FIOR & GENTZ
ORTHOPÄDIETECHNIK MIT SYSTEM

Stroke Guide

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

3rd edition

Introduction

According to the WHO, nearly 15 million people suffer a stroke each year. One third of the affected people remain impaired afterwards [Mac, p. 50]. 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. The sooner a stroke is recognised and treated, the better the secondary damages can be controlled. Thus, a swift orthotic treatment is required [Hes, p. 1150]. Furthermore, numerous clinical studies confirm the indispensability of orthoses for gait rehabilitation after a stroke [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.

This Stroke Guide was created to facilitate the communication on the orthotic treatment of stroke patients between physicians, physiotherapists, orthotists and biomechanics. It provides suggestions for orthotic fittings based on practical experience and scientific knowledge. Last but not least, the patients' partner or carer and, of course, the patients themselves can get involved in the communication leading towards a decision for an orthotic fitting.

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. It divides pathological gait patterns into categories and is easy to use. We are however especially grateful to Beate Hesse, who volunteered as an stroke patient for tests and photos.

We do not claim that our Stroke Guide is perfect. It is rather meant as an impetus to help rethink the orthotic treatment of stroke patients. We rely on your comments and suggestions to continually improve its quality.

Your FIOR & GENTZ team

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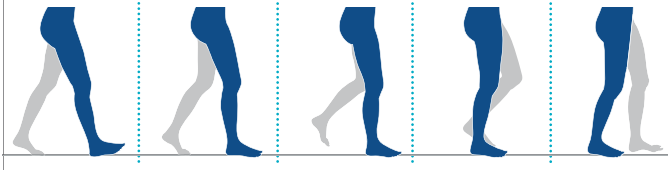
Treatment Goal: the Physiological Gait

What is a Stroke?

A stroke is a sudden cerebral circulatory disorder with secondary complaints that lasts more than 24 hours, is potentially fatal and triggered by a vascular cause. Approximately 80% of all strokes are triggered by an acute decrease in blood flow (ischaemia), whereas in 15% of all cases they are caused by an intracellular bleeding (haemorrhagic infarction) [Did, p. 592]. An undersupply of certain cerebral areas causes impairments of the locomotion programmes, saved inside the nervous system, and manifests itself by malfunctions of the executing extremities [Cor, p. 11f.]. This often results in the development of a pathological gait. Additionally, these malfunctions can be accompanied by spasticity that changes the muscle tone [Thi, p. 1102] and thus influences the gait, too.

Division of Physiological Gait into Individual Phases following

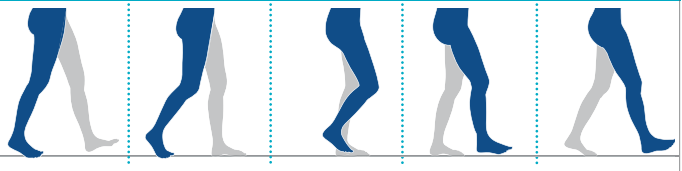


Description (Abbreviation)				
initial contact (IC)	loading response (LR)	early mid stance (MSt)	mid stance (MSt)	late mid stance (MSt)
Percentage Share of Stride				
0%	0–12%	12–31%		
Hip Angle				
20° flexion	20° flexion	10° flexion	5° extension	5° extension
Knee Angle				
5° flexion	15° flexion	10°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

Treating a Stroke in an Interdisciplinary Team

After a stroke, an immediate supply with orthopaedic aids and devices is crucial [Hes, p. 1105]. To avoid secondary damages caused by the pathological gait, the interdisciplinary team consisting of physician, physiotherapist and gait instructor as well as orhotist and biomechanist must pursue a common treatment concept. One of the first steps should be an early start of physiotherapy [Die, p. 34]. The objective is to treat the deficient muscle groups and to thereby establish the right cerebral connection through motor impulses [Hor, p. 5-26]. Combined with an orthotic treatment, an approach to a physiological gait can be supported.
When treating stroke patients, the physiological gait, as shown below in its different phases, provides guidance for the interdisciplinary team [Per, p. 70ff., 92ff., 111ff.; Goe, p. 14ff., 44ff.].

the Model of Jacquelin Perry and Kirsten Götz-Neumann



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

Conventional Orthotic Fittings

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 up to ankle-foot orthoses (AFOs) with or without an ankle joint. In severe cases, the treatment is complemented by canes and walkers.

Effective orthoses are essential as a support of physiotherapy. In some cases, the orthotic fitting needs to be complemented by orthopaedic shoes or shoe modifications or adjustments [Fat, p. 523]. The best-known orthotic treatment methods are summed up on this page. However, even though they are still valid, they must be viewed critically due to new opportunities.

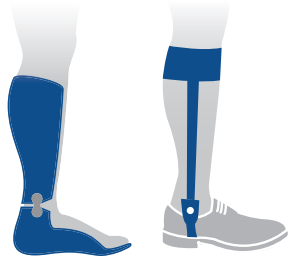
The simplest way to treat an stroke patient is a supramalleolar, dorsiflexion-assist bandage. These bandages stabilise the anatomical ankle joint by using elastic straps and hook and loop fasteners to keep the foot in a neutral position during swing phase. But in comparison to AFOs, they only have a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

bandages

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 ventral shell also blocks any movement of the anatomical ankle joint. A FRAFO is either made of polypropylene or carbon. The ventral shell enables a knee extension in terminal stance. However, this is contraindicated in patients with a hyperextended knee [Fat, p. 527].

SAFO FRAFO

Classical hinged AFOs are blocking any plantar flexion and enabling a dorsiflexion with 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].
A metal AFO integrated into the shoe also has a defined pivot point and a defined range of motion. However, the commonly used simple joints with coil springs do not have a high spring effect.



hinged AFO metal AFO

AFOs with spring effect, referred to as posterior-leaf-spring AFOs, have been used for some time. These orthoses neither have a defined pivot point, a defined or adjustable range of motion nor an adjustable alignment. A high spring effect is achieved by posterior-leaf-spring AFOs with carbon springs in contrast to similar AFOs made of polypropylene. A passive plantar flexion is not possible.

posterior-leaf-spring AFO

Difficulties Regarding Current Orthotic Treatments

Depending on the patient's pathological gait, the physician's requirements and the goal of physiotherapy, the orthotist must align the orthosis in such a way that it provides the required lever effect [Fat, p. 516; Owe, p. 262]. This is where it becomes challenging for the orthotist because, until now, it has been difficult to produce an effective orthosis in practice, due to the lack of adjustment possibilities.

Since all of the currently performed orthotic treatment methods have their advantages and disadvantages, every method can have both positive and negative effects.

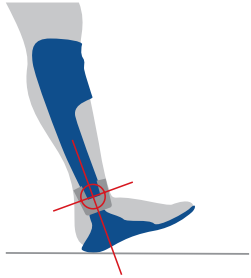
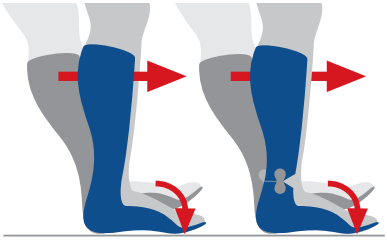
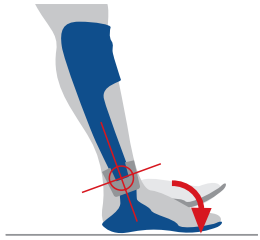
Almost all of the listed AFOs limit the physiological plantar flexion and make it difficult to achieve the best possible compromise of dorsilfexion-assist effect, energy storage for the push off and heel rocker. In a physiotherapy session, the very important heel lever is used. By doing so, the right cerebral connections are established through motor impulses [Hor, p. 5-26] and single muscle groups are strengthened with specific muscle training. This results in a gait that is closer to a physiological one. Furthermore, all of the above-mentioned orthotic treatment methods cannot be optimally adjusted to the pathological gait of the patient and, therefore, reduce the effect of the orthosis.

New Opportunities Arising for Orthotic Treatment with Adjustable System Ankle Joint NEURO SWING

A modern orthotic concept is expected to be optimally adjusted to the patient's needs. This is the only way in which all goals can be achieved in just one AFO. The adjustable NEURO SWING system ankle joint has been developed for that exact reason.

Both dynamic and static AFOs should be produced with an adjustable ankle joint in order to affect the pathological gait as well as the needed range of motion. It is absolutely necessary to adjust the orthosis to the gait pattern, since the position of the patient's foot during the production of the cast differs from its position under load. The adjustable range of motion and the exchangeable spring units make it possible to easily react to changes in the pathological gait that can occur during treatment.

Advantages of an AFO with NEURO SWING

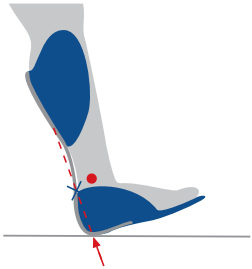
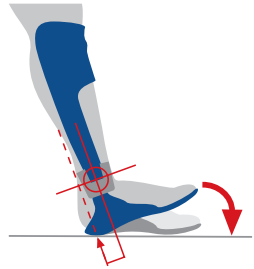
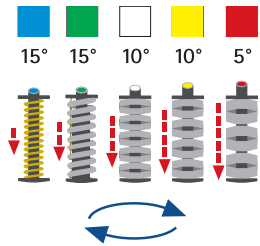
Disadvantages of Existing AFOs	Properties of the NEURO SWING
small dorsiflexion-assist effect	 great dorsiflexion-assist effect
 dorsiflexion-assist by means of blocked plantar flexion	 plantar flexion possible

Description

AFOs keep the foot in a neutral position or in slight dorsiflexion. This enables the affected leg to swing freely without stumbling during swing phase. Additionally, the heel is set on the ground at 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 a 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, thus enabling the affected leg to swing freely without stumbling and to perform initial contact with the heel.

By means of the blocked plantar flexion, the dorsiflexion is effectively assisted during swing phase. But as a consequence, an increased knee flexion moment, leading to an enormous stress on the m. quadriceps (comparable to walking with a ski boot). This enormous stress can cause an increased hyperflexion in the knee that is unphysiological at patients whose quadriceps and gastrocnemius muscles are too weak [Goe, p. 134ff.; Per, p. 195].
A qualified physiotherapist uses the physiological plantar flexion to treat insufficient muscle groups. The right cerebral connections are established through motor impulses [Hor, p. 5-26] and single muscle groups are strengthened with targeted muscle training [Goe, p. 98ff.].

Advantages of an AFO with NEURO SWING

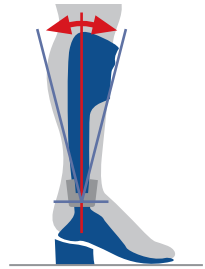
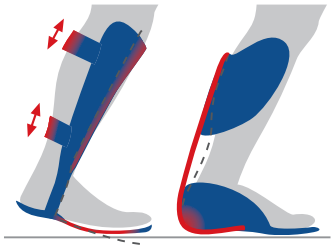
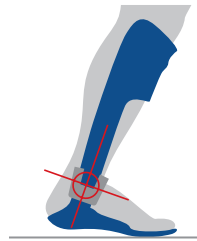
Disadvantages of Existing AFOs	Properties of the NEURO SWING
 no heel rocker	 heel rocker
no variable spring force	 variable spring force

Description

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 plantar flexion via this lever. The plantar flexion is controlled by the eccentric work of the m. tibialis anterior.
Other orthoses such as the posterior-leaf-spring AFO do not enable this lever. These orthoses only allow plantar flexion through active muscle work of the m. triceps surae, which does not correspond with physiological movement. The NEURO SWING system ankle joint enables passive plantar flexion by means of the defined pivot point and the range of motion adjustable in plantar flexion. This movement is controlled by the eccentric work of the m. tibialis anterior and supported by the exchangeable dorsal spring unit.

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 various strengths. The knee position between initial contact and mid stance can clearly be affected by modifying the spring force [Kob, p. 458]. The spring force depending on the used joint can at a similar height only be adjusted marginally or not at all in other AFOs with ankle joints such as an articulated metal AFO.

Advantages of an AFO with NEURO SWING

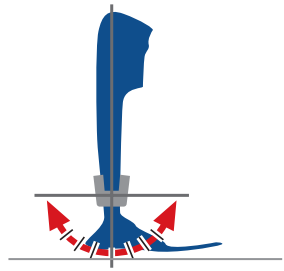
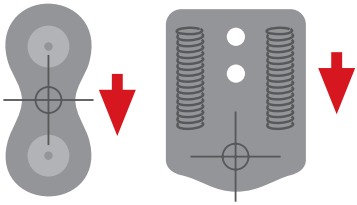
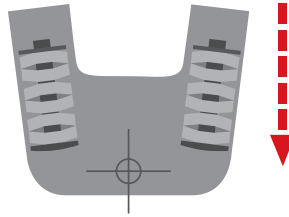
Disadvantages of Existing AFOs	Properties of the NEURO SWING
	
no adjustable alignment	adjustable alignment
	
no defined pivot point	defined pivot point

Description

Since the orthosis must be aligned in such a way that it provides the required lever effect [Fat, p. 516], it is necessary to use an adjustable ankle joint. Firstly, the orthosis can be aligned matching the patient's pathological gait and secondly, it can be adapted flexibly when changes in gait occur.
Thanks to the adjustable alignment of the NEURO SWING system ankle joint, a fine adjustment of the orthosis, a so-called tuning, is perfectly possible. To determine the individual inclination of the lower leg, a basic value of 10° to 12° is recommended [Owe, p. 257].

Some orthoses allow movement between foot and lower leg even without an ankle joint. However, these orthoses do not ensure sufficient movement of the anatomical ankle joint which can result in muscular atrophies [Goe, p. 98f.]. Furthermore, the shells of the orthosis can shift on the patient's leg and thereby cause skin irritations.
The defined pivot point supports qualified physiotherapy in treating insufficient muscle groups by establishing the right cerebral connections through motor impulses [Hor, p. 5-26] and strengthening single muscle groups with specific muscle training.

Advantages of an AFO with NEURO SWING

Disadvantages of Existing AFOs	Properties of the NEURO SWING
	
no adjustable range of motion	adjustable range of motion
	
low spring force	high spring force

Description

After a surgery, it may be necessary to disable the range of motion of an orthosis partially or completely and to enable it again in the course of the therapy. Thus, an ankle joint with individually adjustable range of motion must be mounted to an AFO.
It makes sense to treat stroke patients with a static AFO when success cannot be expected during physiotherapy or the foot is severely deformed. A static AFO provides the greatest possible lever effect and with an adjustable ankle joint it can constantly be adapted to the patient's course of treatment.

The pathological gait of some stroke patients requires very high spring forces. The NEURO SWING system ankle joint achieves these spring forces with disc springs that are stacked to compact spring units. The spring units are preloaded and store the energy brought in by the body weight. Common constructions like elastomer or coil spring joints, often mounted to hinged AFOs or metal AFOs, cannot even come close to 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 the stabilisation of the patient when walking and standing.

Classification of Stroke Patients

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

These classifications accompany patients throughout their entire therapy, but they are especially present immediately after the stroke. In the *Stroke Unit*, an institution specialised on the acute phase, classifications are crucial to localise the damage and prepare a treatment regimen.

Severity and Physical Independence in Everyday Life

There are numerous classifications that are used by hospitals in acute situations. Most commonly, the Modified Rankin Scale and the Barthel Index are applied. The Modified Rankin Scale is a simple scale used to assess the severity or motor disability of a patient after a stroke. It divides the deficits in seven stages, from 0 (no neurological deficits) to 6 (fatal stroke) [Cor, p. 30f.].

The Barthel Index' aim is to measure the performance in activities of daily living of patients with musculoskeletal and neuromuscular diseases as well as of patients with infarction. By assessing 10 daily life activities and exercises of one person (ADL) with regard to functional independence, up to 100 points can be achieved that are used to monitor the rehabilitation process [Cor, p. 26f.].

Spasticity

For an optimal treatment, it can be important to know the severity of spasticity. The Modified Ashworth Scale (MAS) is most frequently used by clinics. Here, the muscle tone is determined by having the patient perform passive movements of the affected joint (see figure below). Based on the velocity-dependent resistance, the examining person categorises the spasticity on a scale from 0 to 4. However, the reliability and sensitiveness of this method are often criticised [Thi, p.1096].

Pathological Gait

Despite many studies concerning the gait after a stroke, a consistent classification is still missing. Jacquelin Perry classified the mobility of stroke patients in 1995. In this examination, 147 patients were divided into six functional gait types based on the situations of their daily life [Per2, p. 982ff.]. In 2001, Rodda and Graham analysed, among others, patients with spastic hemiplegia by using video recordings. They took gait patterns as well as posture into account and divided the patients into four gait types [Rod, p. 98ff].

In 2003, Perry classified stroke patients from a functional point of view. She created four categories based on the patient's walking speed, their knee position during mid stance and ankle position during mid swing. Gait characteristics, angle movements, muscle activity and results of manual muscle testing were evaluated [Per, p. 305ff.].

In cooperation with physiotherapists and hospitals, a classification was created based on experiences and studies, which enabled a simple assessment of the pathological gait. This classification, called N.A.P. ® Gait Classification, describes the knee position in mid stance as a compensation for the talus position. Two gait types are being distinguished, one with hyperextension and one with hyperflexion, each either with an inversion or an eversion of the lower ankle joint. A description of the physiological position in mid stance is given on page 4 and 5.

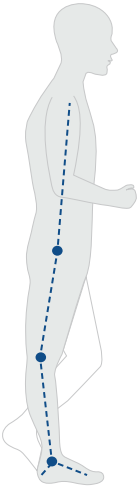
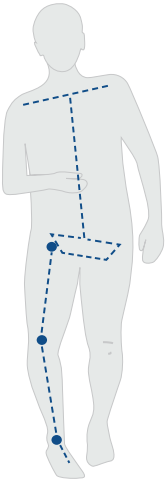
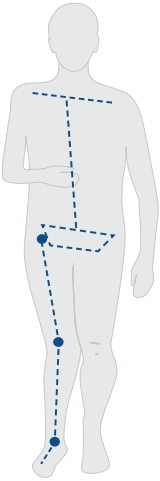
The N.A.P.® Gait Classification makes it possible to easily classify stroke patients according to their gait pattern. This facilitates the interdisciplinary communication as well as the selection of the right treatment method. Furthermore, it can contribute to the standardisation and quality management of the orthotic treatment.

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 to initiate movements during a useful action with the active participation of the patient.

N.A.P.® Gait Classification

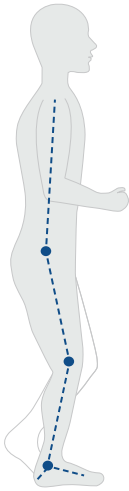
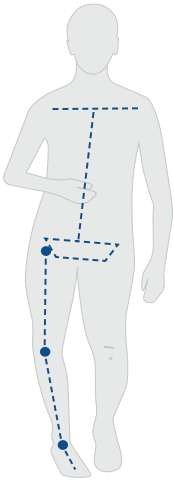
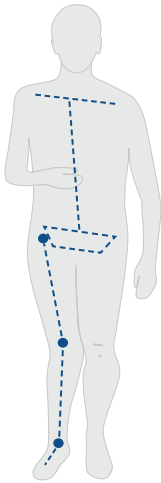
This classification is divided into four basic gait types. In the sagittal plane, there is a malposition of the knee in either hyperextension or hyperflexion in mid stance. Usually, the pelvis is excessively ventrally inclined.

GAIT TYPES ACCORDING TO THE N.A.P.® GAIT CLASSI-

KNEE	HYPEREXTENSION	
SAGITTAL		
FRONTAL		
FOOT	INVERSION	EVERSION
GAIT TYPE	TYPE 1A	TYPE 1B

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

FICATION

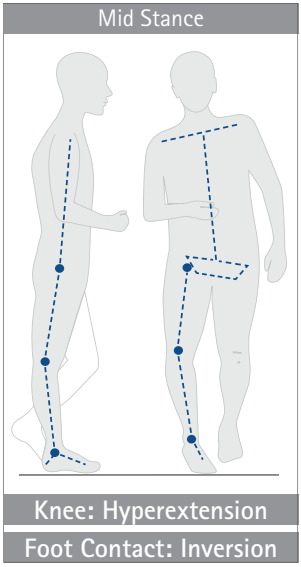
HYPERFLEXION		KNEE
		SAGITTAL
		FRONTAL
INVERSION	EVERSION	FOOT
TYPE 2A	TYPE 2B	GAIT TYPE

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

Treatment Suggestion for Gait Type 1a

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 and the intrinsic foot muscles are too weak. The knee is hyperextended and the pelvis is tilted ventrally. The torso is tilted towards the supporting leg and the arm muscles are tensed to ensure stability.



Recommended Orthosis

Dynamic AFO with high ventral shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint. Why a ventral shell? Please read the last paragraph on page 25.
Spring units to be used:

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

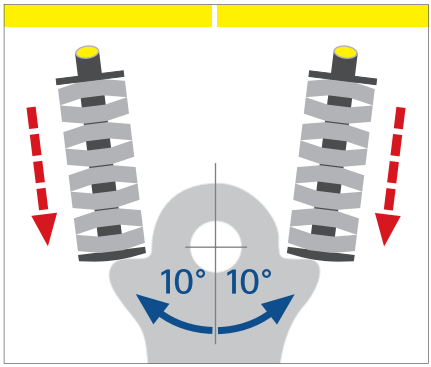
The listed spring units represent an initial suggestion. On this basis, the optimal spring force for every patient can be determined individually. You can find background information on the effects of the spring units on pages 38-41. If the knee-extending muscle groups are hardly activated neurologically, 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:

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

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



range of motion spring force

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 inversion:

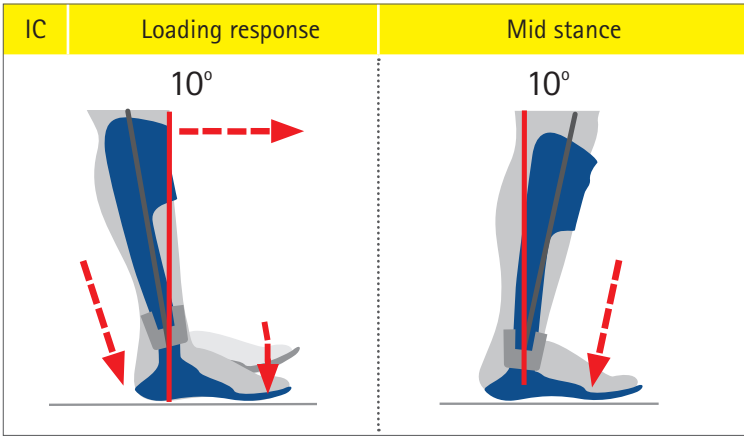
- medial: strengthens the m. tibialis posterior and supports the heel (green);
- lateral: strengthens the mm. peronei and thereby prevents a hindfoot inversion (red).

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 a neutral position or in slight dorsiflexion and the physiological plantar flexion is prevented. This leads to 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 ventral shell.

Effect of the Orthosis (see illustrations below)

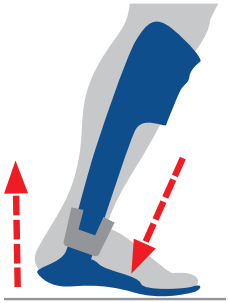
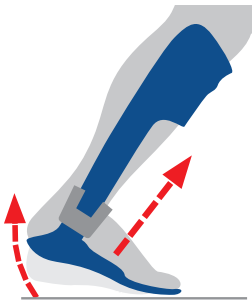
- Initial contact and loading response: the strength of the dorsal spring unit of the NEURO SWING system ankle joint is sufficient to keep the foot in a neutral position, thus ensuring that the heel touches the ground at initial contact. The thereby enabled physiological plantar flexion is ought to prevent an early activation of the m. gastrocnemius. The eccentric work of the pretibial muscles is improved and the heel rocker actively supported, without increasing the knee flexion moment. On pages 38 and 39 you will find an overview of the adjustments to influence the gait by exchanging the spring units.



- Mid stance: the ventral 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 ventral spring unit, a physiological lifting of the heel can be achieved.
- Pre swing: the ventral spring unit releases the stored energy that assists the push off and brings the foot in a neutral position.
- From initial swing to terminal swing: the dorsal spring unit of the NEURO SWING system ankle joint, which has a very strong spring force, is strong enough to keep the foot in a neutral position. The stroke patient can walk without stumbling and, therefore, trunk and hip are relieved.

Why a ventral shell?

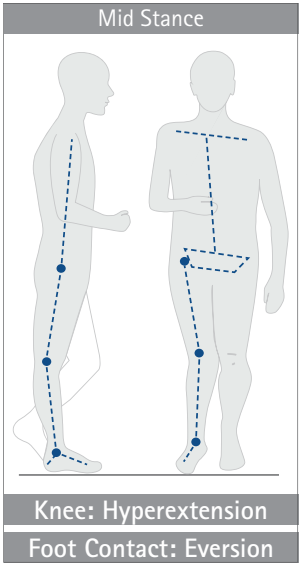
An orthosis with high ventral shell can be produced thanks to the very high spring forces of the applied spring units. Due to the ventral shell, the patient's initial reflex to support themselves to achieve stability is changed. By pressing his body weight with the tibia against the ventral shell, he gains stability in stance. This prevents a constant hyperextension of the knee.

Terminal stance	Pre swing
	

Treatment Suggestion for Gait Type 1b

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 ventrally. As a result, the m. flexor hallucis longus changes its direction of tension and the metatarsophalangeal joint adducts (hallux valgus). The arm muscles are tensed to ensure stability.



Recommended Orthosis

Dynamic AFO with high ventral shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint.
Why a ventral shell? Please read the last paragraph on page 29.
Spring units to be used:

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

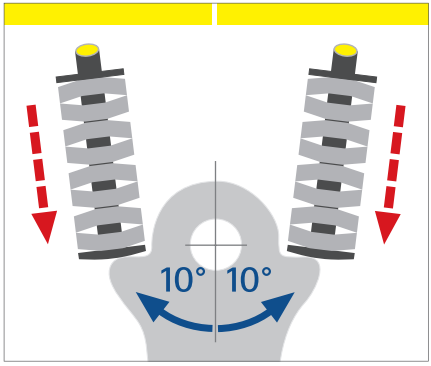
The listed spring units represent an initial suggestion. On this basis, the optimal spring force for every patient can be determined individually. You can find background information on the effects of the spring units on pages 38-41. If the knee-extending muscle groups are hardly activated neurologically, 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:

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

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



range of motion spring force

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:

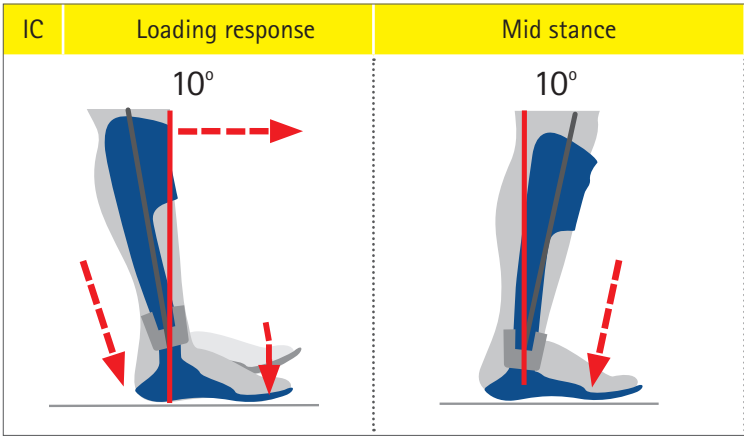
- medial: strengthens the m. tibialis posterior and thereby prevents a hindfoot eversion (red);
- lateral: strengthens the mm. peronei and supports the heel (green).

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 a neutral position or in slight dorsiflexion and the physiological plantar flexion is prevented. This leads to 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 ventral shell.

Effect of the Orthosis (see illustrations below)

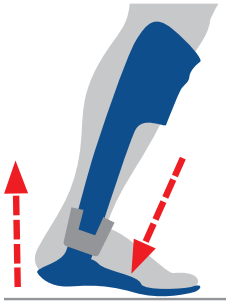
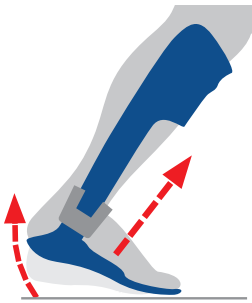
- Initial contact and loading response: the strength of the dorsal spring unit of the NEURO SWING system ankle joint is sufficient to keep the foot in a neutral position, thus ensuring that the heel touches the ground at initial contact. The thereby enabled physiological plantar flexion is ought to prevent an early activation of the m. gastrocnemius. The eccentric work of the pretibial muscles is improved and the heel rocker actively supported, without increasing the knee flexion moment. On pages 38 and 39 you will find an overview of the adjustments to influence the gait by exchanging the spring units.



- Mid stance: the ventral 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 ventral spring unit, a physiological lifting of the heel can be achieved.
- Pre swing: the ventral spring unit releases the stored energy that assists the push off and brings the foot in a neutral position.
- From initial swing to terminal swing: the dorsal spring unit of the NEURO SWING system ankle joint, which has a very strong spring force, is strong enough to keep the foot in a neutral position. The stroke patient can walk without stumbling and, therefore, trunk and hip are relieved.

Why a ventral shell?

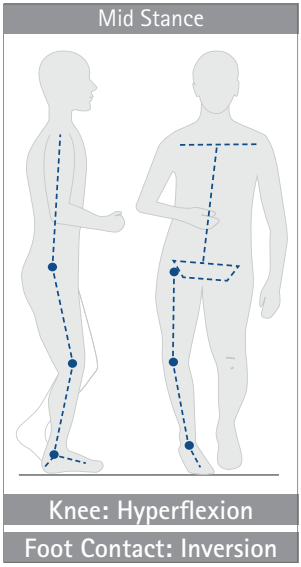
An orthosis with high ventral shell can be produced thanks to the very high spring forces of the applied spring units. Due to the ventral shell, the patient's initial reflex to support themselves to achieve stability is changed. By pressing his body weight with the tibia against the ventral shell, he gains stability in stance. This prevents a constant knee hyperextension.

Terminal stance	Pre swing
	

Treatment Suggestion for Gait Type 2a

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 and the intrinsic foot muscles are too weak. The knee is stabilised in hyperflexion and the pelvis is tilted ventrally. The torso is tilted towards the non-supporting leg and the arm muscles are tensed to ensure stability.



Recommended Orthosis

Dynamic AFO with high ventral shell, long and partially flexible foot piece (rigid sole with flexible toe area) and NEURO SWING system ankle joint.
Spring units to be used:

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

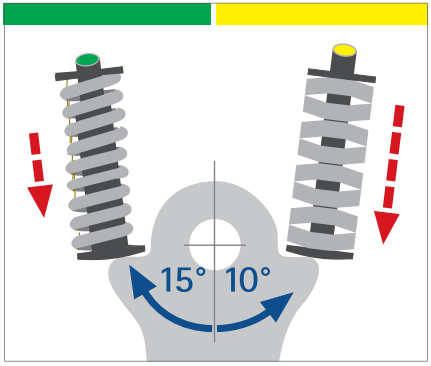
The listed spring units represent an initial suggestion. On this basis, the optimal spring force for every patient can be determined individually. You can find background information on the effects of the spring units on pages 38-41. If the knee-extending muscle groups are hardly activated neurologically, 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:

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

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



range of motion spring force

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 inversion:

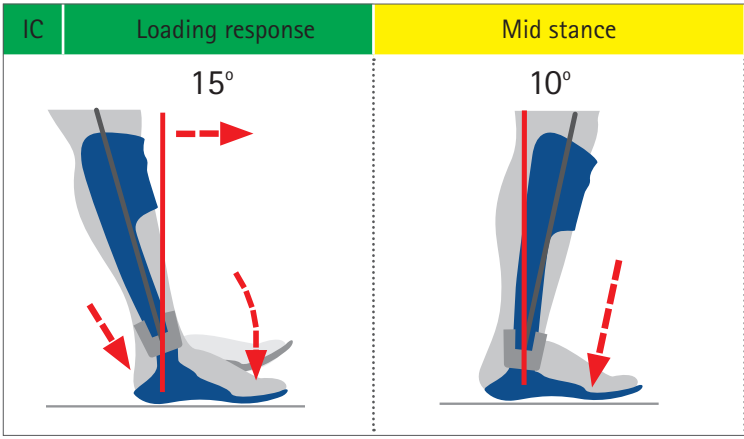
- medial: strengthens the m. tibialis posterior and supports the heel (green);
- lateral: strengthens the mm. peronei and thereby prevents a hindfoot inversion (red).

Present Orthotic Treatment Options

Stroke patients of this gait type have previously been treated with so-called FRAFOs. The foot is kept in a neutral position or in slight dorsiflexion. The ventral 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 restricted. Between initial contact and loading response, an increased knee flexion moment is generated. This results in an enormous stress on the m. quadriceps (comparable to walking with a ski boot) [Goe, p. 134ff.; Per, p. 195].

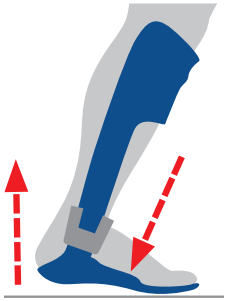
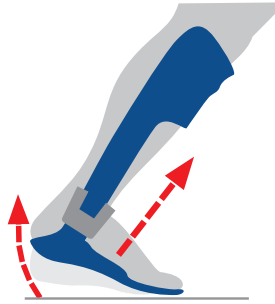
Effect of the Orthosis (See Illustrations Below)

- 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 dorsal spring unit and allows an eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no increased knee flexion moment is generated.
- Mid stance: the very strong ventral spring unit and the long and partially flexible foot piece as well as the ventral shell cause a knee extension moment that brings the patient into an upright position and thus improves the pathological gait. Furthermore, the patient gains stance stability. The ventral spring unit is preloaded from late



mid stance up to the adjusted range of motion and stores the energy brought in by the body weight.

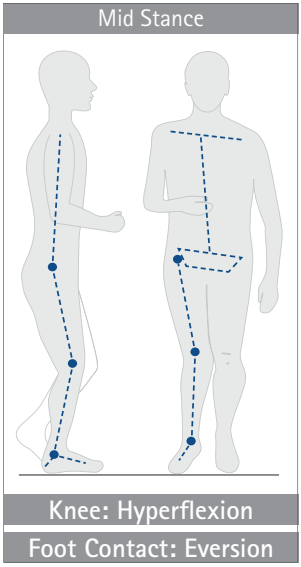
- Terminal stance: the lever effect of the foot piece and the very strong ventral spring unit of the NEURO SWING system ankle joint cause a heel lift at the physiologically right moment.
- Pre swing: the ventral spring unit releases the stored energy that assists the push off. Both the orthosis alignment and the support of the very strong spring unit improve the energy consumption during walking. On page 41 you will find an overview of the adjustments to influence the gait by exchanging the spring units.
- From initial swing to terminal swing: the dorsal spring unit of the NEURO SWING system ankle joint, which has a medium spring force, is strong enough to keep the foot in a neutral position. The stroke patient can walk without stumbling and, therefore, trunk and hip are relieved.

Terminal stance	Pre swing
	

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 adducts (hallux valgus). The arm muscles are tensed to ensure stability.



Recommended Orthosis

Dynamic AFO with high ventral shell, long and partially flexible foot piece (rigid sole with flexible toe section) and NEURO SWING system ankle joint.
Spring units to be used:

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

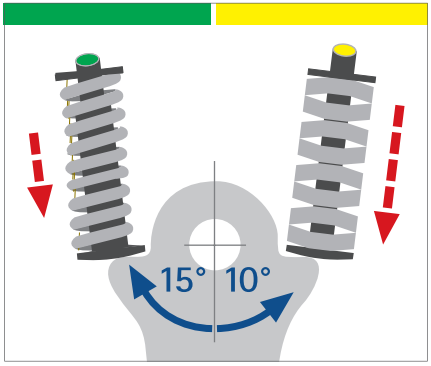
The listed spring units represent an initial suggestion. On this basis, the optimal spring force for every patient can be determined individually. You can find background information on the effects of the spring units on pages 38-41. If the knee-extending muscle groups are hardly activated neurologically, 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:

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

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



range of motion spring force

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:

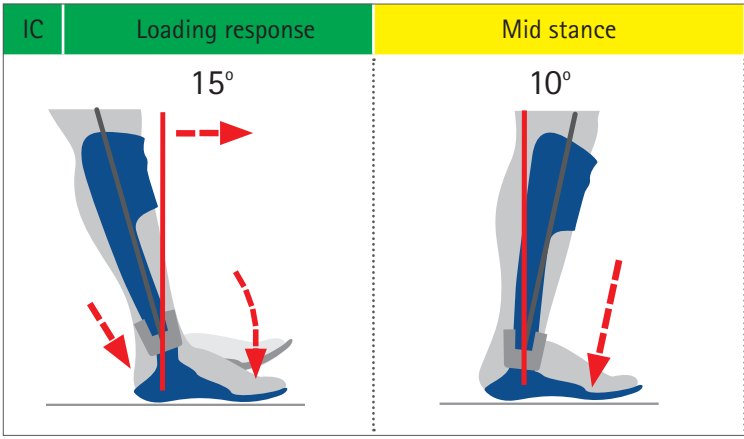
- medial: strengthens the m. tibialis posterior and thereby prevents a hindfoot eversion (red);
- lateral: strengthens the mm. peronei and supports the heel (green).

Present Orthotic Treatment Options

Stroke patients of this gait type have previously been treated with so-called FRAFOs. The foot is kept in a neutral position or in slight dorsiflexion. The ventral 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 restricted. Between initial contact and loading response, an increased knee flexion moment is generated. This results in an enormous stress on the m. quadriceps (comparable to walking with a ski boot) [Goe, p. 134ff.; Per, p. 195].

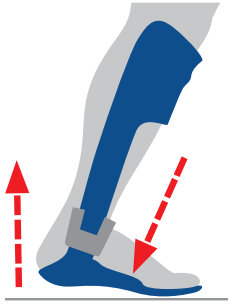
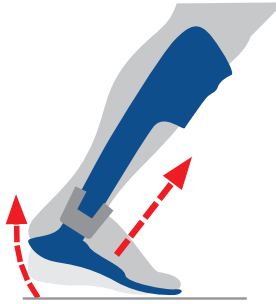
Effect of the Orthosis (see illustrations below)

- 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 dorsal spring unit and allows an eccentric work of the pretibial muscles. Therefore, the heel rocker is actively supported and no increased knee flexion moment is generated.
- Mid stance: the very strong ventral spring unit and the long and partially flexible foot piece as well as the ventral 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. The ventral spring unit is preloaded



from late mid stance 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 ventral spring unit of the NEURO SWING system ankle joint cause a heel lift at the physiologically right moment.
- Pre swing: the ventral 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. On page 41 you will find an overview of the adjustments to influence the gait by exchanging the spring units.
- From initial swing to terminal swing: the dorsal spring unit of the NEURO SWING system ankle joint, which has a medium spring force, is strong enough to keep the foot in a neutral position. The stroke patient can walk without stumbling and, therefore, trunk and hip are relieved.

Terminal stance	Pre swing
	

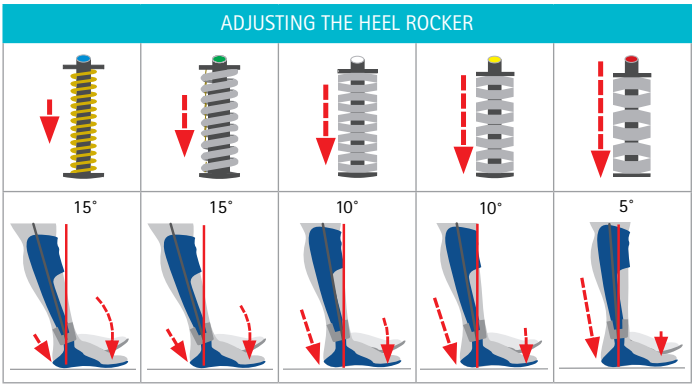
Influencing the Gait by Adjusting the Spring Force

The basic purpose of an AFO for stroke patients is to keep the foot in a 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 purpose.
An AFO must be optimally adapted to the pathological gait to establish the best possible biomechanical situation for each stroke patient. The NEURO SWING system ankle joint achieves this goal due to its interchangeable spring units as well as its adjustable alignment and range of motion.

Effects on Gait during Initial Contact and Loading Response

Due to the interchangeable spring units of the NEURO SWING system ankle joint, the spring force can be adapted in an optimal way to the pathological gait. Finding the appropriate spring force is an optimisation process which sometimes has contrasting effects. Nevertheless, the fact that adjustments are an option is a great advantage for the individualisation of orthoses.

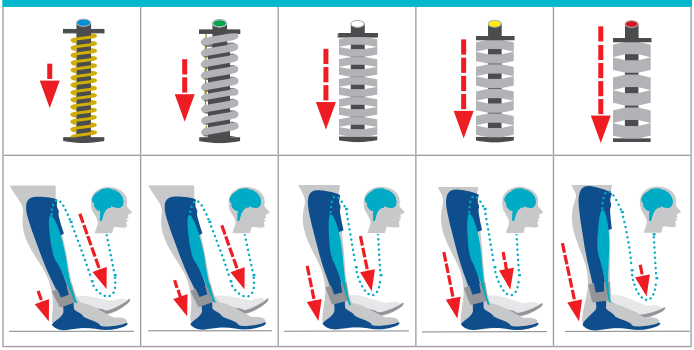
The NEURO SWING system ankle joint enables a passive plantar flexion as well as a physiological heel rocker by means of the defined pivot point and an adjustable range of motion. The range of plantar flexion depends on the chosen spring unit. Passive plantar flexion is controlled by the dorsal spring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



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

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 impulse are influenced by the spring force and the range of motion.

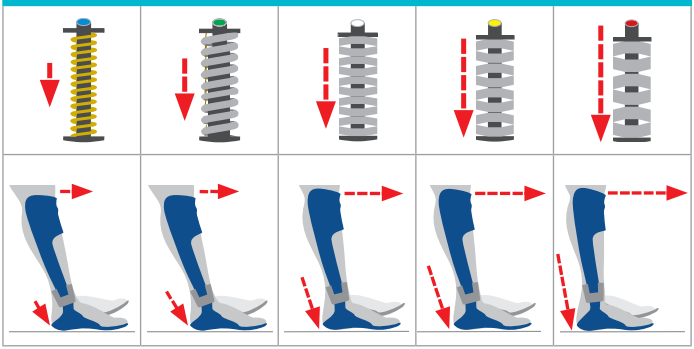
ADJUSTING THE ECCENTRIC LOAD OF THE M. TIBIALIS ANTERIOR



The lower the spring force, the greater the eccentric load of the m. tibialis anterior.

Since the range of the heel rocker and the passive plantar flexion decreases in connection with the increasing spring force, the knee flexion moment increases correspondingly. This results in a faster tibial progression and in a higher load on the m. quadriceps femoris. An increasing resistance against the plantar flexion causes an increasing knee flexion between loading response and early mid stance as well as a lower maximum plantar flexion [Kob, p. 458].

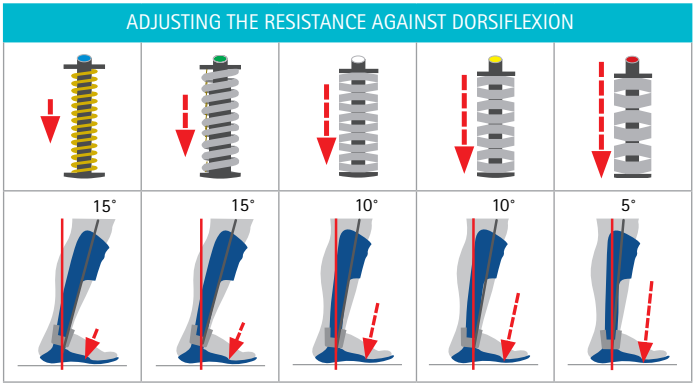
ADJUSTING THE TIBIAL PROGRESSION



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

Effects on Gait during Mid Stance

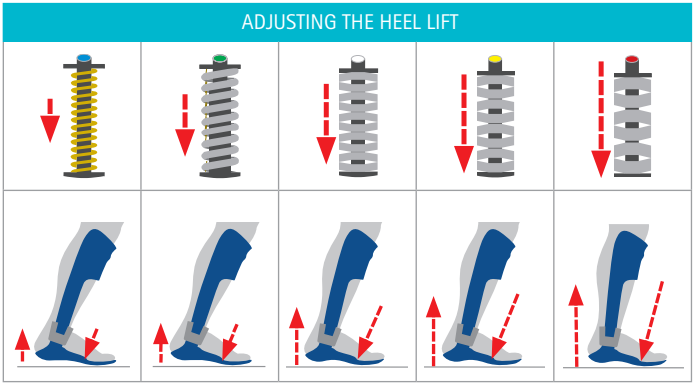
In mid stance the lower leg proceeds against the resistance of the ventral spring. A spring unit with extra strong spring force causes the highest resistance. The energy input is stored inside the disc springs. The range of the ankle joint's movement is limited by the range of motion of the chosen spring unit (5°-15°). It is advisable to consider a lower leg inclination of 10°-12° to fully exploit the adjustability of the orthotic alignment in this gait phase. This inclination offers the optimal leverage ratio [Owe, p. 257]. The orthosis' alignment can be adjusted directly at the system joint.



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

Effects on Gait during Terminal Stance

The tensioned ventral spring unit causes the heel to lift from the ground between late mid stance and terminal stance. At a very high spring force



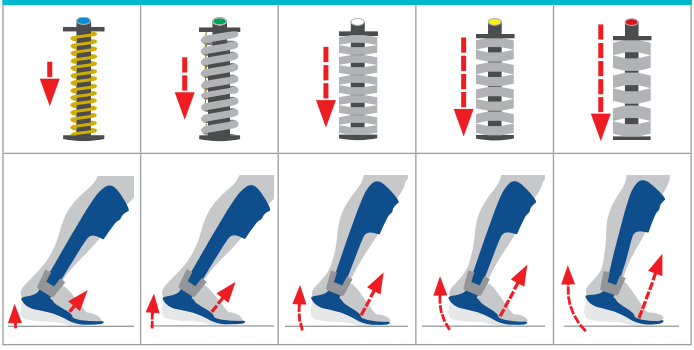
The higher the spring force, the sooner the heel lift.

and a range of motion of 5°, the heel lifts earlier than at a normal spring force and a range of motion of 15°.

Effects on Gait during Pre Swing

The ventral spring unit's energy input is released during pre swing. Since the extra strong spring unit can store the most energy it also supports the push off of the leg the most. In an AFO with strong springs and a defined range of motion, the push off can support an approach 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.

ADJUSTING THE ENERGY RETURN FOR PUSH OFF



The higher the spring force, the greater the energy return for push off.

Effects on Gait during Swing Phase

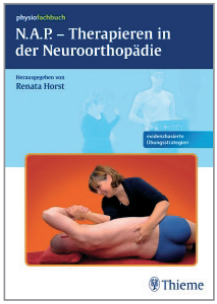
The strength of each of the five spring units of the NEURO SWING system ankle joint is sufficient to keep the foot in a neutral position or slight dorsiflexion, thus ensuring that the heel touches the ground at initial contact. This position is the most important precondition for a heel rocker and a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

About Renata Horst

Born in Hamburg and grown up in New York, Renata Horst has successfully completed her advanced Physical Therapy Education in Germany and Austria. In 1999, she developed the N.A.P.® based on PNF and classic manual therapy. Renata Horst currently runs the Institute for Further Education for Physiotherapy in Ingelheim.

There she works as a physiotherapist and a N.A.P. and PNF instructor. Additionally, she is the author of many professional articles and books about neuro-orthopaedic rehabilitation and operates internationally as a lecturer and supervisor.
Renata Horst instructed and recorded the exercises for this chapter. 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-13: 978-3131468819
March 2011, Thieme Verlag, Stuttgart

The book N.A.P. – Therapieren in der Neuroorthopädie describes the background of the Neuro-orthopeadic Activity-dependent Plasticity and explains evidence-based exercise strategies.
In addition to muscular and neurological basics, a clinical context is established that explains biomechanical human movements, pathological strategies and its therapies. N.A.P.® is based on the idea to initiate movements during a useful action with the active participation of the patient. Thus, orthoses can be integrated actively in the therapy concept. The brain is getting an immediate response about the biomechanical situation.

Introduction to the Exercises:

The following chapter introduces physiotherapeutic exercises based on the 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

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 ventral 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

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 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

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 tread. 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.

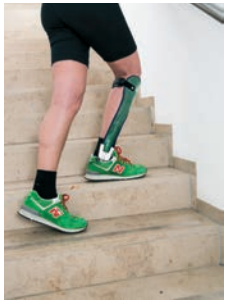


Fig. 1

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

Fig. 2

Exercise 4: Descending Sideways

To stabilise the forefoot during push off.

Fig. 3: The affected foot stands at the back and the patient descends, by anterior crossing of the non-affected 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 brain is getting a response by the precisely aimed manual technique of the therapist on how to organise the forefoot stability and the controlled knee and hip extension.

Fig. 4

Exercise 5: Descending the Stairs

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. 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. 5

Fig. 6

Exercise 6: Ascending the Stairs

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 actively activated by the manual technique of the therapist. The weak knee flexors are simultaneously activated by the pull applied to the lower leg.

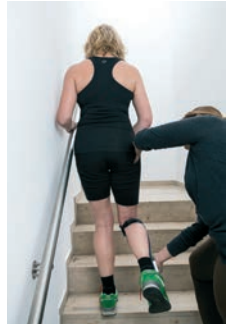


Fig. 1

Fig. 2: The hip extensors are activated by a stimulus on its tendons' onset, the ischial tuberosity. 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 prevented.

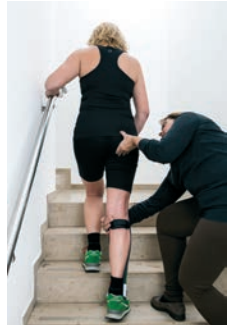


Fig. 2

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

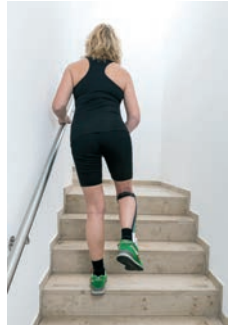


Fig. 3

Exercise 7: Scooter

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 positioned 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

Studies on the NEURO SWING System Ankle Joint

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. Annual meeting of the DGfB (German Society for Biomechanics). Neu-Ulm, Germany, May 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): S89-S90.

Kerkum YL, Brehm MA, Buizer AI et al. (2013): Mechanical properties of a spring-hinged floor reaction orthosis. Gait & Posture 38(Suppl. 1): S78.

Ploeger HE, Brehm MA, Harlaar 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): S4.

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): Classification of Gait Types Following Stroke to Standardise Orthotic Treatment Orthopädie Technik 66(3): 52-57.

Sabbagh D, Fior J, Gentz R (2014): The N.A.P.® Gait Classification as a means for quality assurance and standardisation of orthotic treatment for apoplexy patients 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, Italy, October 2014.

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

Adduction
(from Latin *adducere* = to bring up/to, contract): proximal movement of the leg towards the centre of the body. The opposite movement 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
(ankle-foot orthosis): lower leg orthosis.

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. Mechanical: force starts precisely in the centre. Physiological: concentric muscle work is the work done by a muscle when shortening.

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

Contraindication
(from Latin *contra* = against; *indicare* = to point out): a situation which makes the application or a continued application of a certain medication or intrinsical therapy method inadvisable.

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. A spring stack can consist of either single disc springs or parallel spring sets. The geometric form of the disc spring leads to a ↑concentric force absorption and hence to an almost linear spring characteristic curve.

Dorsal
(from Latin *dorsum* = back): pertaining to the back or to any dorsum; a dorsal shell of an ↑AFO encloses the calf.

Dorsiflexion
Lifting of the foot. Countermovement: dropping of the foot (↑plantar flexion). Called dorsiflexion since it actually involves a ↑flexion of a body part. However, from a functional perspective, the movement would be more precisely described as an ↑extension.

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

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

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

Eversion
(from Latin *everto* = turn out, overturn): eversion is a combined movement of ↑pronation, ↑abduction and ↑dorsiflexion. It happens during the internal 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.

Extrinsic Foot Muscles
(from Latin *extrinsecus* = externally): there is a clinical distinction between extrinsic and ↑intrinsic foot muscles. The lower leg muscles belong to the extrinsic foot muscles, since they originate outside of the foot's skeleton and affect 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 reduces the joint angle.

FRAFO
(floor reaction AFO): solid orthosis with a ↑ventral 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.

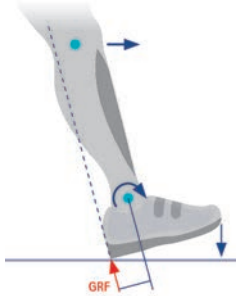
Ground Reaction Force
(GRF): a force exerted by the ground in response to the forces a body exerts on it.

Haemorrhagic Infarction
A stroke that is caused by a bleeding and its consequences for the surrounding tissue. Hence, a brain bleeding is called a cerebral haemorrhage.

Hallux Valgus
Commonly called a bunion. A lateral deviation of the big toe to the little toe.

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

Heel Rocker
means the complete rotation of the foot around the ↑point of heel strike in the anatomical ankle joint between initial contact and loading response: from terminal swing to initial contact, the swing leg drops to the ground from a height of about 1cm. The ↑ground reaction force starts at the ↑point of heel strike and its force vector (broken line) runs dorsally from the ankle. The resulting ↑heel rocker creates a plantar flexion moment in the ankle that drops the foot. The ↑m. tibialis anterior works ↑eccentrically against this movement, thus allowing a controlled plantar flexion.



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

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

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.

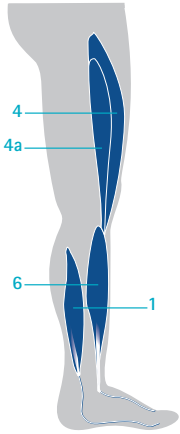
Interdisciplinary
(from Latin *inter* = between two or more): the cooperation between various disciplines.

Intrinsic Foot Muscles
(From Latin *intrinsecus* = from within): there is a clinical distinction between intrinsic and ↑extrinsic foot muscles. The short foot muscles belong to the intrinsic foot muscles which are located within the foot.

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

Ischaemia
(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 insult, the blood circulation in a distinct area of the brain is reduced or interrupted.

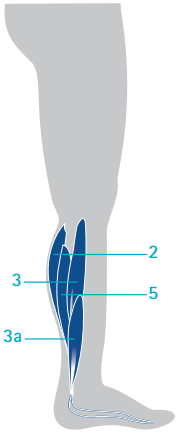
Ischial Tuberosity
(from Latin *tuber* = an outgrowth; bump, excrescence; from Greek *ischium* = hip joint): "sitting bones", the bony swellings on the posterior portion of the ischium that gives attachment to various muscles.



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

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

Mm. Peronei (3)
Musculi peronei: fibularis muscles. The following muscles belong the the fibularis muscles: the short peroneus muscle (m. peroneus brevis, 3a), the long peroneus muscle (m. peroneus longus, 3) and in the broadest sense the third peroneus muscle (m. peroneus tertius).



M. Quadriceps Femoris (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 muscles: m. rectus femoris, m. vastus medialis, m. vastus lateralis (4a) and m. vastus intermedius.

M. Soleus (5)
Musculus soleus: lower leg muscle. Its tendon and the tendon of the ↑m. gastrocnemius form together the Achilles tendon. It supports the ↑plantar flexion of the foot. Part of the ↑m. triceps surae.

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

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

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

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

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

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

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

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

PNF
Proprioceptive Neuromuscular Facilitation. Since the 1940s, PNF belongs to the most important physiotherapeutic treatment concepts. The PNF methods and techniques aspire to the best possible movement quality regarding safe and economical movement strategies to facilitate the learning of motor skills.

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

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

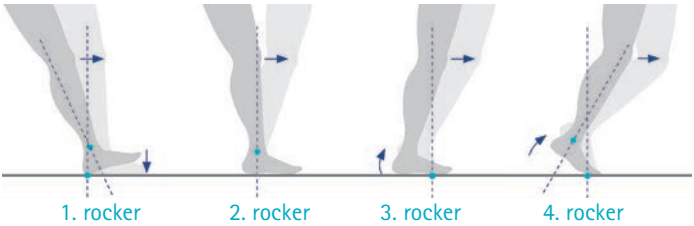
Posterior-Leaf-Spring AFO
(from Latin *posterior* = back): lower leg orthosis with leaf spring attached behind the Achilles tendon. In most cases, it is made of carbon fibres.

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 and/or lifting of the outer foot edge. Countermovement of ↑supination. Muscles which perform this movement are called pronators.

Push Off
Toe-off during pre swing, thereby assisting the leg's push off.

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 hindfoot around the metatarsophalangeal joints in terminal stance, 4. rocker = combined rotation around the ankle the metatarsophalangeal joints 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
Refers to the combination of sensory and motor parts of the nervous system. For example, the sensory impressions of the sole of the foot influence the function of certain muscles. Sensorimotor elements can be integrated, for instance, in inserts, inner shoes or the foot piece of an orthosis.

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

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

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

Stroke
Dated: apoplexy (from Greek *apoplexía* = to strike down): more precise an *apoplexia cerebri* (cerebrovascular accident, CVA) is the loss of certain cerebral areas caused by a vascular occlusion or a cerebral bleeding potentially resulting in paralyses and other disorders.

Stroke Unit
The Stroke Unit of a hospital specialised in the quickest possible intensive care and ↑interdisciplinary treatment of stroke patients.

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 which 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 that is part of the knee and the ankle joint.

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.

Ventral
(from Latin *venter* = belly, body): denoting a position toward the belly surface, abdominal. A ventral shell of an ↑AFO encloses the front side of the lower leg.

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

References

Abbr.	Source	Page
[Bow]	Bowers RJ (2004): Non-Articulated Ankle-Foot Ortheses. In: Condie E et al. (ed.): *Report of a Consensus Conference on the Orthotic Management of Stroke Patients*. Copenhagen: ISPO, 87-94.	2
[Con]	Condie E, Bowers RJ (2008): Lower limb orthoses for persons who have had a stroke. In: Hsu JD et al. (ed.): AAOS Atlas of Orthoses and Assistive Devices, 4th edition. Philadelphia: Mosby, 433-440.	6, 7
[Cor]	Corsten T (2010): Die neurologische Frührehabilitation am Beispiel Schlaganfall - Analysen zur Entwicklung einer Qualitätssicherung. Dissertation. Hamburg University, Germany.	2, 4, 18
[Des]	Desloovere K, Molenaers G et al. (2006): How can push-off be preserved during use of ankle foot orthosis in children with hemiplegia - A prospective controlled study. *Gait & Posture* 24(2): 142-151.	41
[Did]	Diederichs C, Mühlenbruch K et al. (2011): Prädiktoren für eine spätere Pflegebedürftigkeit nach einem Schlaganfall. *Deutsches Ärzteblatt* 108(36): 592-599.	4
[Die]	Diener HC, Forsting M (2002): Schlaganfall, Taschenatlas spezial. Stuttgart: Thieme.	5
[Fat]	Fatone S (2009): Orthotic Management in Stroke. In: Stein J et al. (ed.): *Stroke Recovery and Rehabilitation* 2009. New York: Demos, 515-530.	6, 8, 15, 24, 28
[Goe]	Götz-Neumann K (2011): Gehen verstehen - Ganganalyse in der Physiotherapie, 2nd edition. Stuttgart: Thieme.	5, 11, 15, 24, 28, 32, 36
[Hes]	Hesse S, Enzinger C et al. (2012): Technische Hilfsmittel. In: Diener HC et al. (ed.): *Leitlinien für Diagnostik und Therapie in der Neurologie*, 5th edition. Stuttgart: Thieme, 1150-1160.	2, 5
[Hor]	Horst R (2005): Motorisches Strategietraining und PNF. Stuttgart: Thieme.	5, 8, 11, 15, 39

Abbr.	Source	Page
[Kob]	Kobayashi T, Leung AKL et al. (2013): The effect of varying the plantarflexion resistance of an ankle-foot orthosis on knee joint kinematics in patients with stroke. *Gait & Posture* 37(3): 457-459.	13, 39
[Mac]	MacKay J, Mensah GA et al. (2004): Global burdon of stroke. In: World Health Organization (ed.): *The Atlas of Heart Disease and Stroke*. Brighton: Myriad Editions, 50-51.	2
[Nol]	Nolan KJ, Yarossi M (2011): Preservation of the first rocker is related to increases in gait speed in individuals with hemiplegia and AFO. *Clinical Biomechanics* 26(6): 655-660.	38, 41
[Owe]	Owen E (2010): The Importance of Being Earnest about Shank and Thigh Kinematics Especially When Using Ankle-Foot Orthoses. *Prosthetics and Orthotics International* 34(3): 254-269.	8, 15, 40
[Pan]	Pandyan AD, Gregoric M et al. (2005): Spasticity: clinical perceptions, neurological realities and meaningful measurement. Disability and Rehabilitation 27(1-2): 2-6.	60
[Per]	Perry J, Burnfield JM (2010): Gait Analysis – Normal and Pathological Function, 2nd edition. Thorofare: Slack.	5, 11, 19, 24, 28, 32, 36
[Per2]	Perry J, Garrett M et al. (1995): Classification of Walking Handicap in the Stroke Population. *Stroke* 26(6): 982-989.	19
[Rod]	Rodda J, Graham HK (2001): Classification of gait patterns in spastic hemiplegia and spastic diplegia: a basis for a management algorithm. *European Journal of Neurology* 8(Suppl. 5): 98-108.	19
[Thi]	Thibaut A, Chatelle C et al. (2013): Spasticity after stroke: Physiology, assessment and treatment. *Brain Injury* 27(10): 1093-1105.	4, 18

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