Lokomat® User Script

1. Background Information – Lokomat®

Before starting with the Lokomat training, let's recapitulate some important considerations for the rehabilitation of gait and balance impairments and understand how the Lokomat history is related to these considerations:

Guidelines recommend **task-specific practice** for improving lower extremity motor function, gait, posture, and activities of daily living (NICE 2013, SIGN 2013, Hebert et al. 2016, The Management of Stroke Rehabilitation Work Group 2019, Stroke Foundation 2022). Training should be **meaningful, engaging, repetitive, progressively adapted, task-specific and goal-oriented** (Hebert et al. 2016). **Task-specific practice for gait involves practice of walking or components of walking** to facilitate mobility (The Management of Stroke Rehabilitation Work Group 2019). Task-specific training tends to be more engaging, as it can be tailored to the patient's preferences and individual goals. Walking training (overground or on a treadmill) should be offered to people after stroke who are able to walk, with or without assistance, to help them build endurance and move more quickly (NICE 2013). Those who are severely impaired may require increased staff or the use of technology to assist with safe performance of tasks (The Management of Stroke Rehabilitation Work Group 2019).

Guidelines recommend early weight bearing interventions and gait training as soon as possible after a traumatic injury to maintain and improve muscle function, muscle mass, postural reflexes, balance, strength and range of movement (DMGP 2018, NICE 2022). Walking training can be started if the patient has enough function to stand and walk (DMGP 2018) or if he/she is able to bear weight (NICE 2022).

The Lokomat system was developed in collaboration with the Spinal Cord Injury Center at the Balgrist University Hospital in Zurich, Switzerland. Close collaboration with physicians, therapists, patients, and scientists (Figure 2) made the development of a patient and practice-oriented device possible. The Lokomat development is based on the clinical evidence of motor learning applied to locomotor training:

Figure 1: Manual training on the treadmill with one of the Lokomat inventors

- Repetitive task-oriented execution (Barbeau et al. 2006).
- Neuroplasticity (Cramer et al. 2011).
- Appropriate proprioceptive feedback and leg loading (Dietz et al. 2002).
- Early therapy onset (Krakauer et al. 2012)
- Motivation (Cramer et al. 2011, Gangwani et al. 2022)
- Intensity and challenge (Veerbeek et al. 2014)

The Lokomat has been available on the market since 2001 and it is now used in more than 900 hospitals and clinics worldwide.

Since the first Lokomat version, new features have been developed and continuous improvements have been achieved. This includes, but it is not limited to: Dynamic Body Weight Support System, Assessment Tools, Biofeedback, Augmented Performance Feedback/Virtual reality, Guidance Force, Path Control FreeD and smart algorithms.

The LokomatPro with Pediatric Orthoses was introduced to the market in fall 2005. In March 2011 Hocoma presented a new version of the LokomatPro that featured a new and more compact design and included the Augmented Performance Feedback/virtual reality as a standard feature.

Today, Hocoma develops innovative patient therapy solutions working closely with leading clinics and research centers. In the last 20 years, more than 400 research studies investigated safety, feasibility as well as functional improvements in response to Lokomat assisted treadmill training.

2. What is the Lokomat®?

What is the Lokomat designed for?

The Lokomat is a robotic device for **enabling intensive rehabilitative gait therapy.**

It provides functional locomotion therapy, programmable to the patient's individual needs combined with patient assessment and feedback tools. Benefits from Lokomat training include:

- Allows highly intensive patient therapy even severe patients.
- Ensures a physiological gait pattern with essential sensory feedback through individually adjustable exoskeleton and gait pattern.
- Provides assist-as-needed support with Guidance Force and Body Weight Support individually adjustable to the patient's abilities that enables a therapy beyond present capabilities.
- Provides tools to increase patient's participation with the Augmented Performance Feedback exercises.
- Provides objective analysis and documentation of patient progress (Assessment Tools and Reporting).

Which patients should I include in the Lokomat therapy?

The Lokomat **is intended for the rehabilitative treatment of patients with severe to moderate impairments in walking abilities and functional mobility**. These impairments in body functions and activities can be caused by **different diseases, including, but not limited to, neurological diseases**, such as acquired brain injury (through stroke or trauma), spinal cord injury and cerebral palsy.

The Lokomat is intended for adult and pediatric patients with severe to moderate impairments in walking abilities and functional mobility undergoing gait therapy in rehabilitation hospitals, hospitals with rehabilitation departments, outpatient rehabilitation clinics and physiotherapy practices, and for whom intensive gait training is indicated according to the judgement of the treating clinician (as long as they do not present contraindications).

The intended patient population for the Lokomat is not limited by age, but by body size (height, weight, and leg length):

• Body height: less than 2 m (78.7 in) or less than 1.95 m (76.7 in) (depending on the version)

• Body weight: between 10 kg (22 lb) and 135 kg (297 lb)

• Upper leg length:

  o Between 35 cm (13.8 in) and 47 cm (18.5 in) (adult orthosis)

  o Between 21 cm (8.3 in) and 35 cm (13.8 in) (pediatric orthosis)

The main purpose of the Lokomat is to train gait ability. In addition, it can provide mobilization even if independent ambulation over ground is not a reasonable expectation.

Literature has shown that gait training with the Lokomat leads to **clinically relevant improvements in the following outcome measures in** patients with severe to moderate impairments in walking abilities and functional mobility:

- **walking speed** (10-meter Walking Test)
- **walking endurance** (6-minutes Walking Test)
- **functional ambulation** (Functional Ambulation Category)
- **cardiovascular fitness** (maximal oxygen uptake)
- **functional mobility** (Time Up and Go)
- **balance** (Berg Balance Scale)

3. What does the Lokomat® include?

The Lokomat has predefined parameter settings but at the same time offers you the possibility to adjust these parameters individually to your patients' needs and according to the therapeutic goal for the patient.

Therefore, we will define first the **Gait Pattern**, that means, the movement that we want the patient to do.

Certain **Parameters** can be adjusted, like the speed in which this movement is done, the amount of guidance provided or the amount of weight support.

Moreover, the orthoses includes sensors which measure the **Patient's activity** that can be used to control an avatar and perform exercises.

In addition, we can perform **Assessments** in order to objectively evaluate certain aspects, such as the Range of Motion, the Force (Strength) or the Resistance (Stiffness-Spasticity)

All **Training Data** will be saved on a report file.

Gait Pattern

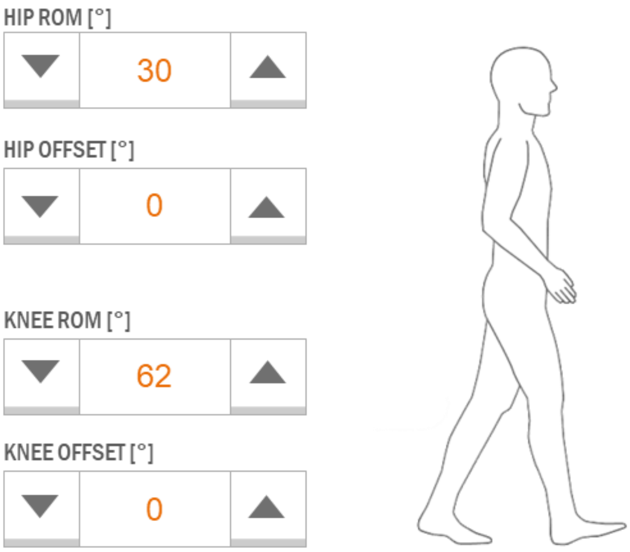
The Lokomat reproduces a physiological gait pattern. The movement that the patient will repeat during the therapy session is established by:

a) **Predefined settings:** The Lokomat always starts with a predefined movement based on a physiological gait pattern. This means, the Lokomat automatically produces a gait pattern. However, this pattern can be adjusted individually to each patient through hardware and software adjustments.

b) **Hardware adjustments - Set up:** The way the orthopedic material is fixed to the patient as well as the adjustments done on the Lokomat orthoses influence the movement that the patient will do.

c) **Software Adjustments - ROM and Offset:** The maximum amount of movements (Range of Motion, ROM) for Hip and Knee joints are adjusted in degrees. This defined range (angle in degrees) can also be shifted towards flexion or extension with the Offset function. Both parameters, ROM and

Offset, can be individually set for right and left sides and they can also be re-adjusted during the session while walking.



In the Graphical User Interface (GUI) – on the therapist screen - , we define the movement pattern for the patient. We can adjust in particular the ROM for Hip and Knee joints **symmetrically or asymmetrically**, e.g. individually for left and right sides. On each joint we can adjust ROM and Offset:

- **ROM:** Range of Motion. Amount of movement (angle) that the joint moves through.
- **Offset:** Variation of the angle (ROM) towards flexion or extension.

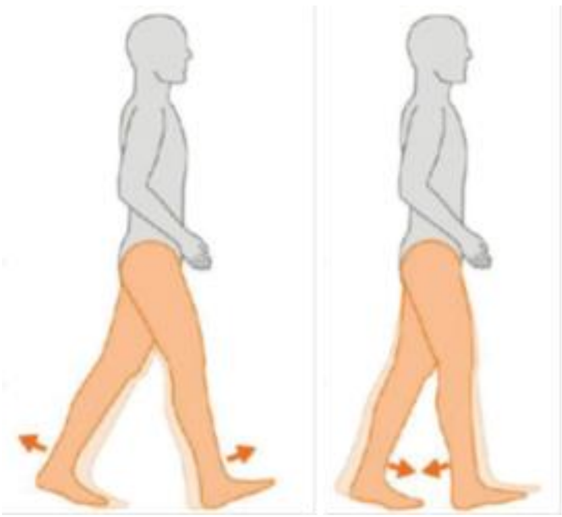
How do these parameters affect the gait pattern of the patient?

HIP ROM

With the ROM, we can increase or reduce the amount of movement of the hip in both directions (flexion and extension), which mainly influences the **stride length**.

Increasing the hip ROM leads to a longer step length, while decreasing the hip ROM results in shorter step length.

Keep in mind that in normal overground walking the step length changes with the walking speed: when a person **walks faster**, the step length (and Hip ROM) tends to be **longer** than when walking slowly. In the Lokomat this will be a manual adjustment on the part of the therapist.



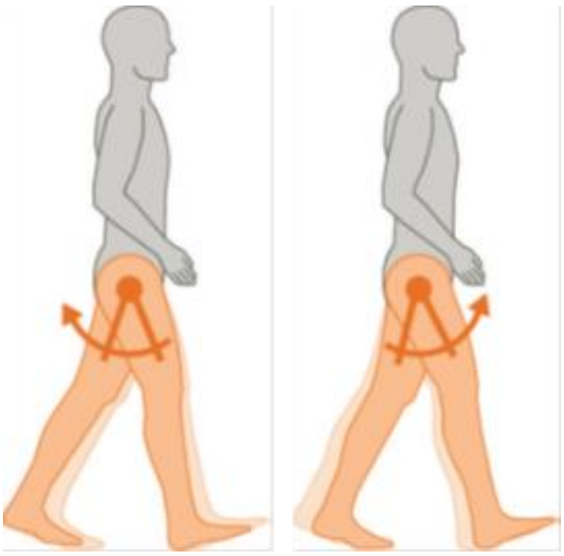
HIP OFFSET

Changing the hip offset **shifts the ROM either towards flexion or extension**. This means, by maintaining the same amount of movement (angle) of the hip joint, the hip offset can shift the hip joint towards flexion or extension.

When shifting the movement towards flexion (positive values), the patient's legs move forward (in respect to the trunk), resulting in more hip flexion and less hip extension.

When shifting the movement towards extension (negative values), the patient's legs move backwards (in respect to the trunk) resulting in more extension and less flexion.

This shifting of the movement towards flexion or towards extension mainly influences when the foot touches the ground **(initial contact)** and when it leaves the ground (toe off):



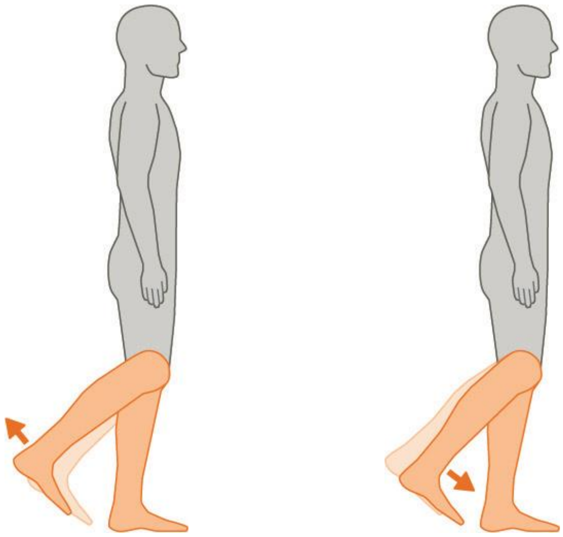
When the movement is shifted **into flexion**, the patient is having the same ROM as before, but with more flexion and less extension. When the hip is in flexion, the foot doesn't touch the ground. Therefore, the patient leg is longer in the air and contacts the ground later **(later initial contact)**.

KNEE ROM

When increasing the knee ROM, the amount of movement of the knee joint is greater. It increases only the amount of knee flexion, while maintaining the same amount of extension. This is because on the hardware adjustments we already defined the maximum knee extension; and if this would be increased, it would result in a hyperextention of the patient's knee.

Increasing knee flexion **increases the distance between the foot and the floor during swing phase**. It is, therefore, used to prevent (or correct) the patient's foot touching the ground during swing phase.

Increasing the knee flexion also means that the patient will do more ROM during the same time. This results in a faster movement and therefore, a **quicker toe-off**.

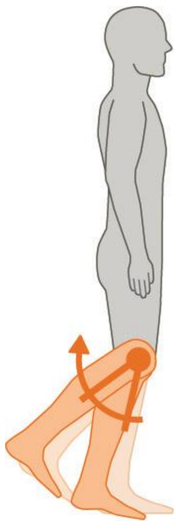


KNEE OFFSET

The offset on the knee shifts the ROM towards flexion. This means, more flexion, less extension. The effect is that the knee will not fully extend, but have the same amount of movement.

This function can be used to **correct a knee hyperextension**.

In order to prevent hyperextension of the knee, is it not possible to select negative values. 0° = full extension.



Parameters

Speed

What is the parameter “speed”?

It defines the speed at which the treadmill runs, and therefore the speed at which the patient walks. The Lokomat starts with a default value for the walking speed of 1.5 km/h. This value can be modified from 0.5 to 3.2 km/h.

What do we use the speed for?

- To ensure a challenging patient therapy session. Depending on the therapeutic goal, the speed value needs to be increased or decreased.

Higher speed values could be helpful in the following instances:

- When the goal is to provide the patient an afferent input of the gait pattern, and thus facilitate neuroplastic changes, a faster speed will lead to **more repetitions and increased challenge**.
- When the goal is to enhance an **“automatized” pattern**, so that the patient is able to walk without thinking about each specific movement.
- When the patient has participated in multiple Lokomat sessions and got used to the regular speed, a higher speed could result in **increased challenge** and thus be useful for **therapy progression**.
- When the gait pattern is not physiological enough because the speed is too low, increasing the speed sometimes makes it **“smoother”** and more rhythmic.
- Patients who practice walking faster are able to walk faster, therefore if **increased gait speed over ground** is a goal then increased gait speed on the Lokomat should be part of the therapy.

Always keep in mind: the faster the walking speed, the more repetitions and intensity, but also the more rapid fatigue.

Lower speed values could be helpful in the following instances:

- During the **first therapy sessions**, so that the patient can get used to the Lokomat and the orthoses.
- When the goal is re-learning a **specific movement** and focusing on a specific gait impairment, a lower speed will give the patient time to think about it (e.g. consciously extending the knee during stance phase).
- To **consciously activate the muscle** and recruit the muscle fibers for specific strength training.
- Useful in **patients with spasticity** at the beginning of the therapy session, until the muscle tone decreases and adapts to the movement. A high speed can trigger a spastic reaction and cause the orthoses to stop for safety reasons.

What to consider when adjusting the speed?

When increasing the speed value, **please consider the following**:

- The **step length** should be adapted to the speed: higher speed – longer step length, thus the Hip ROM should be increased.
- The **orthosis speed** value should be adjusted (or use the automatic setting).
- The **Offset Hip** may need to be adjusted (towards extension).
- The **impact of the heel**could be greater and therefore the joints must be able to support this impact.
- The **quality of the movement** may be affected, e.g. heel strike at initial contact.

Orthosis Speed

What is the parameter “orthosis speed”?

The parameter orthosis speed allows to individualize the patient cadence thanks to the adjustment of the speed of the orthoses. This is needed to synchronize the speed of the treadmill and the speed of the patient legs since differences in leg length have an impact on the cadence of the patient.

The orthosis speed is adjusted manually, which can be helpful in some cases (e.g. not good foot clearance, foot drop at end stance-beginning swing phase).

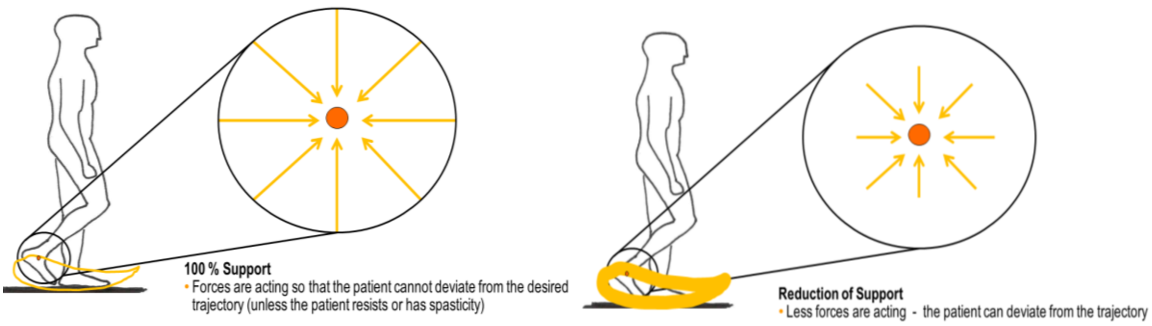
What to use the orthosis speed for?

- To ensure that the patient’s leg movement (orthoses speed) is coordinated with the walking speed (treadmill speed).
- To influence the foot clearance.

Guidance Force

What is the "Guidance Force"?

The Guidance Force (GF) determines the extent to which the patient's movements are guided by the Lokomat orthoses while walking.



How does the Guidance Force work?

Once the ROM and Offset of the hip and knee joints have been selected, the movement trajectory which the patient's legs will do has been defined. Then, the guidance force will assist the patient to always follow the predefined trajectory.

When reducing guidance force, the Lokomat will provide less assistance and will become more tolerant to deviations from the predefined trajectory. This means, the lower the guidance force, the more active the patient needs to be in order to follow the gait pattern and some variability is introduced allowing to train in the concept of "repetition without repetition" or gait variability.

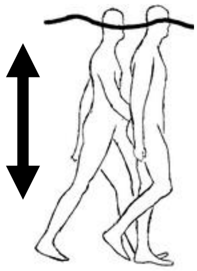
What to use the Guidance Force for?

- To **challenge the patient**: A lower guidance force obliges the patient to "work harder". The patient has to put more activity into his movements and therefore it enhances the patient's **active participation**. It allows grading of the assist to the patient to only **as much as needed**.
- **Active variability** of the gait pattern: On the other hand, reducing the guidance force enables the patient to move more freely, and thus, to deviate actively from the predefined gait pattern. This means, if the patient is "stronger" than the guidance by the Lokomat, he will be able to vary the movement and diverge from the defined pattern.

  If the deviation exceeds the preset safety limits, the Lokomat stops automatically. This can enhance motor learning by establishing an environment where the patient is responsible for the success of the gait pattern and has the opportunity to make errors and learn from them.

Body Weight Support (BWS)

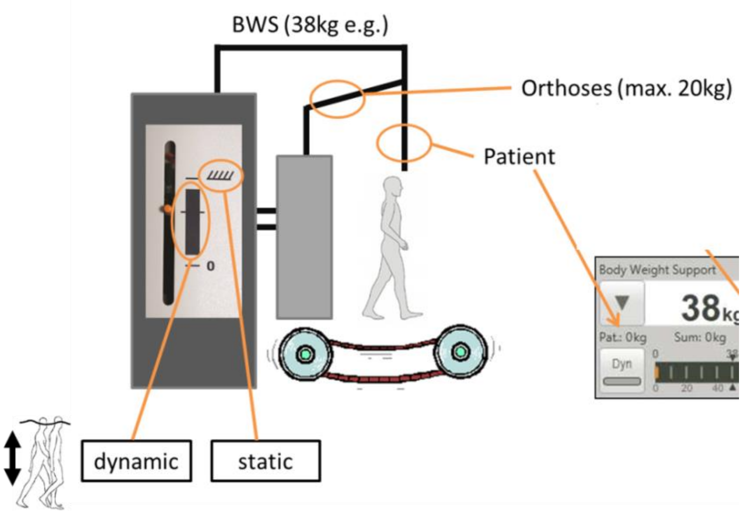
What is the BWS?



The body weight support system provides precise and dynamic weight support. This allows a physiological gait pattern, while still applying enough loading for an appropriate afferent input.

How does the BWS work?

The BWS works by removing a portion of the patient's body weight thus decreasing the amount the patient needs to support through their legs. This support can be dynamic or static. Additionally, the support can be provided through the patient or through the orthoses.



Dynamic BWS:

Gait has a natural vertical component during each step cycle. When the patient is supported dynamically, the BWS system (Levi) adjusts to the physiologic vertical movement of the patient ensuring **precise unloading,** during the vertical translation of the patient**.**

This allows a more physiological gait and an optimized sensory stimulation.

What to use the dynamic BWS for?

- To enable a **physiological gait pattern**, while still applying **enough loading** for an appropriate afferent input.
- To ensure a **precise amount** of BWS, adapted to the vertical movements of the patient while walking.

4. How are we going to use the Lokomat® in a patient therapy session?

First, we will need to **prepare the patient and the Lokomat** by adjusting the Lokomat to the patient and selecting the orthopedic equipment, to ensure a good interface between the patient and the Lokomat. Select the patient according to indications/contraindications (User manual).

Then, we will **put the patient in the Lokomat**, make the movement axis of the Lokomat match with those of the patient and thus, ensure a good posture. This patient setup procedure we will do in a systematic way, step by step, thus making it time efficient and accurate.

Once all is ready, we will start **the training**. During a Lokomat therapy session, first we make sure that the patient's gait is safe ("**Safe Walk**"), then we adjust all parameters aiming the gait to be as physiological as possible ("**Physiological Walk**"), and last we adjust the gait goal-oriented for this specific Lokomat therapy session (**"Goal Oriented Walk"**).

Once the therapy session is finished, we use the reverse order of steps as used to **put the patient in the Lokomat** in order to **bring the patient out**.

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