FIOR & GENTZ
ORTHOPÄDIETECHNIK MIT SYSTEM

MS Guide

A Concept for the Medical Patient History and Orthotic Treatment of Patients with Multiple Sclerosis

Introduction

After intensive work, we are pleased to present to you the **MS guide** – our concept for the medical patient history and orthotic treatment of patients with multiple sclerosis (MS).

MS is also known as the disease with a thousand faces because it affects each patient differently. Especially the many symptoms associated with this disease are very individual. In later stages, these symptoms can severely reduce the patient's quality of life. Therefore, it is difficult to predict the course of the disease at first.

In general, much research is being done to understand this disease and to improve therapy and rehabilitation. However, although the research on drug treatment for MS is excellent, there are few scientific studies related to the effective treatment with medical devices. Unfortunately, orthoses have not yet been included in the guidelines of the European Academy of Neurology (EAN) as part of the symptomatic rehabilitation of MS patients. An internationally uniform strategy in MS rehabilitation is therefore still missing. In addition, the episodic occurrence, which is accompanied by a steady worsening of the symptoms, makes an orthotic treatment difficult to plan.

With this MS guide, we would like to present a medical patient history that takes the disease-specific changes in gait into account. One of the focal points is to take muscle fatigue into account when planning the orthosis.

The featured physiotherapeutic exercises clearly show that qualified physiotherapy and dynamic orthotic treatment complement each other perfectly. In this context, we would like to thank the MS patient who volunteered for the photographs and thus made a valuable contribution to this MS guide.

Even if a successful treatment of MS patients is not always easy – together we can do it.

Your FIOR & GENTZ team

cover page: patient (MS), fitted with a KAFO (NEURO VARIO system knee joint and NEURO SWING system ankle joint) and an AFO (NEURO SWING system ankle joint)

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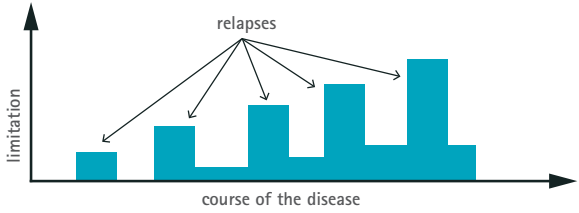
Diagnosis: Multiple Sclerosis (MS)

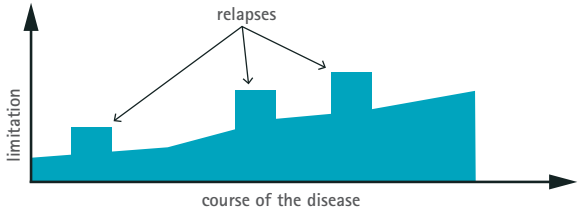
Multiple sclerosis (MS) is caused by a malfunction of the immune system, which leads to an attack on the protective layer (myelin sheath) of the axons, resulting in a single centre or multiple centres of inflammation. The affected nerves can either regenerate or scar (sclerose). MS is characterised by recurring relapses and an often progressive course of the disease (see info box).

Courses of the MS Disease

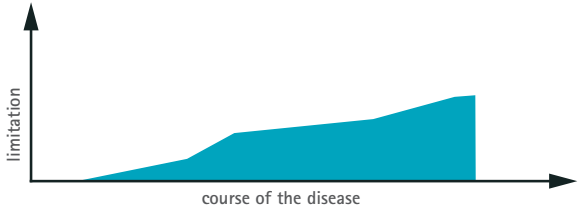
1) Relapsing-Remitting MS (RRMS)



2) Secondary Progressive MS (SPMS)



3) Primary Progressive MS (PPMS)



Who is Affected?

According to the MS International Federation (MSIF), 2.3 million people worldwide are affected. Women are affected twice as often as men. At the time of the initial diagnosis, patients are usually between 20 and 40 years old. A small number of diagnoses are already made during childhood and adolescence or after the age of 60. The frequency of the disease increases with the distance from the equator and is associated with differences in climate and lifestyle (diet, stress, etc.).

Causes of MS

Despite intensive research, it is still unclear what exactly triggers the malfunction of the immune system. However, it is suspected that the cause is a combination of different factors. The predisposition, i.e. the tendency to develop this disease, is also inheritable. Childhood infections, vitamin D deficiency and an unbalanced diet can also contribute to the manifestation of MS.

Symptoms of MS

Due to the damage to the neural pathways, neurological symptoms occur. The beginning of an MS disease is usually characterised by motor limitations, visual or sensory disturbances, which manifest themselves throughout the course of the disease. In the advanced stages, the reduced strength of various muscles and spastic pareses have a negative effect on the ability to walk. Additionally, articulation and bladder dysfunction, cognitive disorders and depression can severely limit the quality of life.

Fatigue

Increased muscular and cognitive exhaustion, known as fatigue, is another symptom that greatly affects many patients' daily lives with MS. Since the ability to walk is highly dependent on muscular performance, fatigue can become a limiting factor for many of the patient's activities.

source: www.msif.org

MS Therapy

While a general practitioner is the first point of contact in the case of early symptoms associated with MS, a neurologist coordinates the target-specific therapy. There are different priorities in therapy, which are applied depending on the severity and the course of the disease:

1) **Relapse Therapy:** drug treatment is used to suppress the acute inflammatory reaction.

2) **Therapy of Disease Progression:** this is used to halt the progression of the disease and its symptoms.

3) **Course-modifying Therapy:** this is used to prolong the periods without relapses or pain with medication.

4) **Symptomatic Therapy:** the various clinical pictures are controlled by means of medication, medical devices, physiotherapy, occupational therapy or psychotherapy.

Within the framework of symptomatic therapy, a combination of orthotic treatment and physiotherapy is used to improve the stability when standing and walking and to avoid contractures.

MS International Federation (MSIF)

The MS International Federation is a global network of 48 national MS organisations that represent the interests of MS patients. The main objective of the MSIF is to facilitate access to current research results and thus to efficient treatment through interdisciplinary and international networking of professionals. Another focus is on initiating and promoting research projects to improve diagnostics, therapy and rehabilitation.

source: www.msif.org

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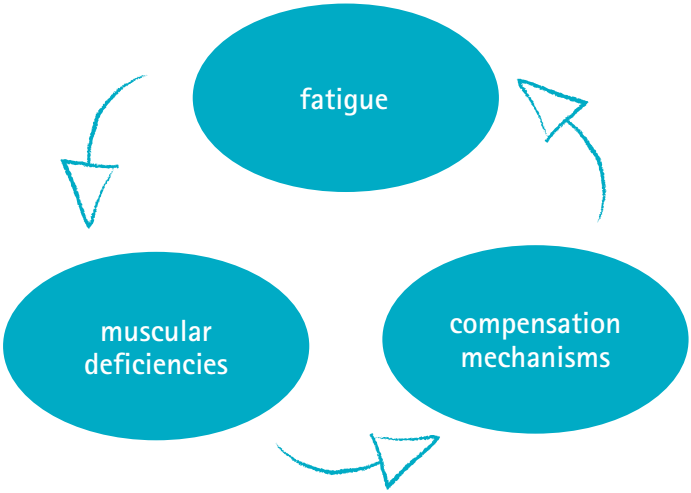
Change in Gait Due to MS

How the gait changes due to multiple sclerosis is very individual for each patient and depends on the course of the disease. It may also play an important role whether the patient is currently in a relapse-free or a relapse phase. In general, the gait is changed by a number of components that influence each other. These components include fatigue, muscular deficiencies and compensation mechanisms (see diagram). The extent of these factors and thus their effect on the gait varies from patient to patient.



Fatigue

The term fatigue refers to muscular and/or cognitive exhaustion that exceeds the physiological level. The extent of the fatigue is very much dependent on the individual clinical picture. For some MS patients, increased exhaustion hardly ever occurs while for others, it leads to significant limitations in everyday life. Although little is known about the cause and triggering factors, evidence suggests that a deterioration in muscle function is caused by prolonged strain (e.g. walking) [Pha]. Fatigue also has a significant effect on the temporal and spatial walking parameters [DeC]. For example, cadence and walking speed are significantly reduced [Kal]. In addition to a decrease in walking ability and an increase in muscular deficiencies, the risk of falling also rises [Cat].

Muscular Deficiencies

The destruction of the myelin sheath and the loss of axons caused by MS results in an insufficient activation of the muscles targeted by these nerves. This results in different muscular deficiencies, which manifest themselves in corresponding movement restrictions. For example, a malfunction of the plantar flexors and the ischiocrural muscles can reduce knee stability in stance phase. During pre swing, a low activation of the toe flexors causes an insufficient knee flexion [Rol], which – in combination with an impaired plantar flexion – causes problems with push off [Kem]. During swing phase, there is often a muscular imbalance between dorsal and plantar flexors. An unnaturally high activity of the plantar flexors can lead to an insufficient dorsiflexion between mid swing and initial contact. In addition, spastic pareses can affect the gait. In combination with the mechanisms carried out by the body to compensate for these muscular deficiencies, this results in a pathological gait.

Compensation Mechanisms

Compensation mechanisms are usually arbitrary movement patterns with which the patient tries to compensate for a muscular deficiency by an increased activation of other muscles. This compensation mainly concerns swing phase. To minimise the risk of falling, the leg must be able to swing through unhindered (see chapter *Compensation Mechanisms in Swing Phase)*. During pre swing, an impaired push off can also be the trigger for characteristic compensation mechanisms. In stance phase, some patients compensate for an excessive activity of the plantar flexors by an increased stiffness of the m. tibialis anterior. All these compensation mechanisms are reactions of the body to a changed biomechanical situation. As a consequence, an unphysiological strain is put on anatomical structures. The increased energy consumption caused by these movement patterns contributes to the development of fatigue.

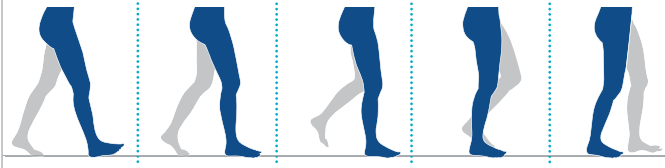
Therapy Goal

As described in the chapter *Multiple Sclerosis*, the disease can influence the gait in various ways. The therapy goal must therefore be defined individually. It may consist of one or more of the following components:

- improving the stability when standing,
- improving the stability when walking,
- preventing contractures,
- optimising the energy balance,
- minimising compensation mechanisms,
- preventing falls,
- prolonging the maximum walking distance.

Maintaining the ability to stand and walk while avoiding contractures is particularly important in the advanced stages of the disease and with increasing muscular deficiencies.

Division of the Physiological Gait into Individual

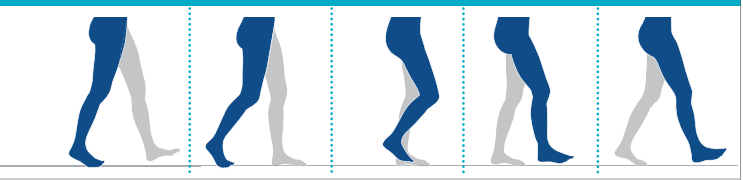


Term (Abbreviation)				
initial contact (IC)	loading response (LR)	early mid stance (MSt)	mid stance (MSt)	late mid stance (MSt)
Percentage of Stride				
0%	0–12%	12–31%		
Hip Angle				
20° flexion	20° flexion	10° flexion	5° extension	5° extension
Knee Angle				
5° flexion	15° flexion	10° flexion	5°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

The therapy goal is achieved with a combination of physiotherapy, orthotic treatment and, if necessary, drug treatment by an interdisciplinary team.

The overall goal of orthotic treatment is to come closer to a physiological standing position and gait. Most common for the description of physiological gait is the division into different phases according to Jacquelin Perry (see table below). Roughly divided, a double step consists of stance phase (initial contact to pre swing) and swing phase (initial swing to terminal swing) of the reference leg. The individual phases each make up a defined percentage of the double step and are characterised by a certain angle of hip, knee and ankle [Per]. The English terms for these phases and their abbreviations have become an international standard.

Phases According to Jacquelin Perry



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° dorsi-flexion	15° plantar flexion	5° plantar flexion	neutral position	neutral position

Requirements for Orthoses

Orthotic treatment should support the patient when standing and walking. In this way, pathological consequences resulting from existing muscular deficiencies and compensation mechanisms can be prevented or minimised.

In modern orthotics, a combination of dynamic, supportive and proprioceptive components ensures that mobility is maintained as demanded by physiotherapy. As a result, the therapeutic goal defined by the interdisciplinary team can be achieved without restricting the patient's mobility. An orthosis that is precisely tailored to the patient's needs and planned and adjusted according to the patient's individual data is essential for coming closer to a physiological standing position and gait.

Based on the pathological gait, requirements for an orthotic treatment can be defined, from which concrete mechanical properties of orthoses for MS patients are derived:

1) Since MS is often accompanied by a worsening of symptoms as the disease progresses, an orthosis must be adaptable to changing needs.

2) The increased muscular exhaustion during walking caused by fatigue means that an orthosis must provide sufficient energy recovery towards the end of stance phase. An active initiation of the swing phase must be enabled while energetically complex compensation mechanisms need to be avoided.

3) An orthosis must compensate for any instabilities when standing and walking by dynamically controlling the movements of the knee and the upper ankle joint. The range of motion must only be minimally restricted.

4) An orthosis should reduce spastic pareses. Hard stops of mechanical joints may contribute to pareses and should therefore be avoided. However, the enclosure of the leg by the tibial shell or the femoral and tibial shell of an orthosis made from a plaster cast exerts a proprioceptive stimulus on the patient and can reduce existing spastic pareses.

The changes in gait described above result in MS-specific requirements for orthoses (see table). The derived mechanical properties can be achieved using modern materials, orthosis joints and production techniques. Given the MS-specific, individual characteristics of the pathological gait, the focus in the orthotic treatment of MS patients lies on a comprehensive medical patient history. Therefore, orthoses should always be produced with the individual muscle strength and fatigue in mind.

Requirements for an Orthosis	Mechanical Properties	Examples
stability when standing and walking	• dynamic dorsiflexion stop with high spring force • ventral tibial shell • foot piece • stance phase control	• resistance in the mechanical ankle joint • rigid or partially flexible foot piece • automatic knee joint
energy recovery	• defined pivot point • high spring force • dynamic dorsiflexion stop	• support for heel lift and push off
range of motion of the anatomical joints	• defined pivot point • passive plantar flexion • heel rocker • dynamic dorsiflexion stop	• precise positioning of the mechanical pivot point on the anatomical pivot point at ankle height
adaptability	• variable spring force • adjustable alignment • adjustable range of motion	• adjustable, dynamic ankle joint
low weight	• use of lightweight materials	• carbon, Kevlar
soft stops	• defined pivot point • high spring force	• dynamic dorsiflexion and plantar flexion stop

Medical Patient History

A comprehensive medical patient history is the basis for an optimum orthotic treatment. This involves collecting all patient data that is relevant for the planning of the future orthosis.*

As part of this planning process, the expected load and the required functions of the orthosis are determined. Especially when fatigue is involved, support and range of motion must be carefully weighed against one another. The muscle function test according to Janda [Jan] provides information about what form of support is ultimately required by the orthosis.**

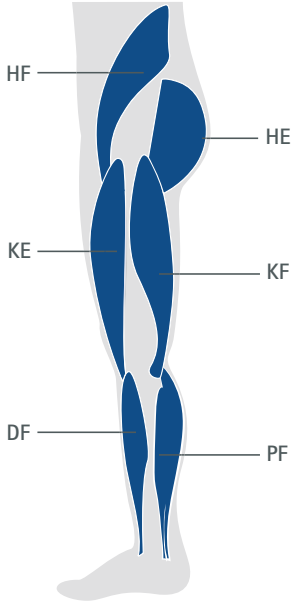
* Patient Data to be Collected

- body weight and height
- shoe measurements
- range of motion in the upper ankle joint
- knee and hip position
- muscle strength**
- activity level
- ap measurement

** Muscle Function Test According to Janda

Muscle Groups (See Right)

- HE (hip extensors)
- HF (hip flexors)
- KE (knee extensors)
- KF (knee flexors)
- DF (dorsal flexors)
- PF (plantar flexors)



Evaluation Scale for the Muscle Function Test

0 (zero)	total paralysis, no evidence of contraction
1 (trace)	slight contraction, but no joint motion
2 (poor)	complete range of motion with gravity eliminated
3 (fair)	complete range of motion against gravity
4 (good)	complete range of motion against gravity with some resistance
5 (normal)	complete range of motion against gravity with full resistance

Consideration of Fatigue

Physical activities such as walking cause muscular fatigue. Such a fatigue has a greater impact on muscle function in people with MS than in healthy people [Pha].

This aspect is particularly relevant for affected patients, as tired muscles in combination with muscular deficiencies can very quickly lead to falls. When producing an orthosis, fatigue should be taken into account in order to ensure the safety required after the muscles tire. Fatigue can be included in the medical patient history with the 6-minute walk test.

The 6-Minute Walk Test

In the clinical context and during physiotherapy, the 6-minute walk test is used in the rehabilitation of MS patients to assess their condition and monitor their progress. It is also suitable for triggering muscular fatigue in a controlled manner [Leo], which is why it is ideal as part of the medical patient history for an orthotic treatment. However, it is important to ensure that no falls are provoked. To increase the patient's safety, medical devices such as crutches can be used.

These are the options for performing a 6-minute walk test:

1) The patient completes the 6-minute walk test without an orthosis.
2) The patient completes the 6-minute walk test with an orthosis since they cannot walk without one.
3) The patient completes the 6-minute walk test with other medical devices or the support of another person.

If the patient is too exhausted to continue before the six minutes are up, the test can be stopped. The goal of triggering muscular fatigue in the patient has already been achieved. The time when the test was terminated and the distance covered should nevertheless be recorded for monitoring purposes.

The orthotist can perform the 6-minute walk test themself with simple means and in almost any environment. All that is needed is a stopwatch and a route that has been measured in advance.

For a better orientation, the route can be highlighted with marking objects like traffic cones. During the test, the orthotist has the patient walk up and down the marked route for six minutes. To determine the distance covered, the length of a single route is multiplied by the number of routes the patient has walked.

distance [m] = length of route [m] x number of routes

Determination of the Muscle Strength

To ensure that both the condition with and without muscular fatigue is taken into account when producing the orthosis, a muscle function test must be performed in both conditions. To correctly determine the extent of muscular fatigue, the second muscle function test is performed immediately after the 6-minute walk test. When conducting the first muscle function test, it should be taken into account that the patient already shows a certain degree of fatigue due to their activities during the day.

The procedure described above can be summarised as follows:

1) first muscle function test (without muscular fatigue)
2) 6-minute walk test directly followed by
3) second muscle function test (with muscular fatigue)

The Orthosis Configurator presented in the next chapter calculates the load and functions of the orthosis based on the patient data mentioned above. This includes the muscle strength in consideration of fatigue.

Orthosis Configurator

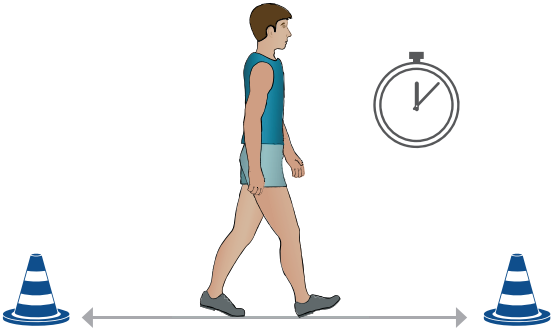
www.orthosis-configurator.com

1. First Muscle Function Test (Without Muscular Fatigue)

dorsiflexion

0	1	2	3	4	5
☐	☐	☐	☐	☐	☒

2. 6-Minute Walk Test



3. Second Muscle Function Test (With Muscular Fatigue)

dorsiflexion

0	1	2	3	4	5
☐	☐	☐	☒	☐	☐

Types of Orthoses

Depending on the muscular deficiency of the patient, there are different options for an orthotic treatment. The most important functional differences consist in the type of orthosis and the properties of the joints.

Ankle-Foot Orthosis (AFO):

AFOs can be produced in different versions and with different ankle joints. They are employed when primarily the plantar flexors and dorsal flexors are affected. Depending on the ankle joint used, AFOs may have a plantar flexion stop to control dorsiflexion and/or a dorsiflexion stop to prevent excessive dorsiflexion [Plo].

Knee-Ankle-Foot Orthosis (KAFO):

KAFOs are produced with ankle joints and depending on the muscle strength with free moving, automatic (with stance phase control) or locked knee joints. They are employed mainly in cases of a pronounced weakness of the m. quadriceps. The patient placing a hand on their thigh when walking so as to support knee extension is an indication of this deficiency. The compensation of a knee weakness through hyperextension or an excessive leaning forward of the torso can also be first indications for the necessity of a KAFO [Nol].

AFO = ankle-foot orthosis – an orthosis encompassing both the ankle joint and the foot

KAFO = knee-ankle-foot orthosis – an orthosis encompassing the knee, the ankle joint and the foot

Ankle Joint Functions (in AFOs and KAFOs):

dorsiflexion stop

- establishing a stable balance when the patient is standing
- physiological knee extension and heel lift starting at terminal stance
- treatment options: ankle joints with a static or dynamic dorsiflexion stop

Example: NEURO SWING system ankle joint

plantar flexion stop

- foot is held in slight dorsiflexion during swing phase
- controlled lowering of the foot
- adjustability of the knee flexion moment and the controlled tibial progression

Example: NEURO SPRING system ankle joint

Knee Joint Functions (in KAFOs):

free moving

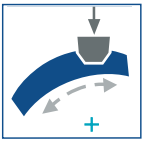
- knee joint remains free moving
- limitation of the range of motion in extension (by means of extension stops)
- lateral guidance and stability
- more safety in mid stance due to free moving system knee joints with posterior offset

Example: NEURO VARIO system knee joint

automatic

- knee flexion is locked in stance phase and released again in swing phase
- locking and unlocking is done mechanically or electronically
- optimum safety with great range of motion
- suitable for training during rehabilitation

Example: NEURO TRONIC system knee joint



locked

- completely locked during walking (no knee flexion possible)
- greatest possible safety in stance phase
- manual unlocking possible (e.g. when sitting)
- disadvantage: development of compensation mechanisms to compensate for the lack of knee flexion

Example: NEURO FLEX MAX system knee joint

Configuration of an Orthosis

In order to provide MS patients with a strong yet lightweight orthosis that also meets all functional requirements, a variety of patient data is required. The patient data provides information on which type of orthosis is required as well as which knee and/or ankle joint functions.

Examples of Relevant Patient Data:

- body weight and height
- diseases and disabilities
- knee and hip position (e.g. hyperextension)
- activity level
- muscle strength

Examples of Orthosis and Joint Functions:

- dorsiflexion stop
- plantar flexion stop
- dynamic knee extension (in stance phase)
- maximum knee stability (in stance phase)
- knee flexion (in swing phase)

It is very difficult for the orthotist to take each of these factors into account when calculating and planning the orthosis. Only intelligent calculation systems such as the Orthosis Configurator by FIOR & GENTZ are capable of evaluating the multitude of data accurately.

Orthosis Configurator

All of the patient data relevant for the treatment is collected and entered into the input masks of the FIOR & GENTZ Orthosis Configurator over the course of the configuration process. By selecting the available orthosis types and joint functions (see p. 18f.) the design of the final orthosis is determined step by step.

The Orthosis Configurator in 4 Steps

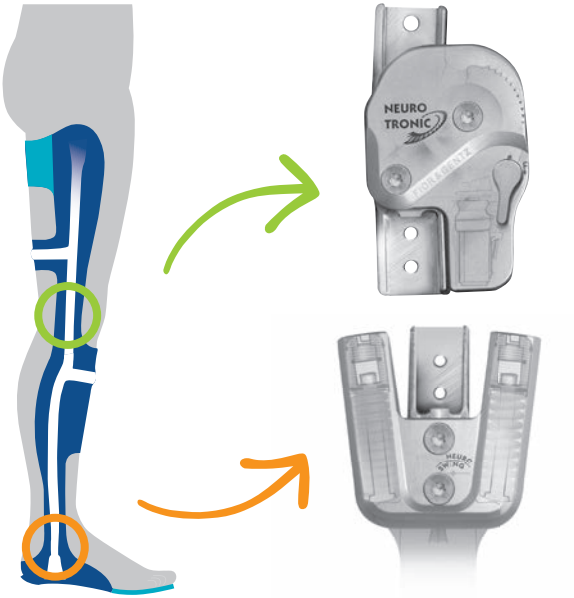
1. Patient Data
The orthotist enters the collected patient data in the corresponding fields of the input masks.

2. System Components
They select from various options and the Orthosis Configurator calculates the required system components accordingly.

3. Individual Adjustments
After the configuration, the orthotist receives a list of components that are necessary to produce the orthosis.

4. Result
They can then order the determined components via the webshop or print out a calculation.

Extract from a Sample Configuration Result:



Influencing the Gait by Adjusting the Spring Force

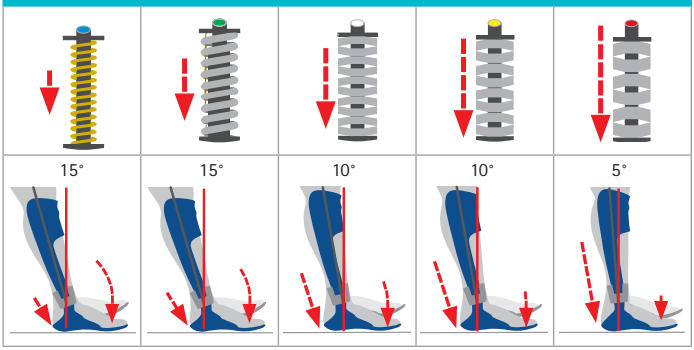
The basic function of an AFO is to keep the foot in a neutral position or slight dorsiflexion during swing phase to enable the leg to swing freely without stumbling. This foot position allows heel contact at initial contact [Nol, p. 659]. However, orthoses must meet other requirements beyond this basic function.
An AFO must be optimally adapted to the pathological gait to establish the best possible biomechanical situation. With the NEURO SWING system ankle joint, this goal is achieved through interchangeable 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.

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 range of plantar flexion depends on the chosen spring unit. The lowering of the foot is controlled by the dorsal spring unit. In combination with a range of motion of 15°, a normal spring force (blue spring unit) enables the largest heel rocker.

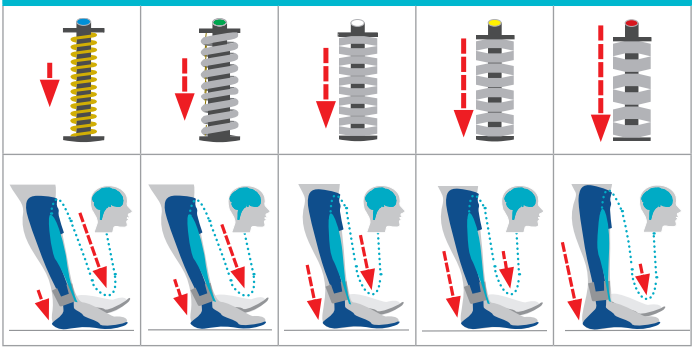
Adjusting the Heel Rocker



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

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.

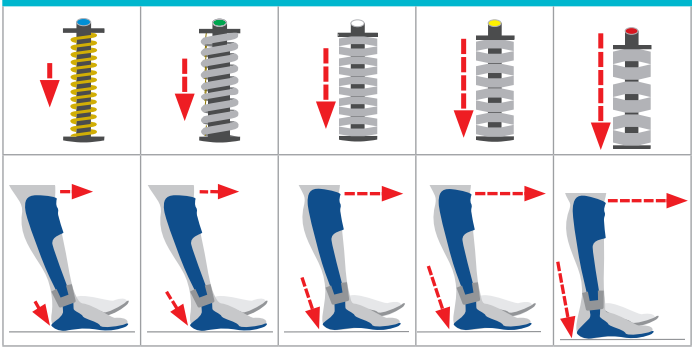
Adjusting the Eccentric Load on the M. Tibialis Anterior



The lower the spring force, the greater the eccentric load on the m. tibialis anterior will be.

Since the range of the heel rocker and the passive plantar flexion decreases with increasing spring force, a proportionately greater flexion moment is applied to the knee. This results in a faster tibial progression 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].

Adjusting the Tibial Progression

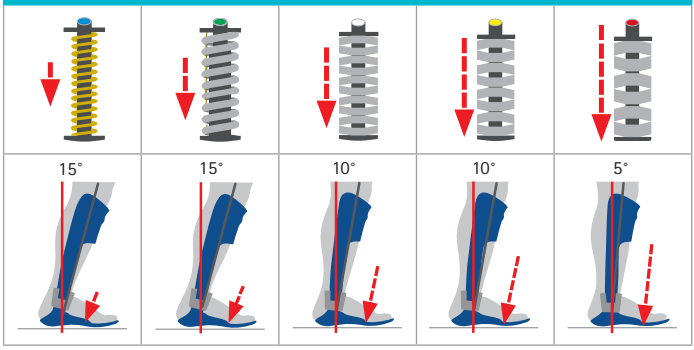


The higher the spring force, the greater the tibial progression will be.

Effects on the Gait during Mid Stance

In mid stance, the forward movement of the lower leg is performed against the resistance of the ventral spring unit. A red spring unit with extra strong spring force causes 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°, which provides the optimum leverage ratio [Owe, p. 257]. This adjustment of the orthosis' alignment can be made directly at the joint.

Adjusting the Resistance against Dorsiflexion

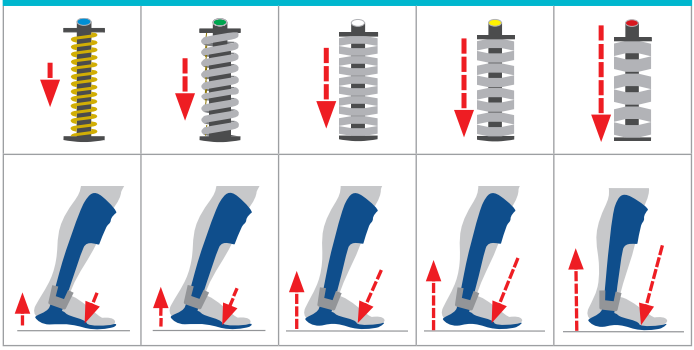


The higher the spring force, the greater the resistance against dorsiflexion will be.

Effects on the Gait during Terminal Stance

Between late mid stance and terminal stance, the compressed ventral spring

Adjusting the Heel Lift



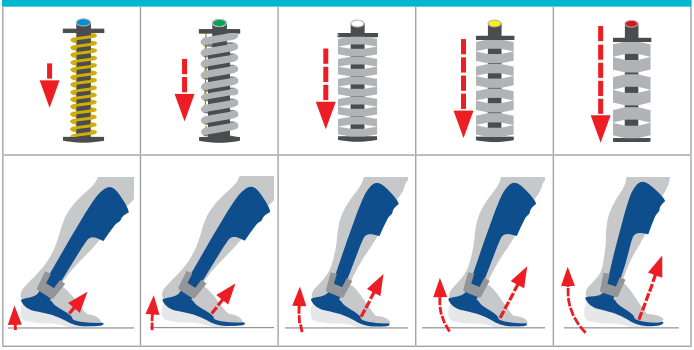
The higher the spring force, the sooner the heel will lift.

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°.

Effects on the Gait during Pre Swing

The energy that was stored in the ventral spring unit 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 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 units with the largest range of motion also cause the foot to take the longest way back into a neutral position.

Adjusting the Energy Recovery for Push Off



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

Effects on the Gait during Swing Phase

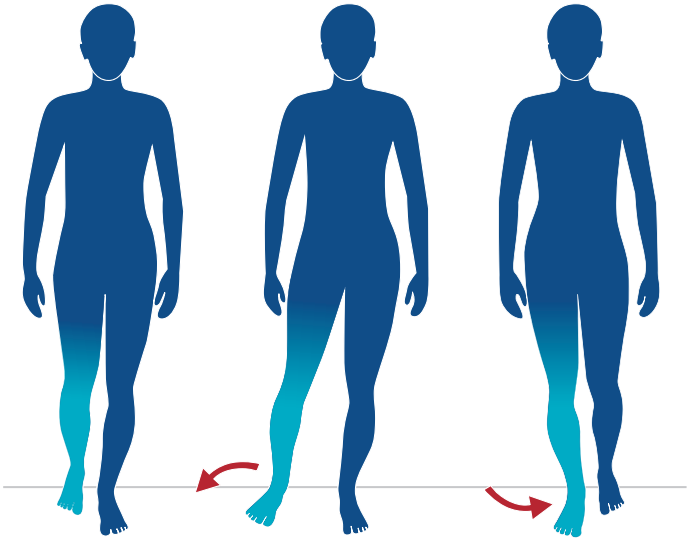
The strength of each of the five spring units of the NEURO SWING system ankle joint is sufficient to keep the foot in a neutral position or slight dorsiflexion, thus ensuring that the heel touches the ground at initial contact. This position is the most important prerequisite for a heel rocker and a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

Compensation Mechanisms during Swing Phase

The swing leg must be effectively shortened to enable a forward movement without stumbling when walking normally. This requirement is met by a physiological hip and/or knee flexion as well as dorsiflexion during swing phase.

In certain gait disorders, this shortening of the swing leg is disturbed, e.g. in the case of a failure of the hip or knee flexors. If the dorsal flexors fail, the swing leg is effectively extended due to an increased plantar flexion during swing phase. When wearing a locked KAFO, the permanent locking of the knee joint also prevents knee flexion.

The body can compensate for this lack of functional shortening during swing phase in various ways, although a combination of several compensation mechanisms can also occur:



Circumduction

During swing phase, the leg is brought forward in a semicircular motion around the supporting leg. During this motion, external rotation occurs in the hip joint. In the long term, this motion can manifest itself and cause hip problems.

Vaulting

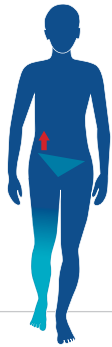
This compensation mechanism describes the contralateral plantar flexion. Since the affected leg is effectively extended or cannot be flexed, the contralateral supporting leg is extended as well to allow the swinging through.

Foot Drop

The patient compensates for a lack of dorsiflexion during swing phase by increasing the knee and/or hip flexion. The initial contact is made with the flat foot or with the toes, which is why this compensation mechanism is also compared to a stork walk.

Lateral Tilt of the Torso

To bring the extended leg forward during swing phase, the patient leans their entire body towards the contralateral side. Medical devices such as forearm crutches can provide the necessary stability.



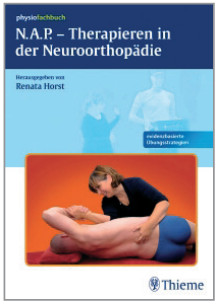
Hip Hiking

Hip hiking refers to the excessive lifting of the pelvis on the swing leg side. This gives the extended swing leg the space to swing through without stumbling.

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.

About the Book



Renata Horst
N.A.P. – Therapieren in der Neuroorthopädie
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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. A separate chapter deals specifically with assessments and exercises for people with MS.

Introduction to the Exercises

Often, both patients and therapists express the fear that the use of medical devices will lead to the muscles becoming even weaker than they already are. However, this is not the case if the treatment creates the best possible biomechanical situation. Through targeted motor impulses, the brain learns to control the corresponding joint-stabilising muscles [Fu]. Especially in the case of depth perception disorders, orthoses can not only provide gait stability but also enable active training. In this way, activity-dependent cortical neural networks are created with the help of orthoses [Jen].

In individual therapy, therapists can work out the necessary structural conditions with their patients and thereby prevent the development of painful contractures above all else. Here, it is also important to mobilise the anatomical joints, e.g. the metatarsophalangeal joints, and to stabilise them by means of a treatment with medical devices. Motor learning involves the transformation of short-term functional changes into long-term structural changes. In combination with orthoses, it is possible to achieve a treatment that supports activity. However, it is essential that the patient continues the training on their own between therapy sessions.

In the following chapter, we will present to you physiotherapeutic exercises which can be performed with the help of a therapist or as independent exercises with or without an orthosis. The correct execution and possible deviations from the physiological state are described in the text and shown in the photos.
All of the presented exercise examples are based on N.A.P.® therapy and aim to maintain the mobility of the anatomical joints while avoiding contractures.

The described exercises can also be used to assess the muscle function as part of a follow-up examination. It should be determined whether or not the foot has enough strength to automatically initiate the non-supporting leg. If, for example, the toe flexors are not elastic enough to generate sufficient acceleration force for push off, then the knee and hip flexors must be trained to lift the foot from the ground, which will minimise the risk of falling.

Exercise 1: Bridging – Pelvis Elevation from a Supine Position

Goal: strengthening of the extensor's synergy (plantar flexors, ischiocrural muscles, gluteal muscles) of the lower extremities, especially the left

Execution: The patient lies on her back and places her feet next to each other. Then she lifts her buttocks.

Method: When the buttocks are lifted, the therapist stabilises the left foot by applying internal rotational pressure on the talus. Furthermore, she supports hip extension by applying pressure via the trochanteric fossa in the direction of the hip joint (fig. 1).

fig. 1

Independent Exercise: The patient performs the exercise with orthosis. The orthosis provides proprioceptive feedback allowing the patient to better perceive the position of her lower extremity. This way, she senses how to control the muscle chain independently (fig. 2).

fig. 2

Exercise 2: Rocking – Sitting Back on Heels from a Position on All Fours

Goal: elasticity training of the toe flexors, the m. quadriceps and the long back extensor in order to train the acceleration force of the extensor's synergy after stretching

Execution: The patient is in a position on all fours with her toes stretched. She slowly moves back towards her heels and then pushes herself forward again with her toes.

Method: When the patient is sitting back on her heels, the therapist stabilises the patient's left foot with her left hand by applying pressure in the direction of the ball of the big toe. To do so, she rotates the calcaneus slightly inwards. The right hand exerts pressure on the trochanteric fossa to stabilise the hip. With her forearm and the support of the therapist, the patient exerts a dorsal and distal pull while sitting back on her heels (fig. 3). Against this pull, the patient pushes herself forward with her plantar flexors (fig. 4).

fig. 3

fig. 4

Independent Exercise: The patient performs the exercise against the pull of a TheraBand. She holds a therapy roll between her heels to stabilise her feet. In this position she can visually check the position of her feet (fig. 5).

fig. 5

Exercise 3
3a: Push Activity by Moving a Stretcher

Goal: elasticity training and improvement of the acceleration force of the toe flexors

Execution: The patient stands in front of a stretcher on which she rests her forearms. Then she pushes the stretcher forward.

Method: A TheraBand is wrapped spirally around the more severely affected leg to give the patient more proprioceptive feedback. This allows her to push off her left foot in a pronating manner (fig. 1).

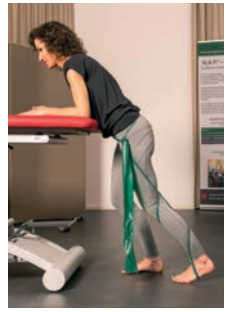


fig. 1

3b: Transition from a Stance to a Kneeling Position

Goal: eccentric and concentric training of the extensor's synergy of the lower extremities and improvement of the toe flexors' elasticity

Execution: The patient slowly descends to her knees from a stance and then raises herself back up to a stance.

Method: A TheraBand is wrapped spirally around the more severely affected leg to give the patient more proprioceptive feedback, making it easier for her to stabilise the foot through pronation (fig. 2).

fig. 2

The patient can perform the same exercise with her orthosis. However, she must put more weight on the tips of her toes (fig. 3).

fig. 3

Exercise 4
4a: Sitting Back on Heels

Goal: elasticity training of the m. tibialis anterior and the m. quadriceps

Execution: The patient positions the back of her feet flat on the ground and sits on top of her heels.

Method: In order to better maintain her balance, she supports herself with one hand on a chair (fig. 4).

fig. 4

4b: Transition from a Heel Seat to a Knee Stance

Goal: extension of the hip by stabilisation of the mm. peronei and the ischiocrural muscles

Execution: The patient raises herself from a heel seat to a knee stance.

Method: In order to better maintain her balance, she supports herself with one hand on a chair (fig. 5).

fig. 5

4c: Transition from a Knee Stance to a One-legged Knee Stance

Goal: improvement of the stability of the supporting leg (right leg) and the functionality of the non-supporting leg (left leg) as well as pre-stretching of the foot lifter (in heel seat) and hip flexors (in knee stance) for an easier initiation of the non-supporting leg

Execution: Starting in knee stance, the patient moves her left leg forward into a step position (fig. 6).

Method: In order to better maintain her balance, she supports herself with one hand on a chair. The same exercise can be performed with an orthosis (fig. 7).

fig. 6

fig. 7

Exercise 5: Standing up from a Step Position

Goal: concentric and eccentric strengthening of the extensor's synergy, improvement of the mobility of the metatarsophalangeal joints

Execution: While sitting, the patient holds on to a bar with both hands and pushes herself up into a stance with her left foot.

Method: The therapist uses her left index finger to perform a rotatory twisting along the Lisfranc joint line in the direction of the ball of the big toe, while the patient pushes herself up into a stance with her forefoot (fig. 1).

Independent Exercise: The patient performs the exercise with a TheraBand that is wrapped spirally around her leg (fig. 2). This supports the forefoot pronation and push activity of the mm. peronei.

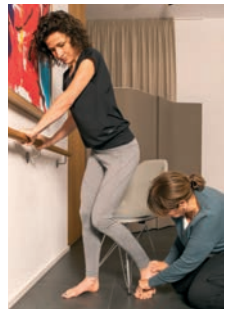


fig. 1

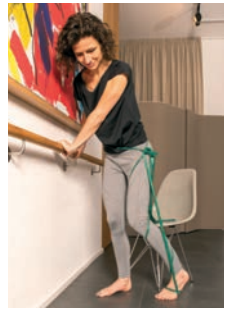


fig. 2

Exercise 6: Standing up from a Seat Position

Goal: strengthening of the extensor's synergy via a leg axis correction

Execution: With her feet positioned parallel to each other, the patient sits down on a chair and stands up again from this position.

Method: The patient can hold on to something for support when standing up. Without the orthosis, the left thigh rotates inwards when leaving the seat position (fig. 3). With the orthosis, the leg axis is corrected as the patient stands up (fig. 4).

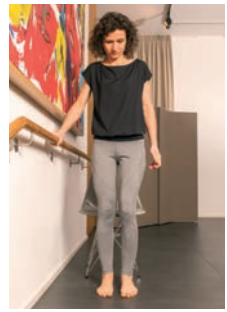


fig. 3

fig. 4

Exercise 7: Climbing Stairs

Goal: optimum loading of the leg axes to train the extensor's synergy of the supporting leg and to facilitate the initiation of the non-supporting leg when climbing stairs

Execution: The patient climbs up one or more steps.

Method: The patient can hold on to a handrail for support. Without the orthosis, the right knee deviates greatly in the medial direction, so that the patient can hardly detach her left foot from the step to climb the stairs (fig. 1). With the orthosis, the leg axis of the right leg is straightened and the patient can climb the step more easily with her left foot (fig. 2).

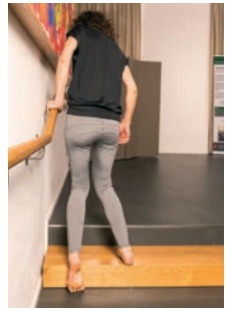


fig. 1

fig. 2

Exercise 8: Rolling from a Supine Position to a Lateral Position

Goal: strengthening of the hip and knee flexors as well as the foot lifter

Execution: The patient rolls from a supine to a lateral position.

Method: A TheraBand wrapped around both feet exerts a pulling stimulus while the patient turns from a supine to a lateral position (fig. 3). The same exercise can be performed with orthoses (fig. 4 and 5).

fig. 3

fig. 4

fig. 5

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

Axon
(from Greek *axon* = axis): extension of a nerve cell. Transmits electrical impulses from the cell body to other nerve cells. The unit of axon and surrounding ↑myelin sheath is called nerve fibre.

Cadence
(from Latin *cadere* = to fall): here: step frequency. Is indicated in steps per time unit (minutes or seconds).

Cognitive
(from Latin *cognoscere* = to recognise): referring to the knowledge, understanding or thinking of a person

Compensation Mechanism
(from Latin *compensare* = to compensate, to replace): compensation or replacement of a missing ↑physiological movement to achieve a certain goal. A deficient foot lift or knee flexion during swing phase can be compensated by various mechanisms to achieve the goal (here: swinging through of the leg).

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
(from Latin *contrahere* = to tighten): 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.

Cortical
(from Latin *cortex* = bark): originating from the cortex, located in the cortex. Cortex here means the cerebral cortex.

Distal
(from Latin *distare* = to be distant): denoting a position away from the centre of the body. The opposite of distal is ↑proximal.

Dorsal
(from Latin *dorsum* = back): belonging to the back, located at the back. If, for example, an ankle-foot orthosis is produced with a dorsal shell, the shell is placed against the back of the lower leg, i.e. the calf.

Dorsiflexion
Lifting of the foot. The countermovement of ↑plantar flexion. Referred to as a ↑flexion motion because it reduces the angle between the 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 foot piece of an orthosis 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 enables 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.

Excessive
(from Latin *excedere* = to cross, to exceed): exceeding the norm considerably, excessively, without restraint

Extension
(from Latin *extendere* = to extend): active or passive straightening of a joint. Straightening is the countermovement of bending (↑flexion) and characteristically leads to an increase of the joint angle. Muscles that perform this movement are called extensors.

Extensor's Synergy
interaction of the muscles acting as extensors in order to perform a complex movement

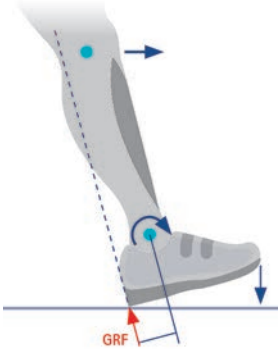
Fatigue
(from Latin *fatigatio* = fatigue): pathological physical or mental exhaustion. Fatigue occurs as a symptom of chronic diseases such as multiple sclerosis, rheumatism, Parkinson's disease or tumours and cannot be resolved by normal recovery mechanisms such as rest or sleep.

Flexion
(from Latin *flectere* = to bend): active or passive bending movement 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.

Gluteal Muscles
Muscles located between pelvis and thighbone that operate the hip joint and shape the buttocks. The gluteal muscles consist of the three muscles m. gluteus maximus, m. gluteus medius and m. gluteus minimus.

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

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.

Hyperextension
(from Greek *hyper* = beyond, above; from Latin *extendere* = to extend): overextension of a body part. For the knee joint also called genu recurvatum (from Latin *genu* = knee; *recurvare* = to bend backwards).

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

Ischiocrural Muscles
Hamstrings. Located on the ↑dorsal side (back) of the thigh. In the hip joint, the ischiocrural muscles cause an ↑extension whereas in the knee joint, they cause a ↑flexion.

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

Lisfranc Joint Line
Named after the French surgeon Jacques Lisfranc (1790-1847). The Lisfranc joint line is a line on the foot between the ↑proximal tarsus and the ↑distal metatarsal bones.

M. Quadriceps
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. Tibialis Anterior
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.

Mm. Peronei
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).

MS International Federation
(abbr. MSIF): global network of national MS organisations

Multiple Sclerosis
(abbr. MS): inflammatory disease of the central nervous system that leads to progressive neuromuscular impairments (e.g. problems with the ability to walk)

Muscle Strength
Muscle strength is a parameter used to assess the force generated by a muscle group (e.g. knee flexors). This force is determined by the muscle function test [Jan], which tests each muscle group to assess the extent to which each respective movement can be performed. The muscle strength is classified on a six-level scale depending on whether or not the subject is able to overcome manually applied resistance or gravity.

Myelin Sheath
(from Greek *myelos* = marrow): a protective layer consisting of proteins and fats, which surrounds part of the nerve cell extensions (↑axons) of vertebrates in a spiral manner. This layer enables the nerve cells to transmit stimuli quickly.

Neural
(from Greek *neuron* = nerve): concerning the function and condition of nerve cells (neurons)

Neurological
(from Greek *neuron* = nerve; *logos* = doctrine): concerning the nervous system

Paresis
(from Greek *paresis* = flaccidity): paralysis. Partial failure of the motor function of a muscle or muscle group. In contrast, plegia refers to the complete failure of a muscle or muscle group.

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.

Plantar Flexion Stop
Constructional element of an orthosis that limits the degree of ↑plantar flexion. A plantar flexion stop is used to activate the hindfoot lever. This activation enables a foot lift, for example during swing phase, and ensures that the leg swings through without stumbling.

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

Predisposition
(from Latin *pre* = before; *disponere* = set up, organise): likelihood to develop a certain disease

Progressive
(from Latin *progredere* = to advance): advancement of a disease or manifestation of the ↑symptoms associated with a disease

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.

Proprioceptive
(from Latin *proprius* = own; *recipere* = to absorb): describes the perception of sensory impressions and their transmission to the brain. These sensory impressions can, for instance, relate to one's own position or state of activity as well as to the forces acting on joints, muscles and tendons. Proprioception is also known as depth sensitivity.

Proximal
(from Latin *proximus* = the nearest): positioned towards the centre of the body. The opposite of proximal is ↑distal.

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

Remit
ease up temporarily

Rotation
(from Latin *rotare* = to turn): circular turning around an axis or a centre. Thus, an internal rotation is a turning of a body part towards the centre of the body.

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.

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. Thus, a static ↑AFO does not allow any movement in the anatomical ankle joint.

Symptoms
total of all signs detected by the patient or physician that occur in connection with a disease

Trochanteric Fossa
Depression in the ↑proximal section of the thighbone. It serves as a collective starting point for different muscles.

Upper Ankle Joint
(from Latin *articulatio talocruralis*): the upper ankle joint and the lower ankle joint are the two joints between the lower leg and the tarsus. It is a hinge joint composed of the tibia and fibula at the lower leg and the ankle bone of the tarsus. It is stabilised by a joint capsule and several ligaments. The upper ankle joint is mainly responsible for the ↑plantar flexion and the ↑dorsiflexion of the foot.

Ventral
(from Latin *venter* = belly, body): abdominal, facing forward. If, for example, an ankle-foot orthosis is produced with a ventral shell, the shell is placed against the front of the lower leg, i.e. the tibia.

References

Abbr.	Source	Page
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