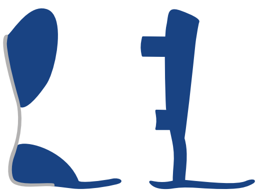
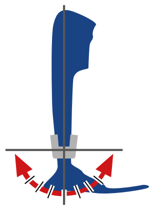
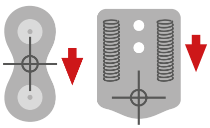
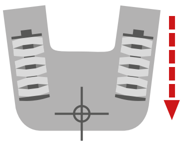
- no heel lift
- body's centre of gravity too low
- excessive knee flexion on the contralateral leg side
- energy consumption during walking too high



Disadvantages of Existing AFOs	Properties of the NEURO SWING	Description
 low dorsiflexion-assist effect	 high dorsiflexion-assist effect	**Dorsiflexion-Assist Effect** AFOs keep the foot in neutral position or in slight dorsiflexion. This enables the affected leg to swing freely during swing phase and to set the heel down during initial contact. Certain bandages were designed to provide a similar effect. However, the dorsiflexion-assist effect is usually too weak to keep the foot in neutral position. This deficit is evident in compensation mechanisms such as a strong hip elevation or an external rotation of the leg during swing phase. Each spring unit of the NEURO SWING system ankle joint is strong enough to keep the foot in the set position and thus enable the affected leg to swing freely without stumbling, as well as allow initial contact with the heel.
 foot lifting through blocked plantar flexion	 passive plantar flexion possible	**Passive Plantar Flexion** By means of the blocked plantar flexion, the dorsiflexion is effectively assisted during swing phase. This, however, causes an increased knee flexion moment, leading to an enormous stress on the m. quadriceps (comparable to walking with a ski boot). In patients with a weak m. quadriceps and m. gastrocnemius, this strain can lead to an increased knee flexion that is not physiological [Goe, p. 134ff.; Per, p. 195]. Qualified physiotherapy uses the passive plantar flexion to treat insufficient muscle groups. The right cerebral connections are established through motor impulses [Hor, p. 5-26] and individual muscle groups are strengthened with specific muscle training [Goe, p. 98ff.].

Disadvantages of Existing AFOs	Properties of the NEURO SWING	Description
 no heel rocker	 heel rocker	**Heel Rocker** The anatomical pivot point creates a lever arm at the hindfoot which runs from the point of heel strike through the calcaneus to the ankle. At initial contact, the body weight triggers a passive foot dropping via this lever which is controlled by the eccentric work of the m. tibialis anterior. Other orthoses such as the posterior-leaf-spring AFOs do not allow this lever. With these orthoses, foot dropping is only possible through active muscle work of the m. triceps surae, which does not correspond to the physiological movement. The NEURO SWING system ankle joint allows passive plantar flexion of the foot by means of the defined pivot point and the range of motion adjustable in plantar flexion. This controls the eccentric work of the m. tibialis anterior and supports it with the interchangeable posterior spring unit.
 no variable spring force	 variable spring force	**Variable Spring Force** The spring force in plantar flexion and dorsiflexion can be individually and easily adjusted to the patient's pathological gait by using spring units of different strength. By modifying the spring force, the knee position can be greatly influenced from initial contact to mid stance [Kob, p. 458]. In AFOs without ankle joint, the spring force can only be changed to a limited extent.

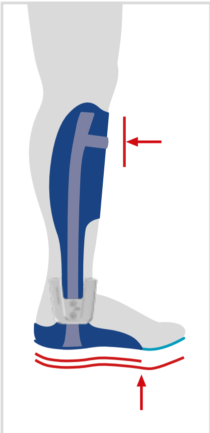
Disadvantages of Existing AFOs	Properties of the NEURO SWING	Description
 no adjustable alignment	 adjustable alignment	**Adjustable Alignment** Since the orthosis must be aligned in such a way that it provides the required lever effect [Fat, S. 516], it is necessary to use an adjustable ankle joint. This is the only way to adjust the orthosis precisely to the stroke patient's pathological gait and to react flexibly to changes. Thanks to the adjustable alignment of the NEURO SWING system ankle joint, the fine adjustment of the orthosis, the so-called tuning, can be done without difficulty. To determine the individual forward inclination of the lower leg, a starting value of 10° to 12° is recommended [Owe, p. 257].
 no defined pivot point	 defined pivot point	**Defined Pivot Point** Some orthoses allow movement between foot and lower leg without an ankle joint. However, these orthoses only allow insufficient movement of the anatomical ankle joint which can result in muscular atrophies [Goe, p. 98f.]. Furthermore, the shells of the orthosis shift unintentionally on the stroke patient's leg and can cause skin irritations. The defined pivot point supports qualified physiotherapy sessions in treating insufficient muscle groups by establishing the right cerebral connections through motor impulses [Hor, p. 5-26] and strengthening individual muscle groups with specific muscle training [Goe, S. 98ff.].

Disadvantages of Existing AFOs	Properties of the NEURO SWING	Description
 no adjustable range of motion	 adjustable range of motion	**Adjustable Range of Motion** After surgery, it may be necessary to limit the range of motion of an orthosis partially or completely and only allow it again later in the course of therapy. Thus, an ankle joint with individually adjustable range of motion must be mounted to an AFO. It makes sense to treat patients with a static AFO when success cannot be expected during physiotherapy or the foot is severely deformed.
 low spring force	 high spring force	**Spring Force** The pathological gait of some stroke patients requires very high spring forces. With the NEURO SWING system ankle joint, these spring forces are achieved by disc springs stacked into compact spring units. The spring units are preloaded and store the energy put in by the body weight. Common constructions like elastomer or coil spring joints, which are often mounted in hinged AFOs or metal AFOs, are far from achieving this effect. At the same time, the two spring units placed opposite of each other have a positive effect on the sense of balance, which results in an improvement of the stability of gait and stance.

Unfortunately, it is still far too common to refrain from orthotic treatment in the acute phase of a stroke, as it is difficult to assess the required support for safe stance and gait. An orthosis is particularly important in this phase for the vertical mobilisation as a basis for subsequent gait training.

In this context, a comparatively early fitting with an orthosis is very beneficial for the patient's independence and safety [Nik, p. 1623]. An orthosis with an anterior shell and a dynamic NEURO SWING system ankle joint activates the forefoot lever. The patient applies their body weight to the orthosis via the anterior shell, which places the body's centre of gravity in front of the ankle joint pivot point. This activates the supportive area and the patient achieves security when standing.

Recommended Orthosis



A dynamic AFO with high anterior shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint is recommended.

Spring units to be used:

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

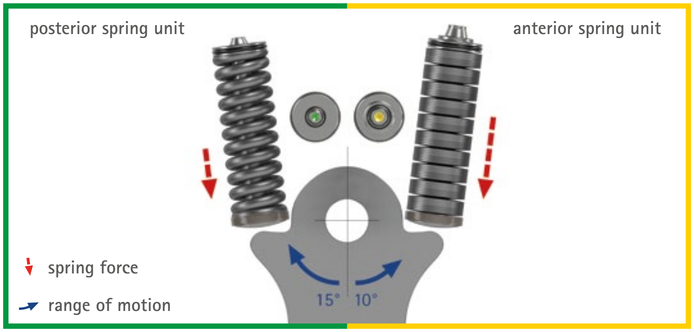
The listed spring units represent an initial suggestion. Based on this, the optimal spring force for every patient can be determined individually. The effects of the individual spring units are described on pages 52-55. If the knee-extending muscle groups are hardly activated neurologically, an orthotic fitting with a KAFO may be necessary.

Adjustment Options of the NEURO SWING System Ankle Joint

Individual adjustment to the pathological gait by:

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

All three adjustment options can be chosen separately. They do not influence each other.



In addition to the quick orthotic fitting of patients in the acute/subacute phase, this treatment suggestion is also suitable for patients,

- who are not able to walk (e.g. in the chronic phase),
- for whom the muscle strength cannot be determined,
- for whom the gait type cannot be clearly determined,
- who do not have a clear gait type (e.g. mildly affected patients).

Thanks to the interchangeable spring units, the orthosis can be adapted to changes in the pathological gait.

In many cases, a stroke causes the loss of control of the muscles that are relevant for standing and walking. A major component of physiotherapy is to train the insufficient muscle groups to establish new cerebral connections through motor impulses [Hor, p. 5-26]. An early and intensive stance exercise can shorten the time to regain independent walking [Cum, p. 157]. Unfortunately, stance and gait training often only starts during rehabilitation. With an early orthotic treatment, the patient achieves safety during stance and can already start the vertical mobilisation in the Stroke Unit. The exercises below describe options to help the patient to slowly get back on their feet with the help of an AFO and another person.

Stance Exercise with an AFO

With an orthosis, standing can already be practised at the patient's bedside during the acute/subacute phase. Another person assists with putting the orthosis on and getting out of bed.

The patient holds onto the edge of the bed and straightens up while being secured by another person (fig. 1 and 2). In this position they can, for example, try to shift their body weight between the left and the right leg.

fig. 1

fig. 2

Walking Exercise with an AFO

When walking, the body weight is carried by one leg in stance phase. The dynamic AFO provides support by stabilising the ankle and knee joint without limiting the range of motion of the anatomical joints too much. However, the orthosis only makes a small difference in initiating swing phase. Therefore, the patient must intentionally train the push-off activity of the affected leg.

The patient stabilises themselves on their affected leg while another person supports them (fig. 3). The patient leans against the other person while moving the swing leg forward (fig. 4 and 5). This exercise trains the push-off activity of the affected leg. The AFO supports the patient using the dynamic dorsiflexion stop.

fig. 3

fig. 4

fig. 5

To achieve the desired treatment goal, the interdisciplinary team needs to find a common basis for assessing the different characteristics of a stroke. This basis can be created by classifying stroke patients according to determined criteria, thereby establishing a classification.

Such classifications accompany the patient throughout the entire therapy, particularly immediately after the stroke. In the Stroke Unit, a specialised facility for the acute phase, classifications are crucial for the localisation of the damage and for the development of a treatment regimen.

Severity and Physical Self-Care in Everyday Life

In addition to numerous classifications used by clinics in acute situations, mainly the Modified Rankin Scale and the Barthel Index are applied. The Modified Rankin Scale is a simple scale for assessing the severity or motor disability of a patient after a stroke. It divides the deficits into 7 levels, from grade 0 (no neurological deficits) to grade 6 (stroke with fatal outcome) [Cor, p. 30f.].

The Barthel Index aims to assess the state of everyday functions of patients with musculoskeletal and neuromuscular diseases, as well as infarct patients. By evaluating 10 daily activities and tasks in a person's life (ADL) regarding functional independence, up to 100 points can be achieved, which are used to assess the progress of the rehabilitation [Cor, p. 26f].

Spasticity

For an optimal therapy, it may be important to determine the extent of the spasticity. The Modified Ashworth Scale (MAS) is the most commonly used clinical practice. The muscle tone is measured by passively moving the affected joint. Based on the speed-dependent resistance, the examiner classifies the spasticity on a scale from 0 to 4. However, the reliability and sensitivity of this method are often criticised [Thi, p. 1096].

Pathological Gait

Despite many studies on the gait after a stroke, there is still no standardised classification. In 1995, Jacquelin Perry classified the mobility of stroke patients. In this study, 147 patients were examined in everyday situations and categorised into six functional gait types [Per2, p. 982ff]. In 2001, Rodda and Graham, among others, analysed and divided patients with spastic hemiplegia into four gait type, using video recording and taking gait pattern and posture into account [Rod, S. 98ff.].

In 2003, Perry classified stroke patients, based on functional criteria, into four different classes according to their walking speed, knee position in mid stance and ankle position in mid swing. Gait characteristics, angle progressions, muscle activity and manual muscle tests of the patients were assessed [Per, p. 305ff].

In collaboration with physiotherapists and clinics, a classification was created, which enables a simple evaluation of the pathological gait, based on experience and observations. This classification, the N.A.P.® Gait Classification describes the knee position in mid stance which compensates for the talus position. A distinction is made between two gait types with hyperextension and with hyperflexion, each associated with either an inversion or eversion position of the lower ankle joint. A description of the physiological gait in mid stance can be found on pages 8 and 9.

The N.A.P.® Gait Classification makes it possible to quickly classify stroke patients according to their gait. This facilitates the interdisciplinary communication as well as the selection of the right treatment method. It can also contribute to the standardisation and quality assurance of the orthotic fitting.

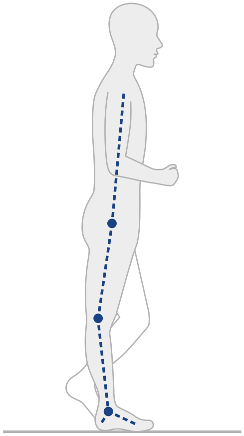
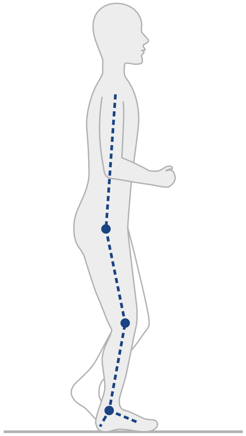
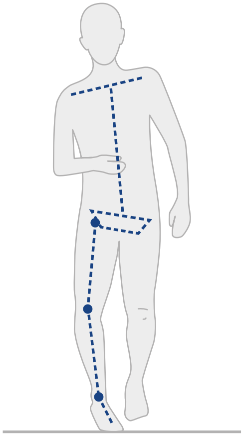
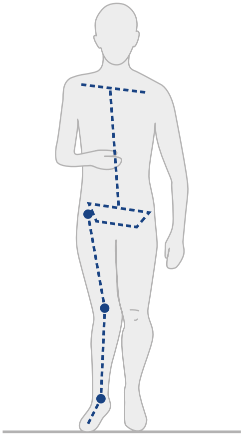
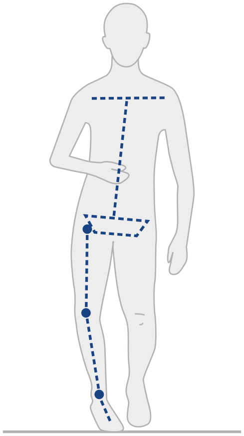
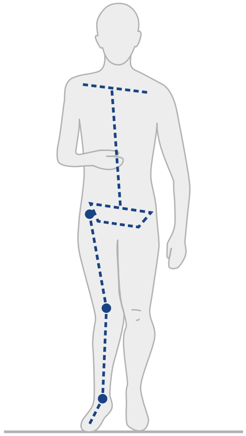
N.A.P.® = abbreviation for Neuroorthopädische Aktivitätsabhängige Plastizität® (Neuro-orthopedic Activity-dependent Plasticity). It refers to a therapy concept developed from PNF and manual therapy by physiotherapist Renata Horst in 1999. N.A.P.® is based on the idea of initiating movements during a useful action with the active participation of the patient.

The N.A.P.® Gait Classification

This classification is divided into four basic gait types. In the sagittal plane, there is a malposition of the knee in either hyperextension or hyperflexion in mid stance. Usually, the pelvis is excessively inclined forward.

The patient's goal is to maintain stability using their existing potentials. Depending on the inversion or eversion malposition in the frontal plane the joints further up are also loaded incorrectly.

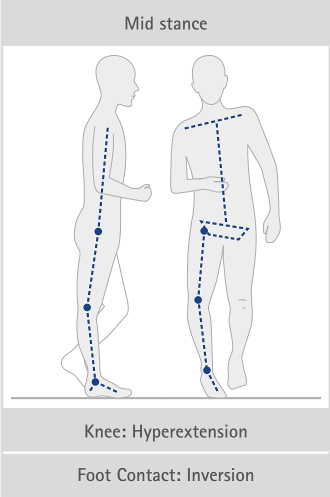
Gait Type according to N.A.P.® Gait Classification

Knee	Hyperextension		Hyperflexion	
sagittal				
frontal				
Foot	Inversion	Eversion	Inversion	Eversion
Gait Type	Type 1a	Type 1b	Type 2a	Type 2b

N.A.P.® is a registered trademark of Renata Horst.

Pathological Gait

Inversion Type with Hyperextension
In mid stance, the load is on the outer edge of the foot. The forefoot cannot be stabilised because the mm. peronei muscles and the intrinsic foot muscles are too weak. The knee joint is hyperextended and the pelvis is slightly tilted forward. The torso is tilted towards the supporting leg and the arm muscles are tensed to ensure stability.

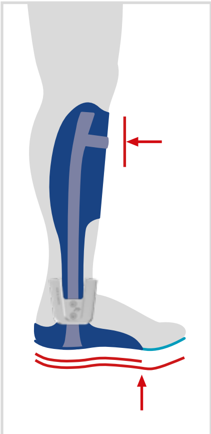


Recommended Orthosis

A dynamic AFO with high anterior shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint is recommended.

Why an anterior shell? Please read the info box on page 39.

Spring units to be used:
- posterior: green marking (medium spring force, max. 15° range of motion)
- anterior: yellow marking (very strong spring force, max. 10° range of motion)

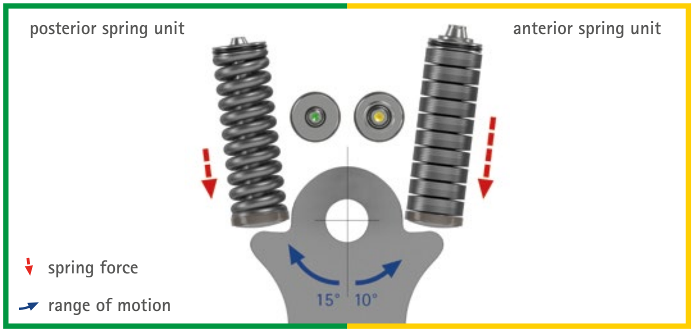


The listed spring units represent an initial suggestion. Based on this, the optimal spring force for every patient can be determined individually. The effects of the individual spring units are described on pages 52-55. If the knee-extending muscle groups are hardly activated neurologically, an orthotic fitting with a KAFO may be necessary.

Adjustment Options of the NEURO SWING System Ankle Joint

Individual adjustment to the pathological gait by:
- exchangeable spring units,
- adjustable alignment,
- adjustable range of motion.

All three adjustment options can be chosen separately. They do not influence each other.



Design of the Insoles

Sensomotoric elements that are integrated in the insoles are well suited to improve the patient's foot position. The following heel supports are most suitable for a targeted correction of the heel inversion:

- medial: strengthens the m. tibialis posterior and supports the heel (green)
- lateral: strengthens the mm. peronei and thereby prevents a heel inversion (red)

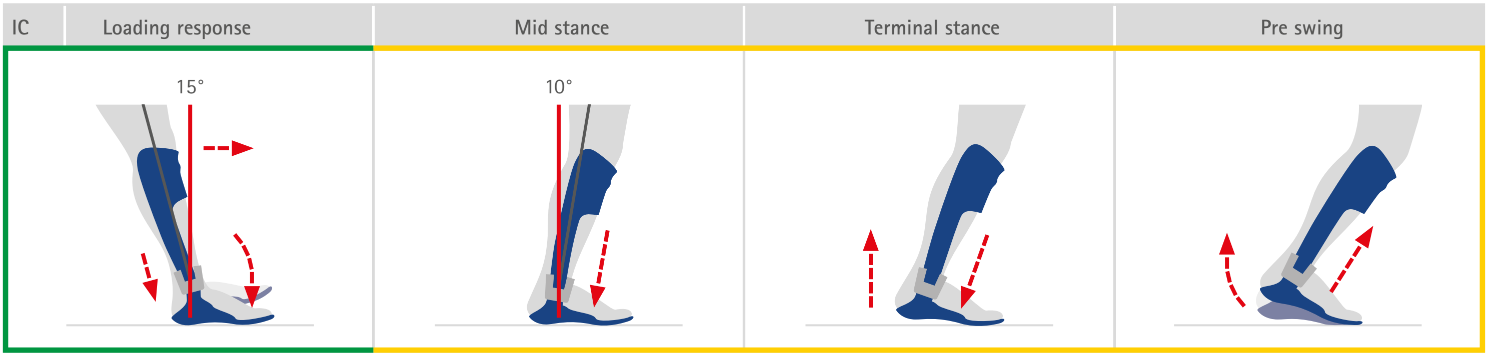
Present Orthotic Treatment Options

Stroke patients of this gait type have previously been treated with hinged or solid AFOs based on the muscle tone. Due to the construction of these orthosis types, the foot is kept in neutral position or in slight dorsiflexion and the physiological plantar flexion is prevented. This leads to an increased knee flexion moment between initial contact and loading response. This results in an enormous stress on the m. quadriceps (comparable to walking with a ski boot) [Goe, p. 134ff.; Per, p. 195]. The orthotic fitting with so-called FRAFOs is contraindicated in patients with a hyperextended knee [Fat, p. 527]. As the alignment of this orthosis cannot be adjusted and there is neither a defined pivot point nor a range of motion, a hyperextension of the knee can be increased when combined with an anterior shell.

Effect of the Orthosis

- Initial contact and loading response: the strength of the posterior spring unit of the NEURO SWING system ankle joint is sufficient to keep the foot in neutral position. Thus, ensuring that the heel touches the ground first during initial contact. The physiological plantar flexion thus made possible is intended to prevent a premature activation of the gastrocnemius muscle. The eccentric work of the pretibial muscles is improved and the heel rocker actively supported, without applying an excessive torque to the lower leg. An overview of the adjustments to change the gait by replacing the spring units can be found on page 52 and 53.
- Mid stance: the anterior spring unit of the NEURO SWING system ankle joint is preloaded from late mid stance to the adjusted range of motion.
- Terminal stance: due to the very strong anterior spring unit, a physiological lifting of the heel can be achieved.
- Pre swing: the anterior spring unit releases the stored energy that assists the push off and brings the foot in neutral position.
- Initial swing to terminal swing: the strength of the posterior spring unit of the NEURO SWING system ankle joint with medium spring force is sufficient to keep the foot in neutral position. The stroke patient can walk without stumbling and, therefore, torso and hip are relieved.

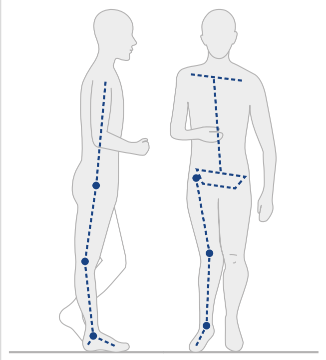
Why an anterior shell?
An orthosis with high anterior shell can only be produced thanks to the high spring forces of the applied spring units. Due to the anterior shell, the patient's initial reflex to support themselves to achieve stability is changed. By pressing their body weight with the tibia against the anterior shell, they gain stability in stance. This prevents an increasing knee hyperextension and the development of contractures in the anatomical ankle joint.



Pathological Gait

Eversion type with Hyperextension
In mid stance, the medial foot arch collapses inwards because the intrinsic foot muscles and the m. tibialis posterior are too weak. The knee joint is hyperextended and the pelvis is slightly tilted forward. As a result, the m. flexor hallucis longus changes its direction of tension and the metatarsophalangeal joint tilts inwards (hallux valgus). The arm muscles are tensed to ensure stability.

Mid stance



Knee: Hyperextension

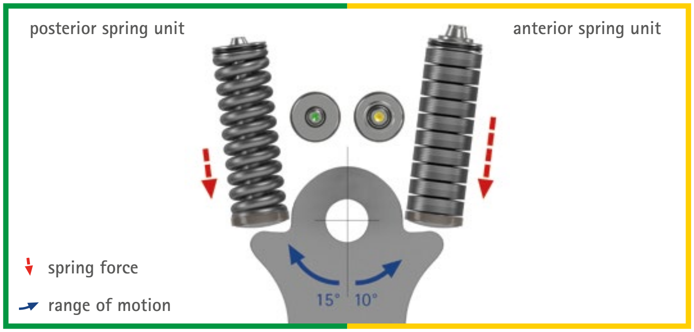
Foot contact: Eversion

Adjustment Options of the NEURO SWING System Ankle Joint

Individual adjustment to the pathological gait by:

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

All three adjustment options can be chosen separately. They do not influence each other.



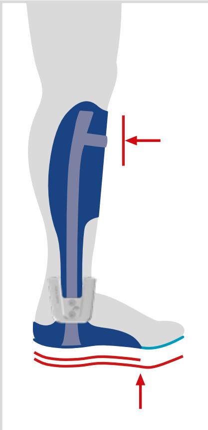
Recommended Orthosis

A dynamic AFO with high anterior shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint is recommended.

Why an anterior shell? Please read the info box on page 43.

Spring units to be used:

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



Design of the Insoles

Sensomotoric elements that are integrated in the insoles are well suited to improve the patient's foot position. The following heel supports are most suitable for a targeted correction of the hindfoot eversion:

- medial: strengthens the m. tibialis posterior and prevents eversion of the heel (red)
- lateral: strengthens the mm. peronei and ensures heel grip (green)

The listed spring units represent an initial suggestion. Based on this, the optimal spring force for every patient can be determined individually. The effects of the individual spring units are described on pages 52-55. If the knee-extending muscle groups are hardly activated neurologically, an orthotic fitting with a KAFO may be necessary.

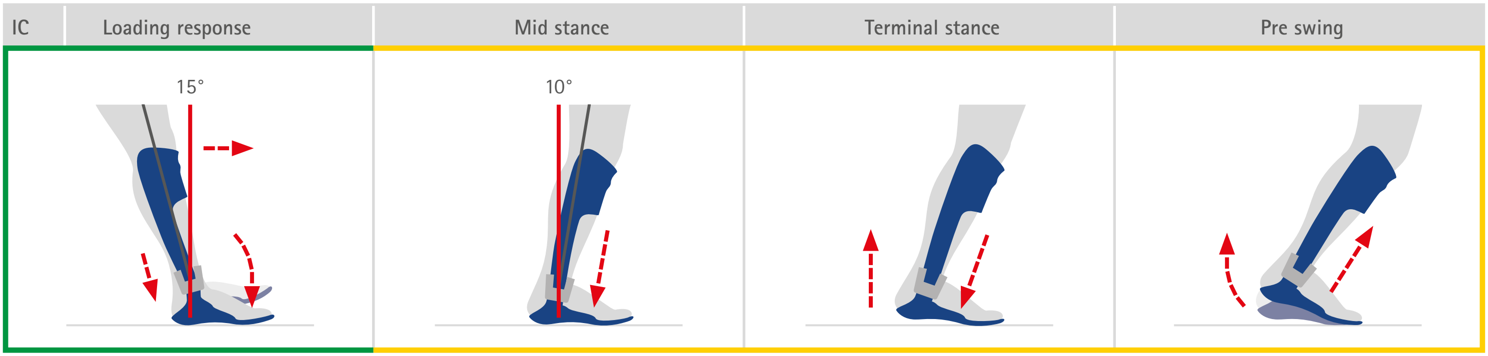
Present Orthotic Treatment Options

Stroke patients of this gait type have previously been treated with hinged or solid AFOs based on the muscle tone. Due to the construction of these orthosis types, the foot is kept in neutral position or in slight dorsiflexion and the physiological plantar flexion is prevented. This leads to an increased knee flexion moment between initial contact and loading response. This results in an enormous stress on the m. quadriceps (comparable to walking with a ski boot) [Goe, p. 134ff.; Per, p. 195]. The orthotic fitting with so-called FRAFOs is contraindicated in patients with a hyperextended knee [Fat, p. 527]. As the alignment of this orthosis cannot be adjusted and there is neither a defined pivot point nor a range of motion, a hyperextension of the knee can be increased when combined with a anterior shell.

Effect of the Orthosis

- Initial contact and loading response: the strength of the posterior spring unit of the NEURO SWING system ankle joint is sufficient to keep the foot in neutral position. Thus, ensuring that the heel touches the ground first during initial contact. The physiological plantar flexion thus made possible is intended to prevent a premature activation of the gastrocnemius muscle. The eccentric work of the pretibial muscles is improved and the heel rocker actively supported, without applying an excessive torque to the lower leg. An overview of the adjustments to change the gait by replacing the spring units can be found on page 52 and 53.
- Mid stance: the anterior spring unit of the NEURO SWING system ankle joint is preloaded from late mid stance to the adjusted range of motion.
- Terminal stance: due to the very strong anterior spring unit, a physiological lifting of the heel can be achieved.
- Pre swing: the anterior spring unit releases the stored energy that assists the push off and brings the foot in neutral position.
- Initial swing to terminal swing: the strength of the posterior spring unit of the NEURO SWING system ankle joint with medium spring force is sufficient to keep the foot in neutral position. The stroke patient can walk without stumbling and, therefore, torso and hip are relieved.

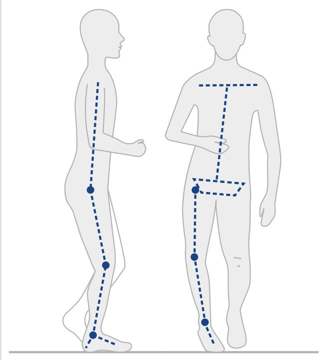
Why an anterior shell?
An orthosis with high anterior shell can only be produced thanks to the high spring forces of the applied spring units. Due to the anterior shell, the patient's initial reflex to support themselves to achieve stability is changed. By pressing their body weight with the tibia against the anterior shell, they gain stability in stance. This prevents an increasing knee hyperextension and the development of contractures in the anatomical ankle joint.



Pathological Gait

Inversion Type with Hyperflexion
In mid stance, the load is on the outer edge of the foot. The forefoot cannot be stabilised because the mm. peronei muscles and the intrinsic foot muscles are too weak. The knee joint is stabilised in hyperflexion and the pelvis is slightly tilted forward. The torso is tilted towards the non-supporting leg and the arm muscles are tensed to ensure stability.

Mid stance



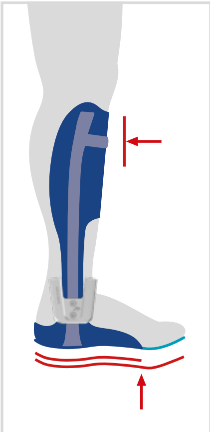
Knee: Hyperflexion

Foot contact: Inversion

Recommended Orthosis

A dynamic AFO with high anterior shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint is recommended.

Spring units to be used:
- posterior: blue marking (normal spring force, max. 15° range of motion)
- anterior: yellow marking (very strong spring force, max. 10° range of motion)

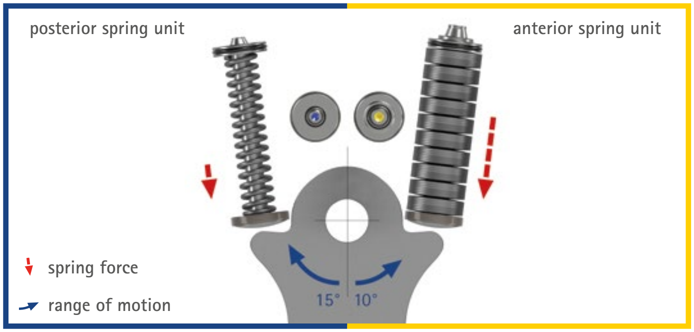


The listed spring units represent an initial suggestion. Based on this, the optimal spring force for every patient can be determined individually. The effects of the individual spring units are described on pages 52-55. If the knee-extending muscle groups are hardly activated neurologically, an orthotic fitting with a KAFO may be necessary.

Adjustment Options of the NEURO SWING System Ankle Joint

Individual adjustment to the pathological gait by:
- exchangeable spring units,
- adjustable alignment,
- adjustable range of motion.

All three adjustment options can be chosen separately. They do not influence each other.



Design of the Insoles

Sensomotoric elements that are integrated in the insoles are well suited to improve the patient's foot position. The following heel supports are most suitable for a targeted correction of the heel inversion:

- medial: strengthens the m. tibialis posterior and supports the heel (green)
- lateral: strengthens the mm. peronei and thereby prevents a heel inversion (red)

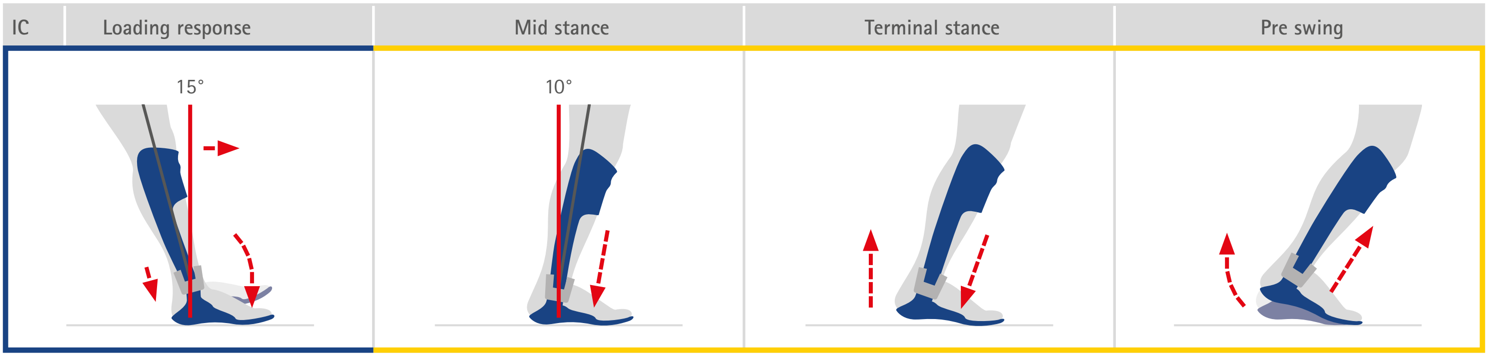
FIOR & GENTZ
ORTHOPÄDIETECHNIK MIT SYSTEM

Present Orthotic Treatment Options

Stroke patients of this gait type have previously been treated with so-called FRAFOs. They keep the foot in neutral position or in slight dorsiflexion. The anterior shell and the rigid sole are meant to extend the knee in mid stance. However, since this orthosis has neither a defined pivot point nor a range of motion, the physiological plantar flexion is severely limited. Between initial contact and loading response, an excessive torque is applied to the lower leg and transmitted to the knee. This results in an enormous stress on the m. quadriceps (comparable to walking with a ski boot) [Goe, p. 134ff.; Per, p. 195].

Effect of the Orthosis

- Initial contact and loading response: the defined pivot point and the adjustable range of motion enable a physiological plantar flexion. The foot drops in a controlled manner against the medium spring force of the posterior spring unit and allows an eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no excessive torque is applied to the lower leg.
- Mid stance: the very strong anterior spring unit and the long, partially flexible foot piece as well as the anterior shell cause a knee extension moment that brings the stroke patient into an upright position and thus improves the pathological gait. Furthermore, the patient gains stability in stance. From late mid stance, the anterior spring unit is preloaded up to the adjusted range of motion and stores the energy brought in by the body weight.
- Terminal stance: the lever effect of the foot piece and the very strong anterior spring unit of the NEURO SWING system ankle joint cause a heel lift at the physiologically right moment.
- Pre swing: the anterior spring unit releases the stored energy that assists the push off. Both the orthosis alignment and the support of the very strong spring unit improve the energy consumption during walking. An overview of the adjustments to change the gait by replacing the spring units can be found on page 55.
- Initial swing to terminal swing: the strength of the posterior spring unit of the NEURO SWING system ankle joint with medium spring force is sufficient to keep the foot in neutral position. The stroke patient can walk without stumbling and, therefore, torso and hip are relieved.

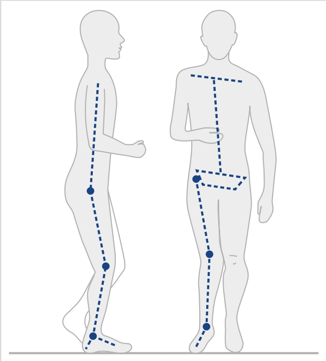


Treatment Suggestion for Gait Type 2b

Pathological Gait

Eversion Type with Hyperflexion
In mid stance, the medial foot arch collapses inwards because the intrinsic foot muscles and the m. tibialis posterior are too weak. The knee joint is stabilised in hyperflexion and the pelvis is slightly tilted ventrally. As a result, the m. flexor hallucis longus changes its direction of tension and the metatarsophalangeal joint tilts inwards (hallux valgus). The arm muscles are tensed to ensure stability.

Mid stance



Knee: Hyperflexion

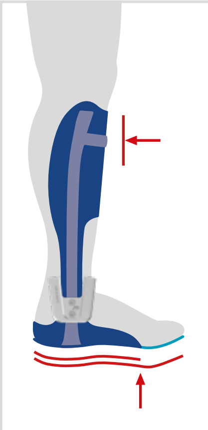
Foot contact: Eversion

Recommended Orthosis

A dynamic AFO with high anterior shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint is recommended.

Spring units to be used:

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



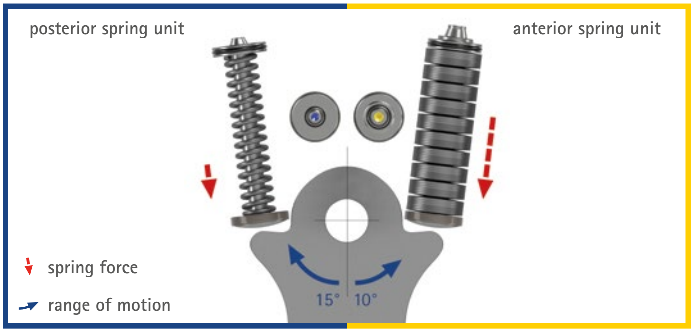
The listed spring units represent an initial suggestion. Based on this, the optimal spring force for every patient can be determined individually. The effects of the individual spring units are described on pages 52-55. If the knee-extending muscle groups are hardly activated neurologically, an orthotic fitting with a KAFO may be necessary.

Adjustment Options of the NEURO SWING System Ankle Joint

Individual adjustment to the pathological gait by:

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

All three adjustment options can be chosen separately. They do not influence each other.



Design of the Insoles

Sensomotoric elements that are integrated in the insoles are well suited to improve the patient's foot position. The following heel supports are most suitable for a targeted correction of the hindfoot eversion:

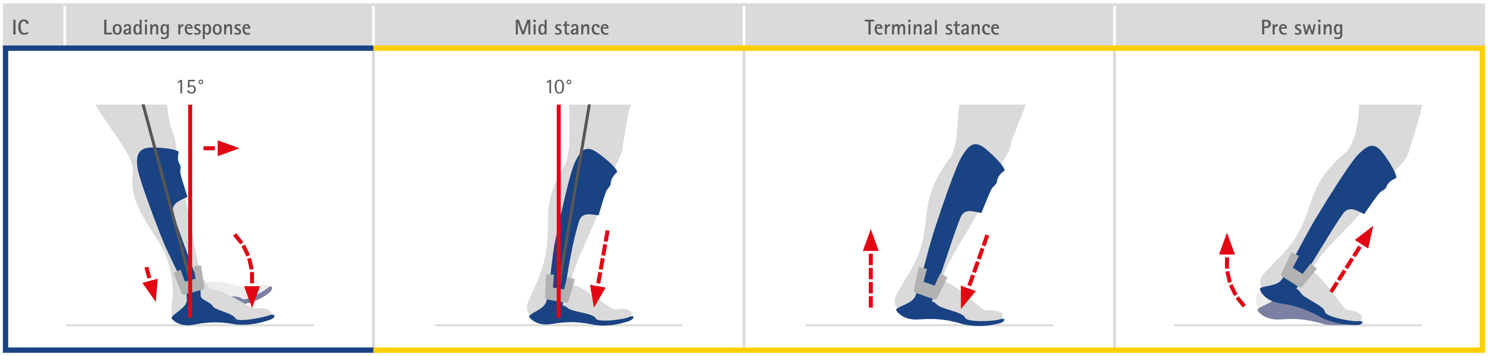
- medial: strengthens the m. tibialis posterior and prevents eversion of the heel (red)
- lateral: strengthens the mm. peronei and ensures heel grip (green)

Present Orthotic Treatment Options

Stroke patients of this gait type have previously been treated with so-called FRAFOs. They keep the foot in neutral position or in slight dorsiflexion. The anterior shell and the rigid sole are meant to extend the knee in mid stance. However, since this orthosis has neither a defined pivot point nor a range of motion, the physiological plantar flexion is severely limited. Between initial contact and loading response, an excessive torque is applied to the lower leg and transmitted to the knee. This results in an enormous stress on the m. quadriceps (comparable to walking with a ski boot) [Goe, p. 134ff.; Per, p. 195].

Effect of the Orthosis

- Initial contact and loading response: The defined pivot point and the adjustable range of motion enable a physiological plantar flexion. The foot drops in a controlled manner against the medium spring force of the posterior spring unit and allows an eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no excessive torque is applied to the lower leg.
- Mid Stance: the very strong anterior spring unit and the long, partially flexible foot piece as well as the anterior shell cause a knee extension moment that brings the stroke patient into an upright position and thus improves the pathological gait. Furthermore, the patient gains stability in stance. From late mid stance, the anterior spring unit is preloaded up to the adjusted range of motion and stores the energy brought in by the body weight.
- Terminal Stance: the lever effect of the foot piece and the very strong anterior spring unit of the NEURO SWING system ankle joint cause a heel lift at the physiologically right moment.
- Pre Swing: the anterior spring unit releases the stored energy that assists the push off. Both the orthosis alignment and the support of the very strong spring unit improve the energy consumption during walking. An overview of the adjustments to change the gait by replacing the spring units can be found on page 55.
- Initial swing to terminal swing: the strength of the posterior spring unit of the NEURO SWING system ankle joint with normal spring force is sufficient to keep the foot in neutral position. The stroke patient can walk without stumbling and, therefore, torso and hip are relieved.

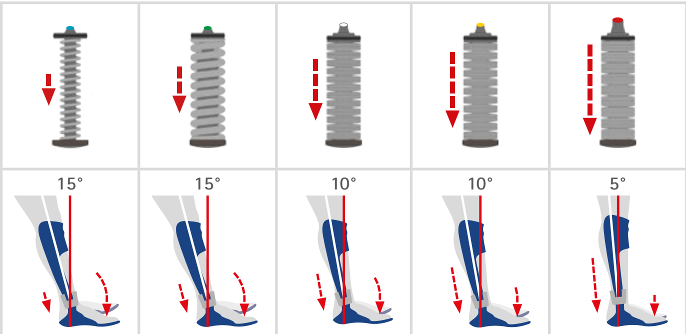


The basic function of an AFO for stroke patients is to keep the foot in neutral position or slight dorsiflexion during swing phase to enable the leg to swing freely without stumbling. This foot position allows heel contact at initial contact [Nol, p. 659]. However, orthoses must meet other requirements beyond this basic function. An AFO must be optimally adapted to the pathological gait in order to create the best possible individual biomechanical situation for stroke patients. With the NEURO SWING system ankle joint, this goal is achieved through exchangeable spring units, an adjustable alignment and an adjustable range of motion.

Effects on the Gait during Initial Contact and Loading Response

Thanks to the interchangeable spring units of the NEURO SWING system ankle joint, the spring force can be optimally adapted to the pathological gait. Finding the right spring force is an optimisation process which requires careful consideration of the different functionalities. Nevertheless, the fact that adjustments are an option is a great advantage for the individualisation of orthoses.

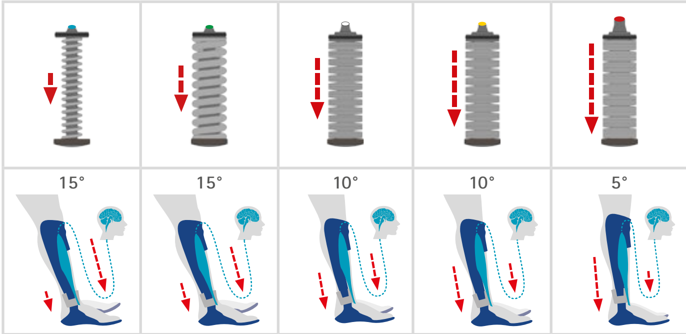
Adjusting the Heel Rocker



The lower the spring force, the larger the heel rocker.

The NEURO SWING system ankle joint enables a passive plantar flexion as well as a physiological heel rocker by means of the defined pivot point and the adjustable range of motion. The maximum plantar flexion depends on the chosen spring unit. The lowering of the foot is controlled by the posterior spring unit. In combination with a range of motion of 15°, a normal spring force (blue spring unit) enables the largest heel rocker.

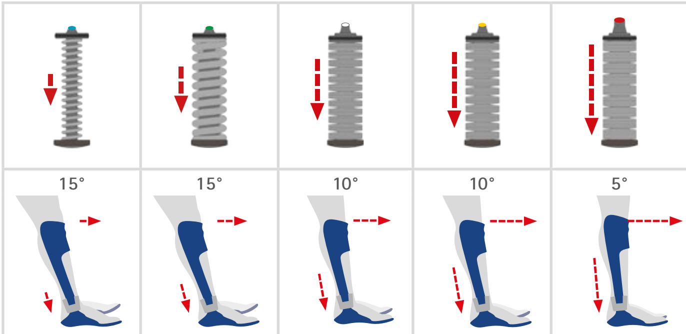
Adjusting the Eccentric Load on the M. Tibialis Anterior



The lower the spring force, the greater the eccentric load on the M. tibialis anterior.

The passive plantar flexion is controlled by the eccentric work of the m. tibialis anterior. Thus, the right cerebral connections are established through motor impulses [Hor, p. 5-26]. The extent of this eccentric work and therefore the level of the motor impulses are influenced by the spring force and the range of motion.

Adjusting the Tibial Progression

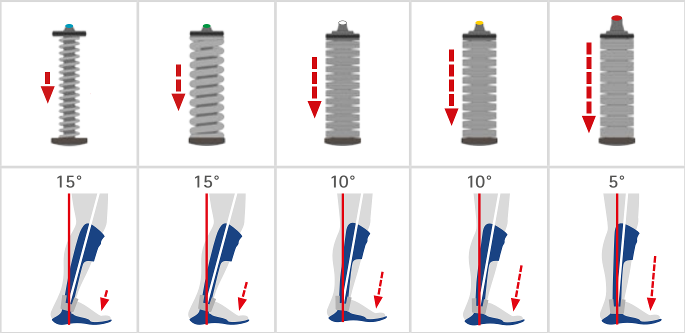


The higher the spring force, the greater the tibial progression.

Since the range of the heel rocker and the maximum passive plantar flexion is reduced with increasing spring force, a proportionately greater flexion moment is applied to the knee. This results in a faster progression of the lower leg and a higher load on the m. quadriceps. Increasing the resistance against plantar flexion results in an increasing knee flexion between loading response and early mid stance as well as a smaller maximum plantar flexion [Kob, p. 458].

Effect on the Gait in Mid Stance

Adjusting the Resistance against Dorsiflexion

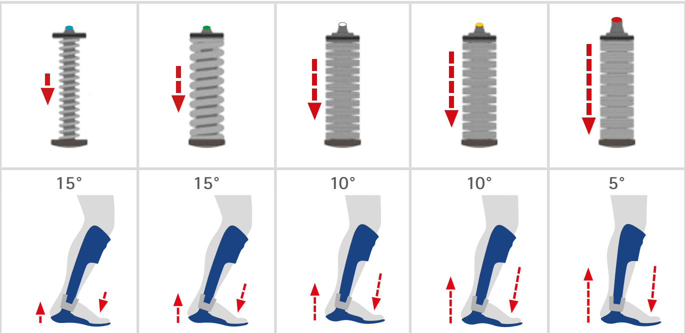


The higher the spring force, the greater the resistance against dorsiflexion.

In mid stance, the forward movement of the lower leg is performed against the resistance of the anterior spring unit. A red spring unit with extra strong spring force produces the highest resistance. The applied energy is stored in the disc springs. The extent of movement in the ankle joint is limited by the range of motion of the chosen spring unit (5°–15°). In order to take full advantage of the adjustable alignment of the orthosis during this gait phase, it is recommended to calculate a tibial tilt of 10°–12°. Optimum leverage ratios exist at this inclination [Owe, p. 257]. This adjustment of the orthosis' alignment can be made directly at the joint.

Effect on Gait in Terminal Stance

Adjusting the Heel Lift

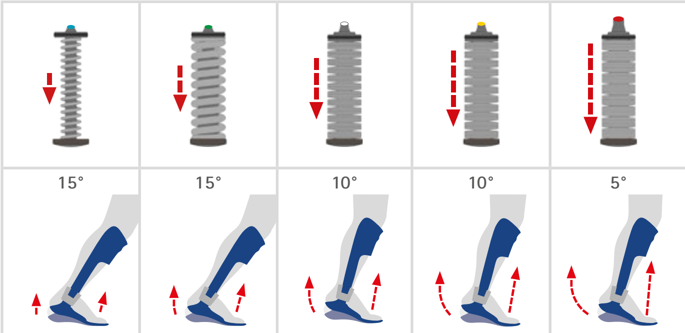


The higher the spring force, the sooner the heel will lift.

Between late mid stance and terminal stance, the compressed anterior spring unit causes the heel to lift from the ground. With a very high spring force and a range of motion of 5°, the heel lifts earlier than with a normal spring force and a range of motion of 15°.

Effect on Gait in Pre Swing

Adjusting the Energy Recovery for Push off



The higher the spring force, the more energy will be recovered for push off.

The energy stored in the anterior spring unit is released during pre swing. Since the extra strong spring unit can store the most energy, it supports the push off of the leg the most. In an AFO with strong spring forces and a defined range of motion, the push off can support an approximation towards a physiological gait during pre swing [Des, p. 150]. The spring unit with the largest range of motion also causes the foot to take the longest way back into a neutral position.

Effects on the Gait during Swing Phase

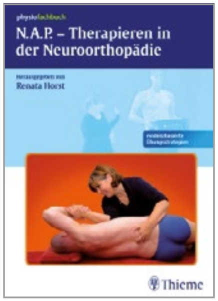
The strength of each of the five spring units of the NEURO SWING system ankle joint is sufficient to keep the foot in neutral position or slight dorsiflexion. This causes the foot to touch the ground heel first during initial contact. This position is the most important prerequisite for a heel rocker and a physiological loading response [Nol, p. 659].

About Renata Horst

Born in Hamburg and raised in New York, Renata Horst completed her physiotherapeutic education and training in Germany and Austria. In 1999, she developed the N.A.P.® as a continuation of PNF and classical manual therapy. Renata Horst currently heads the N.A.P.-Akademie based in Berlin and organises her own training workshops in Berlin, Ingelheim and Freiburg. She works as an N.A.P.® and PNF instructor as well as a physiotherapist in her private practices in Berlin and Ingelheim. Furthermore, she is the author of many professional articles and books about neuroorthopaedic rehabilitation and operates internationally as a lecturer and supervisor.

Renata Horst instructed the exercises for this chapter and described them as the author. Besides, she laid the foundation for the N.A.P.® Gait Classification (see p. 20 and 21).

About the Book



Renata Horst:
N.A.P. – Therapieren in der Neuroorthopädie
ISBN 978-3-13-146881-9
März 2011, Thieme Verlag, Stuttgart

The book N.A.P. – Therapieren in der Neuroorthopädie describes the background of neuroorthopaedic activity-dependent plasticity and explains evidence-based exercise strategies.

In addition to muscular and neurological basics, a clinical context is established, which provides an understanding of the biomechanics of human movements and the pathological strategies with which the body reacts to changes caused by a disease as well as their therapy. N.A.P.® is based on the idea of initiating movements during a useful action with the active participation of the patient. Thus, orthoses can be integrated actively in the therapy concept. The brain receives an immediate response regarding the biomechanical situation.

Introduction to the Exercises

In addition to the exercises described on pages 30 and 31, the following chapter introduces physiotherapeutic exercises based on N.A.P.® therapy. These exercises can be practised alone or with the support of a therapist as well as with or without an orthosis. This text and the associated pictures present the most common mistakes and their correction.

All of the presented exercise examples are aimed to establish the best possible biomechanical situation for the patient in order to activate the muscles needed for an upright gait. For this reason, these exercises are identical for all patients despite their different gait types and orthotic fittings.

Exercise 1: Sitting to Standing Transfer

Goal: to stabilise the lower ankle joint and the supporting leg

Fig. 1: The patient cannot stabilise her knee when standing up. It collapses inwards.

Fig. 2: First, the patient has to to stabilise her foot. To do so, she needs to put it back under the chair. The therapist creates the correct biomechanical situation by rotating the talus inwards with her right hand. To achieve the necessary elasticity of the calf muscles, the therapist applies lengthwise tension from the distal to the proximal direction.

Fig. 3: When standing up, the therapist stabilises the foot and supports the anterior tibial movement to allow an extension of the hip. By doing so, the plantar flexors (m. peroneus longus) and m. quadriceps are activated in an eccentric way. The activity of the hip extensors and external rotators, which is needed to lift the pelvis up in a dorsal direction, is achieved by the pressure put on the tendons origin at the trochanteric fossa.

Fig. 4: With the NEURO SWING orthosis, the patient can bring her tibia forward without help in order to extend her hip and thus bend her knee in a controlled manner.

fig. 1

fig. 2

fig. 3

fig. 4

Exercise 2: Barbell Bar

Goal: for a preactive stabilisation of the foot and the torso

Fig. 5: A barbell bar forces the patient to stabilise her foot and torso. At first, she cannot hold her knee in the axis.

Fig. 6: Pressure in the direction of the ball of the big toe and on the hip joint activates the entire muscle chain needed for stabilising the supporting leg.

Fig. 7: The therapist's right hand applies pressure in the direction of the ball of the big toe to activate the m. peroneus longus. With the fingertips of her left hand, the therapist puts the pelvis slightly up in dorsal direction. She applies pressure with her thumb via the tendons onset towards the acetabulum.

Fig. 8: When practising on her own, the patient can refer to the experience gained throughout the therapy.

fig. 5

fig. 6

fig. 7

fig. 8

Exercise 3: Ascending Sideways

Goal: to stabilise the forefoot during the transition from loading response to mid stance

Fig. 1: The patient stands facing the handrail and places her affected foot on the next higher stair step. Due to the anterior crossing, she is forced to stabilise her forefoot. This is how she manages to bring her tibia in front of the forefoot.


fig. 1

Fig. 2: The foot stability enables her to extend her hip while ascending. This activity, as well as the lengthening of the plantar flexors, exerts a pull on the back of the knee. The patient can now extend her knee in a controlled way.


fig. 2

Exercise 4: Descending Sideways

Goal: to stabilise the forefoot during push off

Fig. 3: The affected foot stands at the back and the patient descends by crossing her anterior leg with her other leg, to the next lower step. This situation forces her to actively pronate her forefoot and stabilise her knee in the axis. In order to optimally activate the muscles, the therapist makes sure that the heel is lifted and the pelvis is kept centred.


fig. 3

Fig. 4: When ascending, the therapist's targeted grip technique gives feedback to the brain on how to organise the forefoot stability as well as the controlled knee and hip extension.

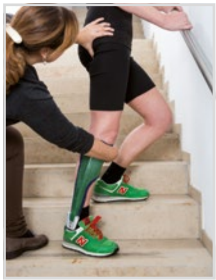


fig. 4

Exercise 5: Descending the Stairs

Goal: to stabilise the forefoot and eccentrically control the extensor synergy

Fig. 5: When descending, the mm. peronei and the long toe flexors are activated by the pressure of the therapist's right hand in the direction of the ball of the big toe. The external hip rotators are activated by the therapist's left hand.


fig. 5

Fig. 6: By doing so, the patient learns to descend the stairs without any evasive movements of the upper ankle joint, the knee and the hip.


fig. 6

Exercise 6: Ascending the Stairs

Goal: to flex the knee during pre swing and initial swing

Fig. 1: To avoid evasive movements when ascending the stairs, the external hip rotators are activated by the grip technique of the therapist. The weak knee flexors are simultaneously activated by the pull applied to the lower leg.

Fig. 2: The hip extensors are activated by a stimulus on its tendons' onset, the tuber ischiadicum. The forward movement of the tibia to the front of the forefoot is guided by the therapist's fingertips. The control of the plantar flexors is thereby enabled and a hyperextension of the knee is prevented.

Fig. 3: Afterwards, the patient can practice descending the stairs on her own.

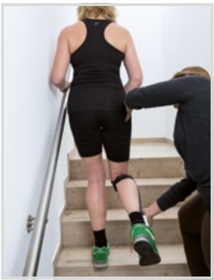


fig. 1

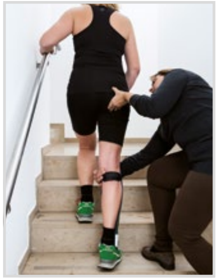


fig. 2

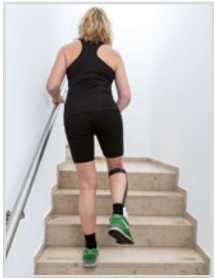


fig. 3

Exercise 7: Scooter

Goal: to achieve stabilisation during loading response, mid stance and push off.

Fig. 4: The affected leg stands on the scooter. The loading response of the right leg is improved by the push off of the left leg.

Fig. 5: The stronger leg is standing on the scooter. The patient tries to push herself forward with her affected foot.

Fig. 6: After the guided movement flow, the patient practises riding a scooter while the physiotherapist supports her on the handlebar.

fig. 4

fig. 5

fig. 6

The NEURO SWING system ankle joint has been used in a wide range of studies since 2012. The results of these studies were presented as posters or presentations at various national and international conferences and/or published in renowned journals. The listed publications are mainly about the indication stroke and the mechanical basics of the NEURO SWING system ankle joint.

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.

Block J, Heitzmann D, Alimusaj M et al. (2013): Dynamische Untersuchung einer Unterschenkelorthese mit Federgelenk zum Einsatz bei neuromuskulären Defiziten. Jahrestagung der DGfB. Neu-Ulm, Deutschland, Mai 2013.

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, Noort JC et al. (2015): The effects of different degrees of ankle foot orthosis stiffness on gait biomechanics and walking energy cost. Gait & Posture 42(Suppl. 1): 89–90.

Kerkum YL, Brehm MA, Buizer AI et al. (2013): Mechanical properties of a spring-hinged floor reaction orthosis. Gait & Posture 38(Suppl. 1): 78.

Kerkum HE, Brehm MA, J et al. (2014): Gait responses to modifying the spring stiffness of a dorsiflexion stopped ankle-foot orthosis in a polio survivor with plantar flexor weakness. Gait & Posture 39(Suppl. 1): 4.

Sabbagh D, Fior J, Gentz R (2017): Adjusting spring force of ankle foot orthoses according to gait type helps improving joint kinematics and time-distance parameters in patients with hemiplegia following stroke. Cerebrovascular Diseases 43(Suppl. 1).

Sabbagh D, Horst R, Fior J et al. (2015): Ein interdisziplinäres Konzept zur orthetischen Versorgung von Gangstörungen nach einem Schlaganfall. Orthopädie Technik 66(3): 44-49.

Sabbagh D, Fior J, Gentz R (2015): Klassifizierung von Gangtypen bei Schlaganfall zur Standardisierung der orthetischen Versorgung. Orthopädie Technik 66(3): 52-57.

Sabbagh D, Fior J, Gentz R (2014): Die N.A.P.® Gait Classification als Werkzeug zur Qualitätssicherung und Standardisierung der orthetischen Versorgung bei Schlaganfallpatienten. Neurologie & Rehabilitation 20(6): 339.

Sabbagh D, Fior J, Gentz R (2014): Classification of Gait Pattern in Stroke Patients to Optimise Orthotic Treatment and Interdisciplinary Communication. 23rd Annual Meeting of the ESMAC. Rom, Italien, Oktober 2014.

Abduction
(from Latin *abducere* = to withdraw, lead away): a movement of the foot, away from the centre of the body. The countermovement of ↑adduction.

Adduction
(from Latin *adducere* = to bring up/to, contract): a movement of the foot, towards the centre of the body. The countermovement of ↑abduction.

ADL-Score
(Activities of Daily Living): the ADL score is a procedure to measure the ability of patients suffering from degenerative diseases such as ↑stroke or multiple sclerosis to perform daily tasks.

AFO
short for ankle-foot orthosis; an orthosis encompassing both the ankle joint and the foot

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 control programmes in the brain. In turn, each environmental disturbance can result in a repeated control programme error and thus in a ↑pathological movement pattern.

Concentric
(from Latin *con* = with; *centrum* = centre): moving towards a centre; having a common centre. In a mechanical context this means that the force is applied exactly in the centre. In a ↑physiological context, a muscle performs concentric work by shortening itself and thus causing a joint movement.

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

Contraindication
(lat.*contra* = against, contrary to, lat. *indicare* = display): circumstance that prohibits the use or continued use of a particular medication or therapeutic measure that is appropriate in itself

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. Can be used as a single spring or a stack of springs. 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): belonging to the back, located at the back. Location designation at the foot: on the side of the foot's dorsum.

Dorsiflexion
Lifting of the foot. The countermovement of ↑plantar flexion. Referred to as a ↑flexion motion because it reduces the angle between lower leg and foot. Functionally, however, it is a stretching movement in the sense of an ↑extension. Muscles which perform this movement are called dorsal flexors.

Dorsiflexion Stop
Constructional element of an orthosis that limits the degree of ↑dorsiflexion. The dorsiflexion stop activates the forefoot lever, thereby creating an area of support. Furthermore, a dorsiflexion stop causes, together with the orthosis' foot piece, a knee extension moment and a heel lift starting at terminal stance.

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

Eccentric
(from Latin *ex* = outside; *centro* = centre): located outside of a centre or away from a centre. In a mechanical context this means that the force is applied off-centre. In a ↑physiological context, a muscle performs eccentric work by actively extending itself and controlling a joint movement by decelerating it.

Equinus
Fixation of the foot in plantar flexion causing the heel being lifted. Since the heel does not touch the ground when walking, the equinus is also called dropfoot (pes equinus).

Eversion
(from Latin *everto* = to turn around, to twist): Eversion is a combined movement of ↑pronation, ↑adduktion and ↑plantar flexion. It happens during the internal rotation rotation of the ankle bone (talus) on the calcaneus during loading response. The countermovement of ↑inversion.

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. Muscles which perform this movement are called extensors.

Extrinisic Foot Muscles
(from Latin *extrinsecus* = externally): there is a clinical distinction between extrinsic and ↑intrinsic foot muscles. The extrinsic foot muscles include the lower leg muscles, as they start outside of the foot skeleton and act on the foot via the long tendons.

Flexion
(from Latin *flectere* = to bend): active or passive bending of a joint. Bending is the countermovement of straightening (↑extension) and characteristically leads to a decrease of the joint angle. Muscles that perform this movement are called flexors.

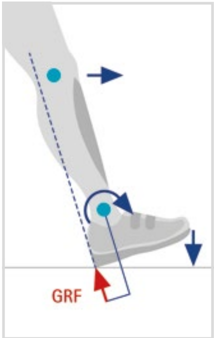
FRAFO
(floor reaction AFO): solid orthosis with an anterior shell which provides a knee or hip extension moment starting at terminal stance. FRAFOs can be made of ↑polypropylene as well as of carbon fibre. They either have a rigid or a partially flexible foot piece. However, the name FRAFO is misleading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

Ground Reaction Force
(abbr. GRF): force generated in the ground as a counterreaction to the body weight

Haemorrhagic Infarction
Infarct caused by bleeding and its consequences for the surrounding tissue. In the case of a cerebral haemorrhage, it is called *haemorrhagia cerebri.*

Hallux Valgus
X-big toe. Inclination of the big toe joints in the direction of the little toe.

Heel Lever
A lever, which uses the ↑point of heel strike as the pivot point and the distance of the point of heel strike to the anatomical ankle joint as the lever arm. At initial contact, the ↑ground reaction force running ↑dorsally from the ankle causes a rotation around the point of heel strike.



Heel Rocker
Involves the complete rotation of the foot around the ↑point of heel strike. It occurs 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 1 cm. The ↑ground reaction force becomes effective at the point of heel strike. Its force vector (broken line) runs ↑dorsally from the ankle. The resulting ↑heel lever creates a plantar flexion moment in the ankle, which lowers the foot. The ↑m. tibialis anterior works ↑eccentrically against this movement, thus allowing a controlled foot dropping.

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

Hinged AFO
The classic hinged ↑AFO is an orthosis with posterior shell made of ↑polypropylene with an elastomer spring joint or a simple coil spring joint. Hinged AFOs allow a ↑dorsiflexion in the anatomical ankle joint. In most cases, the used elastomer spring joints are not strong enough to allow a ↑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 usually locked.

To Innervate
(from Latin *nervus* = nerve): to supply an organ, e.g. a muscle, with nerve stimuli.

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

Intensive Care Medicine
A branch of medicine dealing with acute life threatening diseases and their treatment.

Interdisciplinary
(from Latin *inter* = between): concerning the cooperation between several fields; cross-disciplinary

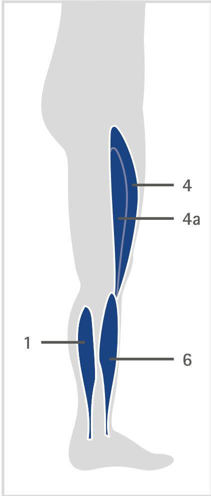
Intrinsic Foot Muscles
(from Latin *intrinsecus* = from within): there is a clinical distinction between intrinsic and ↑extrinsic foot muscles. The intrinsic foot muscles include the short foot muscles, where both the root and the base are located on the foot itself.

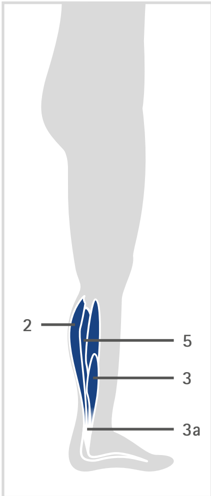
Inversion
(from Latin *inverto* = to turn around): inversion is a combined movement of ↑supination, ↑adduktion und ↑plantar flexion. It happens during the external rotation of the ankle bone (talus) on the calcaneus during mid stance. The countermovement of eversion.

Ischaemic Stroke
(from Greek *íschein* = to hold back, to restrain): localised loss of blood, an inadequate blood supply or a complete restriction of the arterial blood flow. During an ischaemic strokes, the blood circulation in a distinct area of the brain is reduced or interrupted.

KAFO
short for *knee-ankle-foot orthosis*; an orthosis encompassing the knee, the ankle joint and the foot

M. Flexor Hallucis Longus (1)
Musculus flexor hallucis longus: the flexor hallucis longus muscle. The long flexor muscle flexes the big toe.





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

Mm. Peronei (3)
Musculi peronei: fibula muscles. These include the short fibula muscle (musculus peronaeus brevis), the long fibula muscle (musculus peronaeus longus) and in a broader sense the third fibula muscle (musculus peronaeus tertius).

M. Quadriceps (4)
Musculus quadriceps femoris: four-headed muscle of the femur. The largest muscle in the body. It causes the extension of the lower leg in the knee joint. It consists of the following submuscles: musculus rectus femoris, musculus vastus medialis, musculus vastus lateralis and musculus vastus intermedius.

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

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

M. Triceps Surae (2 and 5)
Musculus triceps surae: three-headed calf muscle. Summarising term for the two-headed ↑m. gastrocnemius and the ↑m. soleus.

Muscle Atrophy
(from Greek *atrophia* = depletion, emaciation): visible decrease in the circumference of a skeletal muscle due to reduced strain

N.A.P.® Gait Classification
Neuro-orthopaedic Activity-dependent Plasticity®; N.A.P.® is an integrative neuro-orthopaedic therapy process for the improvement of motoric strategies in daily life. The N.A.P.® Gait Classification divides the ↑pathological gait of stroke patients into 4 gait types. This classification evaluates the knee position (hyperextension/hyperflexion) in the sagittal plane and the foot position (inversion/eversion) in the frontal plane during mid stance.

Neutral Position
Refers to the body position that a person assumes as a normal, upright, approximately hip-width stance. The joint's range of motion is determined in neutral position.

Pathological
(from Greek *pathos* = pain; disease): abnormally (changed)

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

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

Plantar Flexion
Lowering of the foot. Countermovement of dorsiflexion. Muscles that perform this movement are called plantar flexors.

PNF
Proprioceptive Neuromuscular Facilitation. Since the 1940s, PNF belongs to the most important physiotherapeutic treatment concepts. PNF methods and techniques strive for the best possible movement quality in terms of safety and the most economical movements to promote motor learning.

Point of Heel Strike
point where the heel first touches the ground at initial contact

Polypropylene
(PP): group of thermoformable and weldable plastics.

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

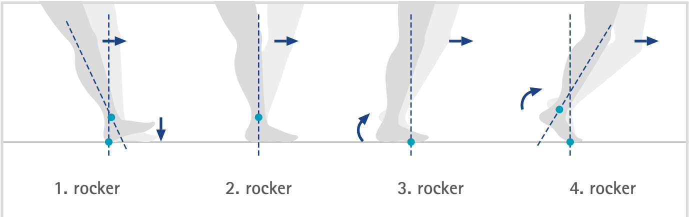
Postural Sway
Postural fluctuations. Seemingly coincidental movement of the body's centre of gravity when standing upright.

Pretibial
(from Latin *prae* = before; *tibia* = shinbone): situated in front of the tibia

Pronation
(from Latin *pronare* = to bow, to bend over): inward rotation of the foot around its longitudinal axis or lifting of the outer edge of the foot. Muscles that perform this movement are called pronators.

Push Off
Toe-off during pre swing. This accelerates the leg into a forward movement.

Rockers
Rotations around three different points of the foot in stance phase: 1. 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. rocker (ankle rocker) = rotation of the lower leg around the ankle in mid stance, 3. rocker (toe rocker) = rotation of the heel around the heads of the metatarsal bones in terminal stance, 4. rocker = combined rotation around the ankle and the heads of the metatarsal bones in pre swing.



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
Interaction of sensory and motor parts of the nervous system. For example, the sensory impressions from the soles of the feet influence the function of certain muscles.

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

Spastic
(from Greek *spasmos* = cramp): a state of intermittent or sustained involuntary muscle activation caused by a damaged first motor neuron, which is responsible for sensorimotor functions [Pan, p. 2ff.]

Static
(from Greek *statikos* = standing; causing to stand): the equilibrium of forces concerning statics, in equilibrium, at rest, standing still. A static ↑AFO does not allow any movement in the anatomical ankle joint.

Stroke
(from Greek *apoplexía* = stroke flow): stroke, in a narrower sense apoplexia cerebri (cerebral stroke); a failure of certain brain regions caused by a vascular occlusion or cerebral haemorrhage, which can lead to paralysis and other disorders.

Stroke Unit
The Stroke Unit of a hospital is specialised in the quickest possible ↑intensive care and ↑interdisciplinary treatment of stroke patients. In Germany, it is certified according to the joint process of the German Stroke Society and the German Stroke Foundation.

Supination
(from Latin *supinare* = to move backwards, to lean backwards): outward rotation of the foot around its longitudinal axis and/or lifting of the inner edge of the foot. The countermovement of ↑pronation. Muscles that perform this movement are called supinators.

Talus
(from Latin *talus* = ankle bone): the top tarsal bone that transfers the load of the body from the tibia to the foot's arch

Tibia
(from Latin *tibia* = "shinbone"): the stronger of the two lower leg bones, which is part of both the knee and ankle joints

To Tone
(from Greek *tónos* = to tighten): in the broadest sense: to strengthen something

Trochanteric Fossa
(from Latin *fossa* = ditch; gr. *trochazein* = to run, turn): depression on the posteromedial surface of the femur's greater trochanter which serves as the attachment site for various muscles.

Tuber Ischiadicum
(from Latin *tuber* = growth on the body; bump, hump; gr. *ischium* = hip joint): "ischial tuberosity". Thickening on the back side of the ischium, which serves as the attachment of several muscles.

Verticalisation
(from Latin *vertex* = apex): straightening the body into a vertical position

WHO
The World Health Organisation is an agency of the United Nations that is globally concerned with public health.

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Gesellschaft für Entwicklung und Vertrieb von orthopädietechnischen Systemen mbH

Dorette-von-Stern-Straße 5
21337 Lüneburg (Germany)

+49 4131 24445-0
+49 4131 24445-57

info@fior-gentz.de
www.fior-gentz.com