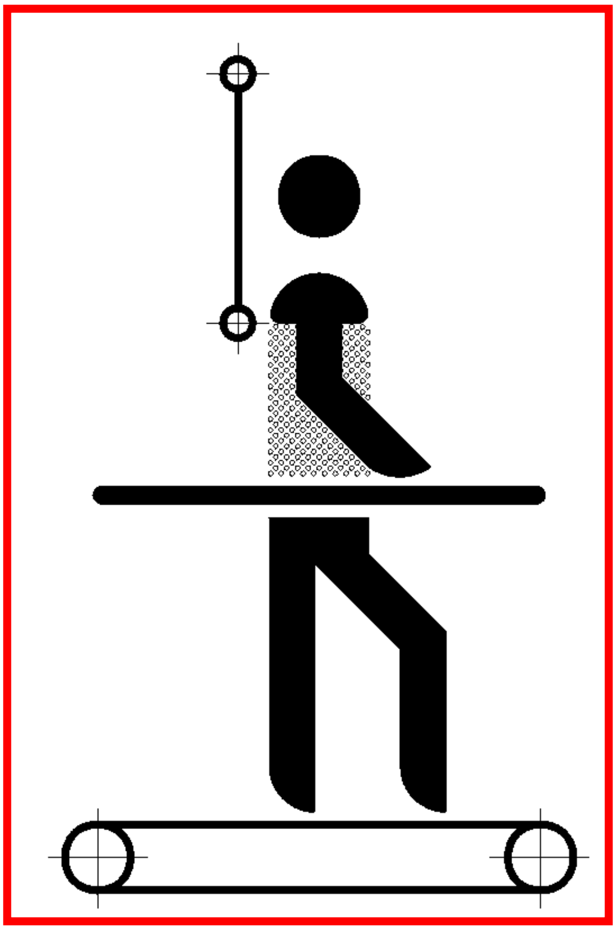
Laufband Therapy

The Manual



For

Spinal Cord Damage

Stroke, Brain Damage and MS

Orthopedic Disorders and others

Written by

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MANUAL
LAUFBAND (LB) THERAPY

Synonima: BWSTT, treatmill therapy a.o.

For the treatment of spinal cord lesioned persons, hemiplegics, brain damaged, orthopedic and other patients

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MANUAL

Laufband (LB) therapy for the treatment of spinal cord lesioned persons, hemiplegics, brain damaged, orthopedic and other patients

1 INTRODUCTION

Laufband (LB) therapy was originally developed for spinal cord injured persons and has consequently been successfully applied also to hemiplegia, multiple sclerosis and other diseases. The common denominator for all these diseases is activity dependent learning and adaptation of the CNS to an altered periphery; it is like learning to work with new tools. The simplicity of the instruments, the safety in use and the low number of therapists needed for handling even most severely paralysed patients, make the technique a suitable tool in rehabilitation of locomotion This apparent easiness in use on the other hand seduces therapists to use it without proper training. Especially for neurological patients there are **rules** to comfort and these have to be learned in theory and in praxis. Thus each therapist needs to be trained properly in at least two aspects: Know the new therapeutic goals a patient might be able to reach, and: Learn the practical handling of patients on the Laufband. Some institutions have been purchasing the equipment and have been advertising that they are performing LB therapy. We have over the years seen some rather poorly trained patients and on our visits to clinics sometimes had to see exotic mountings of the harness and counter-productive “help” provided by the therapist.

To sum up: There is no magic with the use of a treadmill for training of locomotion. In principal, walking over ground aided by skilled therapists should also be effective as long as the specific rules of locomotion (described in this MANUAL) are observed and maintained. In fact, there are clinical trials in which the amount of walking by definition was kept the same in the experimental (LB) and control group; expectedly, the outcome is similar. The difference is in the amount of effort for both patient and therapists: Both are afraid of falling and for setting limbs when walking over ground, 3-4 therapists are needed (that high costs in manpower might be available in funded trials, but rarely in everyday life).

In this manual we describe the selection of patients, techniques, handling, equipment etc in detail for therapy of **SCI persons** and describe in extra chapters those details special to **hemiplegia and other diseases**.

The authors thank many colleagues and patients around the world which did in many discussions over the last 15 and more years contribute to our understanding, starting with H. Barbeau whom we first met and exchanged experiences at a meeting in Bonn, Germany in 1990 (see the book: Plasticity of Motorneuronal connections, Progress in Brain Research 5, 1991, Elsevier). Laufband therapy is directly derived from animal experiments and here the work by Edgerton and his group in Los Angeles showing in the cat

that the spinal cord can learn, was something like a trigger to look into the behavior of the s.c. injured human. New assessments and motor scores more functionally oriented and finer graded than the ASIA scores had to be installed to assess the progress achieved by LB therapy for SC damaged persons, similarly assessments for evaluation of locomotion in stroke patients are included. In addition, protocols for clinical trials are added which might be used for research purposes. Some of these were elaborated in preparation of a European multicenter trial (which did not get funded by the EU Commission in spite of high ranking by the referees) and we want to thank all those many colleagues who contributed to this proposal. Finally we cordially invite new suggestions.

2 EQUIPMENT FOR LB THERAPY

2.1 The treadmill (German: Laufband, Tretmühle).

Since a treadmill, Tretmühle was a device for very hard (slave) work to grind corn or move heavy loads we have been using the term Laufband or Laufband therapy instead. Laufband means "moving band" and describes the equipment we actually use in our therapy much closer: A motor driven moving band with a special frame and a suspension system.

There have been different versions of treadmills on the market, none of which, however, could be used as they were when we started in 1989. The only other group then working on the therapy (Barbeau in Montreal) built the necessary equipment themselves, we asked WOODWAY GmbH, Germany to adapt their equipment according to our needs. Meanwhile a few suitable apparatus are commercially available. Here are the necessary requirements:
Speed range: 0.1 to 5.0 km/h, steps of increment: 0.1 km/h.
Motor needs to produce enough power to allow an even progression of the band also against resistance. Band speed must not become significantly reduced by loading.(Check yourself by trying to stop the band).
To the sides of the moving band, a *broad board* equipped with seats for the therapists is absolutely necessary. The therapists not only have to sit comfortably but sometimes also need to lean with their back against one of the poles of the frame to balance themselves when moving very spastic legs. For that purpose, therapists also put one of their legs onto the board. Obviously, the surface of the band and this board need to be sufficiently elevated from the ground to allow (relatively) comfortable *sitting (some 35 cm*). For handling of less spastic patients some therapists find it comfortable to work in standing; for this purpose the whole treadmill may be put onto a *stage* with adjustable height. For such setting width of the moving band should not be broader than some 55 cm so a single therapist can reach both legs. An elevated surface, however, may cause fear and additional confusion in patients with deficits in perception.
Somewhat surprizingly, there are very expensive models of treadmills on the market, which don't allow the therapist to sit at the side and the surface of the moving belt is close to the ground. Obviously with such equipment, little help can be given by therapists with limb setting, consequently only patients already ambulating may be properly trained with such models (s.Nilsson et al 2001).

2.2 The frame (3 in Fig 1).

The frame needs to be adjustable in height to comfort patients with different body sizes. There need to be three horizontal rods, one to each side and one in front. It is important that the vertical poles are not in the therapists way when working limbs of the patients. Rod diameters need to be suitable also for tetraplegics with little hand and finger functions, 4 cm to 5.5 cm diameter have been found practical.
Patients need to use the frame for balancing with help of their arms and initially most patients cannot do without. However, pulling and thus transferring body weight onto the frame is strongly discouraged, since it provides additional help and might prevent full loading of the limb. There are

therapists who – to avoid this help – do not allow the patient to touch the frame at all; however, they need to have an extra therapist to give additional help for controlling posture and the lateral swing from the back.

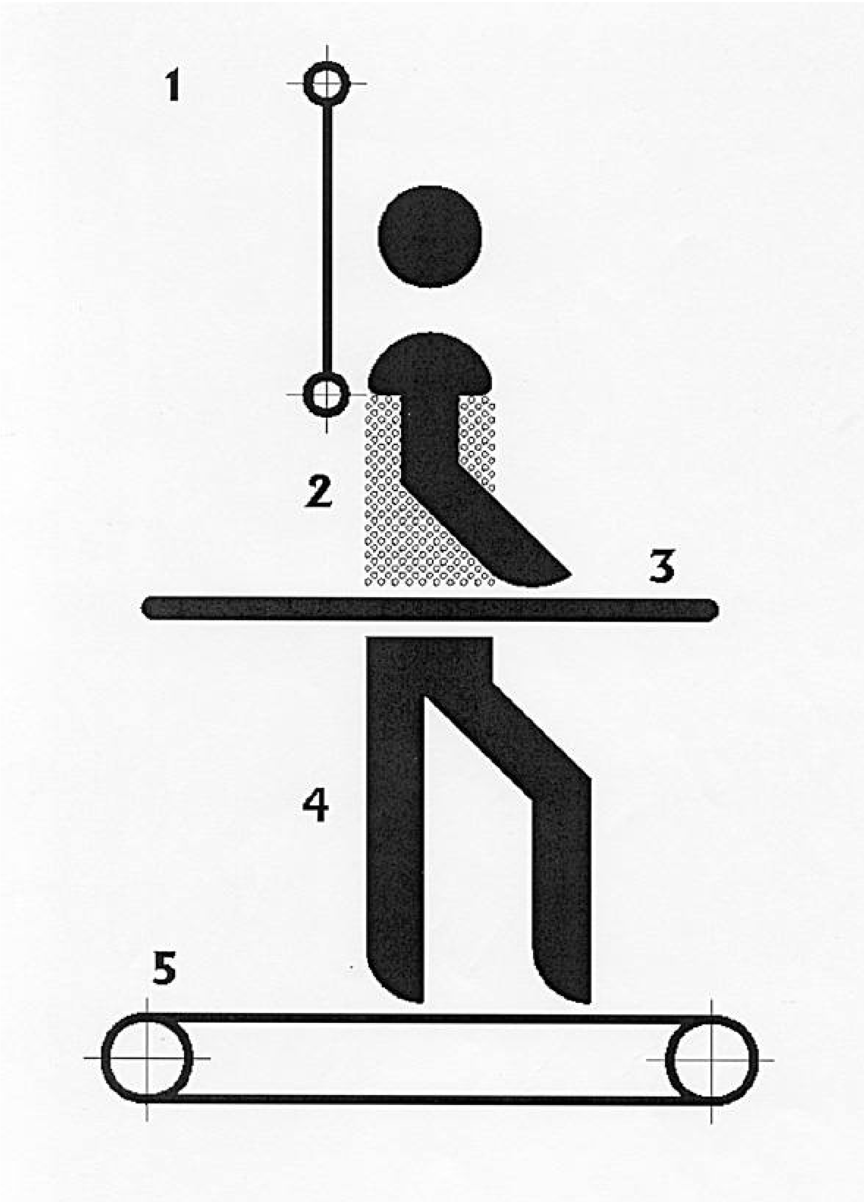

Fig. 1 Schematic representation of equipment and principles of Laufband (LB) therapy. 1: Suspension system, 2: Harness, 3: Frame allowing use of arms for balance but not body weight support, 4: Knee is extended to allow full loading during stance phase, 5: Moving belt of treadmill (0.1 – some 4.0 kmh).

However, only few institutions if any can afford to have three therapists working on a patient simultaneously and it has not been shown to be as effective or even more effective than the patient using his arms.(see below). The frame needs to be constructed in a way to allow mounting of additional supporting devices for the patients. We found a simple but very effective device, two rubber bands, one in front one at the patient`s back, crossing on both sides. A disadvantage of bands is that they hinder arm swing; however, when arm swing is being attempted towards the end or at advanced stages of LB therapy, the bands usually are not in use any longer. It is important to have them in the correct height, running across mid pelvis. This is one reason why the frame must be adjustable in height. Don't put the bands into the lumbar lordosis (you will enhance lordosis) or below the pelvis (the patients will sit on it). You will be surprised how much stability you add to your patient when properly mounted. (For this reason with improvement of the patient, the bands eventually need to be taken away in the course of LB therapy.)

2.3 Suspension systems

Summary: For patients not capable of independent standing the "static system" is needed. This system can basically be used for all patients, and it is by far the simplest system in terms of handling and price. For finer tuning and endurance training of already ambulating patients, the dynamic systems have advantages

Only the "static system" and the "weight adjustable" system allow unsymmetrical body weight support which some find helpful for training of severe hemiplegic patients.

2.3.1 "Static system"("the original"): This was our first and is still our most used system. Regularly equipped with a pair of spring balances, a pair of pulleys and the harness, this set up theoretically might be a static system but practically is not. A static system in the true sense would not allow for the vertical and lateral movements our body performs during normal gait. In our system, the little yield of the spring balances under load as well as the movement of the body within the harness give sufficient freedom to allow the necessary vertical movements. There are three enormous advantages of this so-called "static system": It is its unbeatable simplicity in handling, allowing - as the only system up to now - to adjust body weight support during walking (by simply pulling the rope/s even with one hand so that the other hand of the therapist is still free to handle the patient's limb). The second superb feature of the system is in fact its inherent stiffness with little displacement when under load . This gives additional support to maintain up-right position of the rump in most severely paralyzed patients. Thisway, the system is most useful and actually necessary for patients not capable of standing or walking by themselves. Last not least there is an inherently low price which should not be higher than some 250 – 300 Euro including a metal mounting plate for fixation to the ceiling. In this setting the suspension can be mounted to the ceiling with about 290 cm as the minimum height of the room.

As with the other systems, the non-ambulating patients enter the treadmill with the wheel chair via a ramp, the harness is mounted and fixed and the patient is pulled into upright standing position with help of the pulleys (see accompanying film HARNESS on CD).

2.3.2 Dynamic systems: "Adjustable weights" . Physiotherapists in Basel had the idea to increase the vertical yield by loosening but basically maintaining the ropes of the static system and perform the actual body weight support with help of defined weights (e.g. bags filled with sand). The vertical yield is limited by the ropes of the static system and thisway a high degree of security is achieved; patients can first be mounted under the static system, subsequently weights are applied and the ropes loosened. However, patients who cannot stand and brain damaged patients might feel unsecured by the yield of the suspension. In such cases the static system should be used. At least theoretically inertia of the moved weights introduces some abrupt movements especially with fast stepping; apart from this, smooth walking is achieved. Change in body weight support needs loading or removing of sand bags which is less comfortable than pulling a rope in the static system (see above). Woodway company has built a system based on these ideas using an array of weights and metal springs.

2.3.3 Dynamic system: Pneumatic. We have so far tested a German made pneumatic system which bears a considerable amount of sophistication (CONNEX). Body weight support is pre-adjustable as percentage of body weight (which can be measured by the system). Also adjustable is the amount of allowable yield i.e. the distance a patient can sack before he is automatically pulled up again (which, of course, would interrupt walking). Thus the system is **of little use for patients who cannot stand**, but it has shown optimal for learning finer corrections and for endurance training under BWS of patients who can already walk independently. There are US American systems which have a similar principle but are somewhat less comfortable in handling. The price of such systems is relatively high.

2.4 The harness.

If a patient can already walk on the treadmill without body weight support and is capable of independent walking, the harness is uncritical and any model can be used to serve as (necessary) safety belt. (For safety reasons it is generally not allowed to walk on the Laufband without harness). The only problem then to consider is that the harness does not hinder the patient when walking, e.g. forces him into sitting position or blocks hip extension.

With patients who need much body weight support, the harness and its proper fit are of most critical importance. With these patients considerable amounts of weight support have to be applied especially when the patient is not capable of independent upright standing. Then the harness has to be mounted while the patient is sitting in the wheel chair. We have developed a harness which meets these requirements and will be described here in some detail. A film showing the principles of mounting the harness on differently disabled patients is included in the CD accompanying the manual (HARNESS).

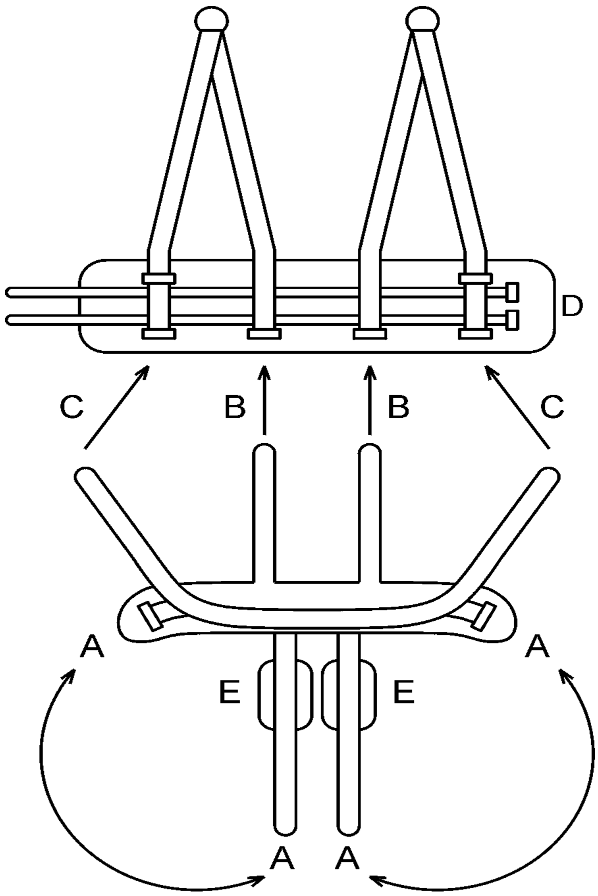

Fig.2 The harness. One important feature is the distribution of body weight onto several supporting points. Some weight is carried by *the pelvis_part* (A in Fig. 2) which is put at the lower edge of gluteus maximus (care has to be taken that the patient does not sit in the harness). Most of the weight is carried by the *leg straps* (E); it is important to pull them as deep down as possible and towards you before fixing them at the buckles: Obviously, straps running too steep cause pain and may jeopardize male genitals. Genitals need to be clearly free, and this needs to be positively confirmed by the patient (cave reduced sensibility) *and* the therapist. For further descriptions see film on the accompanying CD.The distance between pelvis and chest part is adjustable (B and C in Fig.2), thisway patients with a range of different body proportions can be accommodated. Also, it can be changed even under load (due to special *buckles* which have been developed for the parachutes of US army) e.g. to relieve hyperlordosis by tilting of the pelvis. However, too large distance causes a reduction in support for the pelvis/trunk and might allow too high mobility in the lumbar region.

2.4.1 Mounting of the harness is described in detail in the included film.

2.5 Laufband-shoes
In the beginning of LB therapy in particular with SCI persons, maximal sensory input from the sole of the feet is important. Apparently this addition of excitation helps spinal motor programs to reach threshold levels such that flexion and extension patterns may arise. For this purpose shoes with thin leather soles are very helpful. We use shoes made of a single piece of leather, which also provides a handle for therapists when setting the patient's limb.

The harness and the LB-shoes may currently be purchased from BONMED, Tel/FAX 0049 (0)228 634884, see www.bonmed.com

3 Handling of the patient. *General principles*

Here we first summarize the general handling of patients common to all diseases. Features special to a disease or severely deviating from the other conditions are dealt with separately in detail below.

3.1 Body weight support (BWS): Patients are allowed to hold on to the frame (lateral or in front) (No. 3 in Fig. 1) using their arms for balance, but are strongly discouraged to use them for body weight support. Body weight support (BWS) is set when the patient is in an upright position with knees fully extended.
Rule: ***BWS supplied via the harness is totally dependent on the needs or capability of the patient***. Thus in the first session several attempts may be necessary to find the right values. Chronic patients already ambulating or accustomed to standing upright often perform better with little or even without body weight support. Some patients feel insecure with BWS: In any case, BWS up to about 40 %, used especially in the initial phase, is gradually reduced in the course of therapy.
Also on a day to day basis, body weight support and speed of walking are set according to the momentary capacity of the patient which, however, does not vary too much from one day to the other (see below, "speed").

3.2 Therapist`s intervention
NOTE: ***Help given by the therapist for walking on the Laufband should be: As little as possible, as much as necessary.*** In other words, the principle is to have the patient use his (remaining) voluntary activity and merely help to maintain the flow of stepping. Note that patients tend to stop their own walking activity when the limb(s) is (are) moved by the therapist(s) (or mechanical devices, see below). Help basically depends on the defects the patient has and will include one or all joints of a limb. The goal is to achieve rhythmic and symmetric movement of both limbs for training on the LB. For this purpose not only limbs need to be controlled but also the rump.
In general the therapist has to avoid brisk grips when holding or moving a limb since this might by itself cause spasticity (as does the harness when not properly mounted, see below "Spasticity")

3.2.1 Help at single joints

Rump*:* By pulling and pushing (hands on the harness) the therapist sitting at the side may with one hand on the harness help shifting body weight onto the limb coming into stance phase. Help can also be given by an additional therapist – if available - standing behind the patient and working on the shoulder and/or rump/pelvis, trying to shift body weight and initiate counterrotation of the upper body.

Hip joint: Hip extension and thus upright position are maintained by the rubber bands or by the therapist pulling on the harness or a therapist behind the patient. Hip flexion can be aided by pushing the weight -relieved limb upwards (hand of therapist firmly holding the foot) or simply by moving the distal part of the upper thigh. Spastic patients often pull the pelvis up during attempted swing phase, stop this by pulling the pelvis down (hand on the harness) and encourage movement out of the hip joint. Verbal commands can include: "Try to climb a step" rather than just "Hip flexion".

Knee joint: If necessary break extensor spasticity at the end of stance by firmly pushing with one hand into the hollow of the knee with the other hand located at or above the ankle joint. Bring knee joint into full extension during stance, always encourage the patient verbally to try himself; tapping on the quadriceps above the knee might help. If not actively done, bring knee passively into full extension before mid stance and before under full load. Thisway the otherwise occurring "snapping" into full extension which in the long run might jeopardize ligaments is avoided; when muscles at the knee joint are too weak altogether (e.g. in flaccid paralysis like Guillain Barre syndrome) early knee hyperextension is unavoidable and must be done at heel strike. The command: *Put strength into your knee* sometimes helps *(Bringen Sie volle Kraft in das Knie*), or: *Stand on this limb (Stellen Sie sich auf dieses Bein*); after all stabilization needs co-contraction of Quadriceps and Hamstrings.
Always work with the patient's sleeves put up (or use shorts) so you can see active contraction of muscles, particularly Quadriceps and control for knee extension/hyperextension

Ankle joints*:* Encourage (verbally) or help/perform passively placement of the foot with attempted heel strike at the beginning of stance. If active knee extension is a problem, though not strictly physiological, the knee joint might already at heel strike be brought into full extension (see above). Correct for too much supination (pronation), but always ask the patient to perform actively or at least demand his help. A useful command to antagonize pronation at ankle joint and at the same time too much adduction at the hip joint is: "Walk on the outer edge of your foot, prepare this attempt already during preceding stance." To counteract supination, demand: "Heel strike and roll over digit I (large toe)".
Usually in the beginning ***only one command at a time can be realized by the patient.*** *Thus a second correction is worked out only after the first goal has been achieved.* This principle of goal oriented training on single joints is

helpful and necessary for SCI patients, hemiplegics, some brain injuries. Brain damaged patients with severe deficits in perception (Wahrnehmung) might be tried differently (Vreni Jung): Give a specific task, like: "Try to climb an (imaginary) step" (to get more hip flexion).

3.3 LB-Speed: Again: *Speed is adjusted according to the patients status and needs ("Most comfortable speed")***.** Apart from that, according to current experience, two speed ranges may be used with each patient even in one and the same session:

Low speed (**0.2– 1.0 km/h):** Gives patient enough time to use his voluntary activity and walk with as little as possible help by therapists. Forces/allows the patient: to have a long stance phase to properly load the limb, learn to carry weight and balance the whole body (particularly important and effective with hemiplegics). With low speed, single features can be focused on, like knee extension or active abduction in case of too high adductor tone, better placing of the foot etc.. You will be surprised how much is possible; however, only one feature can be trained at a time and previously learned ones need to be rehearsed. Even with severe paralysis on both limbs, *training at this speed can be done with a single (well trained) therapist* sitting at the side and controlling both limbs. This speed range resembles speed the patient might initially be capable of performing over ground. With improvement both, stepping on the treadmill and walking over-ground will be increased in speed.
High speed **(up to some 3 km/h):** Experience has it that limb setting is easier and also the patients feel that they have to put less effort into stepping with high speed. The reasons for this apparent facilitation are certainly complex, one being that the swinging limb gains a higher centrifugal force at high speed. Also, stance phase is shorter and the need for balancing the whole body eased. If one limb is already performing some independent stepping, a single therapist may handle the patient also at high speed. If both limbs are not capable of stepping, passive limb setting by two therapists – one at each limb – has to be performed. Rarely and not as a rule, a third therapist may - standing behind the patient – rotate the patient`s rump / shoulder / pelvis. Periods of training at high speed during a session will be maintained especially when there are obvious benefits, e.g. reduced spasticity, better rhythm of walking etc

There is a group in USA led by Susan Harkema, which mainly and immediately goes on even higher speeds (**ultra high speed, 4.5 km/h**) with SCI patients; as a consequence they regularly have to employ *three therapists* which makes the therapy unnecessarily expensive and handling much more tedious. There are not many institutions who will be able to afford this. Moreover, purely passive movement at such speeds is likely to involve forces which might harm the limbs of patients especially with flaccid paralysis and osteoporotic bones. Finally, the ultra high speed version will yet have to prove that it is similarly effective as compared to the less consuming regimen we and others have been employing. In fact, **only if it proofs largely superior** in achieving overground ambulation, the significantly higher effort might be warranted.

3.4 Do we need machines to move the limbs of our patients on the treadmill? Our current believe is ***no, no, possibly in the future***.
No, because all patients trained thisway stop using their own voluntary activity during the whole or part of the gait cycle. This violates one of the main principles (see above): Use as much and as intensively as possible your remaining activity and thereby enhance it. **Activity related motor learning will not happen with passive movements**. Elegant animal experiments are currently being performed by the Edgerton group in Los Angeles, which show precisely that this prediction is correct.

***No*,** because nothing can be better in setting, tilting, dorsiflexing etc a limb and can react immediately if the gait does not develop properly than a skilled therapist. An impractical number of sensors on each joint would be needed to report – very fast - the emerging movement, the computing device calculate the deviation and several motors correct the movement via a feedback loop. The active component contributed or anticipated by the patient (which might then be pre-settable) needs to be worked in.

***Possibly in the future*:** Interesting features might evolve from such presetting (see above), if they allow the patient to realize his achieved or expected active contribution. Thisway a feedback type of setting is created, which when properly set, demands active movement by the patient which can be graded according to the patients momentary conditions or the state of the training schedule.
Most recent models of the **Locomat** (Colombo ETH Zürich, 2005) include some feedback features. However, when we recently (Jan. 2005) tested the device together with a mid thoracic completely paralyzed girl which had been using it for a few weeks, we realized that she had learned to trick the robot: By using her latissimus dorsi muscles she moved her pelvis enough for the machine to assume active hip flexion. And it had taken a considerable amount of time to mount the robot, too much for everyday use. One argument pro robot we often heard (and might in fact be a major reason why it was purchased by some rehab institutions) is that “patients like it”. An unusual level of decision making indeed, if it is not accompanied by superior progress in walking capability (which there is no published evidence for up till today, July 2005). The **Step Trainer** introduced by Hesse has a similar problem: While during stance phase active work by the patient is demanded, swing phase happens passively lest the patient is continually reminded to actively contribute.

3.5 Spasticity
***Spasticity*:** Often higher on Mondays, with infections of the bladder and injuries at the toes or elsewhere. Apart from these specific cases, spasticity usually is reduced in the course of a training session . Only rarely the opposite happens, in this case check the position of the harness: Ease a too

high pressure possibly put on the adductors. Otherwise stop training for this day and try to find out the cause for the enhanced spasticity.

Clonus*:* When clonus in the ankle and/or knee joints develops this is often a sign of the patient getting tired and loosing attention. Try to have the patient put more weight onto the limb early in stance; calm him down, try reduced speed. Help with knee extension, perform already during heel strike. If all fails take a short break. It is the quality of walking which counts, not primarily quantity of movement however performed.

Antispastic medication: Antispastic drugs may reduce voluntary activity as well, thus we try to avoid them as much as possible. When reducing the amount taken (gradually over weeks), some problems during the night might arise with spastic movements (with the blankets being delivered to the ground). Chronic patients who are used to take the antispastic drugs often realize an increase in voluntary force upon withdrawing and such patients will tolerate the nightly troubles. It is worse with acute patients who don't have these experience. However, we don't in all patients reduce antispastic drugs to zero, usually it is a matter of titration between reduction in voluntary activity and too high spasticity.

4 HANDLING OF THE PATIENTS. SPECIFIC DISEASES

4.1 Incomplete spinal cord damage: Spastic paretic paralysis

In spastic paretic patients the ***"rules of spinal locomotion***", derived from animal experiments and found useful in human (Wernig & Müller, 1992; Wernig et al., 1995) need to be applied. These include: Full extension of knee and hip joint with full loading of this limb during stance phase, physiological hyperextension of the hip joint at the end of stance phase, deloading of this limb and shifting of body weight onto the contralateral limb. Additional afferent stimulation, like skin irritation by pinching or pressing or electrical stimulation may be effective in inducing or *facilitating flexion and extension movements*. The optimal positions need to be found by trying; often for pinching/pressing the foot or digit I, the lower thigh or the back of the knee joint, for the stimulating electrode a site above the knee is effective. At this stage special shoes with thin leather soles are used for the same purpose often with considerable success.

4.2. Cauda, Cauda-Conus lesions. Flaccid paralyses.

In the acute state the rule is to *enable active movements by maximally reducing the load.* Remember that in these diseases the connections between spinal cord and muscles (and the afferents vice versa) are disrupted. Spontaneous nerve regeneration occurs to some degree, but this takes time and there is no convincing evidence that it can be accelerated by exercise or drugs. Axons grow about 1 – 4 mm per day, thus for reaching muscles and skin in the foot (say 1000 mm away from the site of injury) they

would thus take 250 to 1000 days.
Keep in mind that those parts of the muscles which remained innervated or are first re-innervated are already doing the work of the whole muscle and must not be overworked: From animal experiments we know that eccentrically worked muscles which are stretched while contracted, may undergo focal muscle fiber damage (which is repaired again but we don't know about long term effects).

We do not train acute patients who are still completely paralyzed after cauda or cauda-conus lesion. With incomplete acute patients you may start early for psychological reasons, but postpone start of *daily* LB therapy and start with 1 –2 –3 times a week. A minimum voluntary activity for start would be: Hip flexion 1-2, knee extension: 2; BWS 30-50 %, and it is important to use **the "static" suspension system** which provides more support. Due to spontaneous regeneration of axons, improvements may go on for 1-2 years (see above). Still, the first goal of therapy is to make the patient capable of walking (at least for a short distance with e.g. two canes). For those who cannot achieve ambulating during the first stay in the clinic an interval regimen might be adequate: Resume intensive rehabilitation after a longer domestic period (1 year from the event) . According to current knowledge we cannot influence speed of peripheral regeneration but also cannot keep the patient in the clinic for such long periods of time till regeneration is completed.

4.3. GBS (Guillain-Barre Syndrome).

Training on the treadmill starts as soon as any voluntary activity in the lower limbs develops. This usually happens at a time when over ground walking is practically not possible, also due to paralysis of rump muscles. The initial amount of BWS is high (40-50%), therapist intervention depends on the needs of the patient and it might suffice to have only 2-3 sessions per week. Even if recovery is slow and often incomplete or remains poor, we eventually start walking patients over ground. If necessary, compensatory mechanisms are entrained like "locked" knee joints (full extension with weak quadriceps muscles) with flexion in the hip joints (thus only limited upright position), some body weight put via the arms on the rollator. Thisway only small steps are possible since the pelvis must not be brought before the vertical axis running through the shoulder and ankle joints in order to avoid unlocking of the knee joints. In fact, training of the best position of the pelvis should be optimized. Stair case walking with such patients usually is not possible, but has been achieved in some (supported by one person). One may argue that such unphysiological walking jeopardizes joints and ligaments. This is basically true, however, the amount of walking performed thisway is bound to be very limited and thus not dramatically harmful. On the other hand these few steps which can be made without foreign help are of enormous practical (and psychological) importance for the patient.
In summary: GBS patients can start locomotor training with suspension on the LB much earlier and less stressful for all involved. Apart from a possible earlier recovery of walking, there are considerable trophic (e.g. circulation) and obvious psychologic effects. For those with only poor recovery, strategies may be worked out which allow some limited an aided walking.

4.4 HEMIPLEGIA

4.4.1 Help by therapists: Always assess the amount of voluntary activity in the paretic limb so you know what you may demand from the patient. At the start of LB therapy there is to decide on the initial regimen:

4.4.1.1 Which leg to work first

If the ***less affected limb*** does not step properly by itself and the patient does not properly load it, i.e. does not rely on it, first train this limb. Have the patient concentrate on this limb and "actively" work with it till it carries load etc. During all this time take care of the other leg by passively moving it. During this period either two therapists have to work the patient, if only little help is needed for the less affected limb, one therapist can manage. As soon as the less affected limb moves more or less correctly (which usually happens within a few or even a single session), focus is laid on the paretic limb.

Paretic limb: Depending on the degree of paralysis, move passively till some tonus is built up during stance phase.Tapping might help to increase tone. As soon as voluntary activity starts, it must be verbally encouraged. It is important to have the active phase done by the patient and the therapist has to learn when to step in with her/his own help in due time to produce a smooth and increasingly symmetric stride. If voluntary activity can be elicited in resting position (while sitting), you know what you can demand. To increase stance length of the paretic limb, have the patient perform **excessive and prolonged hip flexion with the non-paretic contralateral limb** to enforce prolonged stance phase of the affected limb. "Make yourself large" is a verbal command quite often helpful. Support heel strike at the beginning of stance, also support knee extension and hip flexion (similar to SCI patients, see above), but always with demanding maximal initial effort from the patient. In case of strong extensor tonus which hinders hip flexion, try to break this by inward rotating the tibia at the end of stance (you will be surprised how effective this can be).

The commonly present circumduction of the affected limb may be avoided by the therapist pulling down on the harness and at the same time with the other hand support hip flexion.

Facilitation of rump, pelvis and limbs according to BOBATH principles may be applied by a second/third therapist standing behind the patient during LB locomotion.

Patients with deficits in perception (Wahrnehmungsstörungen) might react better to "indirect" than to "direct" commands: Verbal commands like "hip flexion now" or "extend the knee" might be replaced by commands like: "Try to climb a step" (for hip flexion), "make yourself larger", "grow" (during stance phase) etc..

When the patient mounted in the harness with symmetric suspension still looks very unsymmetrical, one might try asymmetric suspension (not more than 3-5 kg difference between left and right).

As described for SCI, the therapist sitting at the side may shift body weight by pulling/pushing the patient onto the paretic limb with her hand on the harness. Help for loading the paretic limb may come from the patient if he is able to push himself over to the affected side with his laterally (on the frame) positioned arm.

4.4.1.2 Paretic arm: When possible, symmetric placement of both arms on the frame (sides or front) is the first choice, but check that tonus in the paretic arm does not go up significantly. If this setting is not practical (flaccid arm or too high tonus), the arm may be put in a sling or on a board mounted in front of the patient or may hang down.

4.4.1.3 Flaccid shoulder: May be stabilized by rubber bands (rucksack bandage) with KLETT fixation. The aim is to have a better symmetry in the shoulder girdle.

4.4.1.4 Pushers*:* Have non-affected arm brought over the head of the patient to straighten his rump and become more symmetric (but patient must not pull himself up): This might help to maintain/establish symmetry with pushers when the patient pushes over to the affected side.

Quite effective**:** Enhance and prolong swing phase in the non-affected side (see above).

4.4.2 Speed: As with SCI patients two speed ranges should be applied (see above): *Low speed* with as little help by the therapists as possible to allow a long stance phase and sufficient time to shift body weight. *High speed (up to about 1.5 km/h)*: 2 – 3 therapists if necessary, one shifting body weight from behind, two for setting limbs. However, make sure that the patient maintains his active effort to move limbs and does not quit doing so.

4.5 Brain damaged persons

We have over the years been treating hemi - and tetraparetic as well as ataxic BDP patients. The most prevailing experience is that each patient has to be tried whether or not he can profit from LB therapy. For operational reasons we may dissociate two groups of patients: ***Patients with and patients without voluntary limb movement.***

4.5.1 Patients without active lower limb movements: The therapeutic effect of patients passively moving on the laufband is to apply strong awakening effects (stronger than standing). Apart from that trophic effects on circulation, bone and muscles may be discussed.

4.5.2 Patients with (some) active limb movements: Therapeutic goal depends strongly on the patients capability and thus reaches from learning free/aided standing to aided/free walking. For all these patients the help given by the therapists is the same described above for hemiplegics.

4.5.3 Ataxia: We are still in an experimental stage trying different approaches. with ataxic patients. The rigid suspension system (without significant body weight support) and the crossed rubber bands are obvious supports for postural control during walking. The therapist verbally reminds the patient to actively control limb movement (which often is successful on the Laufband) and may hold back the ataxic limb during swing. For less handicaped patients, sessions of **reduced help** are included: Remove crossed rubber bands, have patient hold one holm of the frame only or do not allow the use of arms at all a.s.o.. *Secured walking on the laufband without visual feedback control (closed eyes) with and without arm support might challenge and force training of the proprioceptive system as well as other compensatory mechanisms.* In most cases it has not been possible yet to transfer successful corrections achieved on the laufband to walking over ground to a satisfactory degree, obviously the time span of a few weeks is not sufficient in these cases and longer periods on an outpatient basis are currently investigated.

Brain damaged patients who dont reach stepping capabilities within the first major attempt (during postacute or later hospitalization) might still try on a regular basis (e.g. once a week) or during one longer period (weeks with daily training) per year. This could be done in their domestic surrounding with trained outdoor therapists or in local facilities. Obviously with such severe deficits a single period of therapy is bound to be less effective. A similar case should be made with severe tetraplegics who have barely reached some locomotor capability during the first postacute rehabilitation or have arm paralyses hindering the use of canes or other devices: Since continual exercise of upright walking is the best therapy, and they cannot do it over ground independently, regular access to a treadmill (daily or intermittently, see above) have shown to be helpful (Hicks et al., 2005).

4.6 Multiple sclerosis

LB therapy has been effective in improving the current motor capability of MS patients in our clinic. The precise regimen of therapy depends on the symptoms the patient shows. In general we are less demanding e.g. dont walk with high speed but stick to the patient`s over ground speed. Rules of spinal locomotion are often effective.

4.7 Orthopedic patients and others

With fresh surgery after e.g. placement of artificial joints when full weight bearing is not allowed, the harness and BWS are helpful. In fact whenever the patient has suffered a change in his periphery (limb problems including amputation) or is too weak to walk by himself or with some help, the suspension system and the moving band of the treadmill will be helpful.

5 SELECTION OF PATIENTS

5.1 Spinal cord damaged persons.

Our current criteria for selecting **chronic SCI** spastic paretic patients to enter LB therapy are: presence of some voluntary muscle activity in the lower limbs, particularly the quadriceps femoris; mobility of joints; no severe muscle shortenings, and no skin ulceration or other severe diseases. Missing voluntary hip flexion can be tolerated initially, especially when it can be elicited by facilitating measures in the initial testing on the treadmill (see above). With all patients we thoroughly discuss the possible therapeutic goals based on the results presented and referred to in this report. Thus for patients with low amounts of voluntary activity in their legs and with additional arm and/or rump paralyses hindering the use of crutches or rollators, gain of independent walking is an unlikely outcome, while walking with help is still a realistic outcome . In severely paralyzed paraplegics, even with the use of arms, the possible entraining of stepping may allow limited walking over short distances only. However, aided walking with the help of another person, including or not including stair case climbing, or independent walking for even a few steps only, would be of advantage in daily life, and are thus acceptable therapeutic goals. The leading principle may thus be to ***enable each patient to reach his/her highest level of individual walking capability by intensive and aided training of upright walking. In general it is important to stress that LB therapy is always combined with training of independent standing up from the wheel chair as well as sitting down and the manoevers connected to this, like curving with the rollator on narrow space, walking backwards for a few steps and so on***.

Criteria for selecting **acute patients** are basically similar as described for chronic patients. Taking into account spontaneous recovery continuing for several weeks after spinal cord damage, LB therapy is started as soon as some voluntary movements in lower limbs appears rather than waiting for spontaneous recovery of motor functions to plateau. In acute patients who have suffered trauma of the spinal column, the safety of the procedure has to be assured by the orthopedic surgeon. With surgical stabilization of the vertebral column (Harms, 1992), the start of walking exercise was usually allowed within a few weeks after trauma (for details see Wernig et al., 1995). Also with acutely spinal cord lesioned patients, LB therapy was usually performed for 5 days a week from the very beginning, which was well tolerated.

The cause of spinal cord injury is not an important criterium but the degree of flaccid paralysis due to cell loss in myelitis or vascular disorders can be a limiting factor. In our collection of patients trauma was most frequent, followed by non-progressive myelitis, tumors, vascular disorders and other causes.

5.2 Flaccid paralyses:

There are no particular restrictions for patients suffering from cauda and cauda-conus lesion and GBS. LB training can start as soon as some voluntary muscle activity is present. However, keep in mind that the connections between spinal cord and muscles are missing and those parts of the muscles innervated do already more work than usual. Because of slow regeneration, often intermittent therapy is the choice (see above).

5.3 Hemiplegia:

As with SCI patients our strategy is to focus on ***non-ambulating hemiplegics***, pushers and neglect patients and try to help them become independent walkers or make them walk with help. Already ambulating hemiplegics might profit from LB therapy too, but the effective gain is bound to be less and might be achieved – though with somewhat higher efforts from therapists side - by intensive walking overground as well. This is different for the **non-ambulating hemiplegic**s: The amount of effort needed for overground walking (number of therapists necessary to walk the patient, physical effort by the therapists, security of the procedure and the practicability of correcting severe deficits like pushing and neglect) is bound to be in-comparably higher than on the treadmill (assuming a suitable treadmill; but see above and Nilsson et al. 2001) with the securing suspension system and body weight support. Therefore, with LB therapy, more and especially more older patients will have access to training of walking and will thus benefit from the new paradigm in rehabilitation of locomotion: Activity related learning, i.e. to train upright walking as intensive as possible. On the other hand, LB therapy is no magic and the proper locomotor training can of course be done over ground – though with much more effort. In fact, one of our paraplegic patients who walks for some 40 meters over ground without help but has extremely little voluntary muscle activity in his lower limbs, has successfully trained himself over ground (Wernig&Müller, 1991; 1992). Interestingly, in recent controlled clinical trials which compare LB therapy with “conventional” physiotherapy or other approaches (eg Nilsson et al., 2001; Kosak et al., 2000), the control groups are made to perform intensive training of locomotion over ground with good success . Even then it appears that for non-ambulating hemiplegics LB therapy is still considerably more effective (Kosak et al., 2000). See also 7.1.3

In times of reduced allowance for rehabilitation efforts it will be deciding **how much can be achieved in the shortest possible period of time with the lowest possible amount of man power.**

A recent study (Copenhagen Stroke Study) shows that regaining of walking under conventional physiotherapy either occurs early, within weeks after the event or hardly ever again (Jorgensen et al., 1995). We too see remarkable improvements within short periods of time under LB therapy even with severely paralyzed hemiplegics; however, also with chronic patients we would try and see what happens within a few sessions …..

There is converging information from several clinics including our own that with LB therapy we might have a break through with the severely paralyzed non-ambulating hemiparetic patients.

One might argue that severely paralyzed hemiplegics (or any other person with severe locomotor deficits) are better off in the wheel chair

rather than walking for some distance with or without help from other persons. We feel that alone the easier handling of patients who can leave the wheel chair, be it only for a few steps or for standing up, makes the effort worth while. In addition we may assume positive effects on circulation, muscles and bones and prevention of skin ulceration. And we have seen how much it may mean to individuals to be capable of being upright and perform steps.

Thus, as long as other criteria are not available, all hemiparetic persons non-ambulating, acute and chronic might be tried with LB therapy, much can be seen within a few sessions already.

5.4 Brain damage

With brain damaged patients the goal of working on the treadmill is not always to achieve independent walking (see above, 4.). Depending on the therapeutic goal (awakening reactions, standing, walking or simply trophic effects on muscle, bones and vascular system) different criteria apply.
If standing/walking is the immediate aim, some voluntary activity in the lower limbs needs to be present. Obviously, every muscle shortening is an obstacle, as are severe emotional and vegetative instabilities. Even more so than with other diseases, trying is the best way to proceed. One information can be passed on: While usually progress is slow or missing, “awakening” effects with start of stepping often within a single session, have been observed; this led from no stepping to independent walking or walking with little help.

5.5 Multiple sclerosis

Every patient who is still capable of walking on the LB with little help should be tried.

5.6 Orthopedic patients

The orthopedic surgeon will have to define when and with how much of BWS patients may walk on the treadmill. Note that patients with spine injuries/surgery often have neurological deficits as well.

6. PROTOCOLS OF LB THERAPY

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NOTE: It has been our principle that LB therapy replaces other physiotherapy (e.g. standing or walking in parallel bars) and does not consume additional therapy time or personal. This can be achieved with some skill in organization and sufficient therapists knowledgeable in performing LB therapy. From a practical and economical point of view, it is advisable for larger institutions to have two or three laufband set-ups running in parallel in a single room; this way a single therapist can often operate and supervise two advanced or less paralyzed patients at the same time.

6.1 In - patient therapy: LB therapy performed in the hospital during regular indoor rehabilitation, usually only a single, less often two LB session per day for periods of 30 minutes during 5 days per week can be performed. Once a week walking over ground is attempted, even if massive help by two therapists for balance and weight support are necessary. As soon as a few steps can be made with moderate help only, walking over ground is performed daily during this therapy unit of 30 minutes, usually immediately before or following training on the treadmill (walk from and to wheel chair and treadmill). With further improvement, walking over ground increasingly replaces walking on the treadmill which, however, is often maintained to train for endurance and speed. Stair case climbing may be attempted surprisingly early after gain of stepping capability over ground and can be achieved even in severely paralyzed patients (Wernig et al., 1995). When walking over ground, the same "rules of spinal locomotion" need to be applied; for practical reasons, therefore, walking is initially only allowed during the LB therapy session and under the guidance of therapists specially trained in LB therapy. It is an important goal to teach patients to generally maintain these rules during all walking activities. Apart from LB therapy, all patients participate in the regular conventional rehabilitation program for indoor patients, which includes training of functions for every day living, sports and other activities aimed to enhance muscle strength and mobility. In general, patients who took part in the program for LB therapy obtain the same total amount of individual and other therapy as all other indoor patients: Currently this amounts to 2 units individual therapy for paraplegics, 3 units for tetraplegics and brain injuries (the latter with 2 therapists).

6.2 Out - patient therapy: LB therapy has been successfully applied also to outdoor patients. Here the regimen adopted is: 2-3 LB sessions each for 30 minutes, with breaks of at least 30 minutes in-between. During the breaks the patients may lay down, drink and eat or do some extra exercise like stretching. Thisway the patients stay at the institution for 2 - 3 hours on a single day.

7. APPENDIX I: Assessments of motor capability in SCI and stroke patients

In order to be sure of progress in motor rehabilitation, video documentation and regular measurements are helpful and they are a must for any scientific work to be done. In the latter case it is also important to have comparable assessments.

7.1 SCI. In **spinal cord injury** the **ASIA scores** have been in use internationally. However, for measuring progress in motor rehabilitation in a realistic way ASIA scores are impractical. Their classification is A=motor and sensory complete, B=motor complete, sensory maintained, C=sensory and motor incomplete with less than half of the segmental key muscles with values of 3 and above and D= more than half of the segmental key muscles with values of 3 or more. In terms of walking we have a very unlucky mixture of the function of key muscles important for defining a segment but not necessarily important for walking; thus in C and D there can be patients capable of walking as well as not capable of walking. The same is true to an even higher degree for the ASIA muscle score: segmental key muscles rather than muscles relevant for walking are being evaluated.

FRANKEL scale is very practical since it gives a quick and simple functional assessment, but is not sensitive enough to measure progress in walking either,

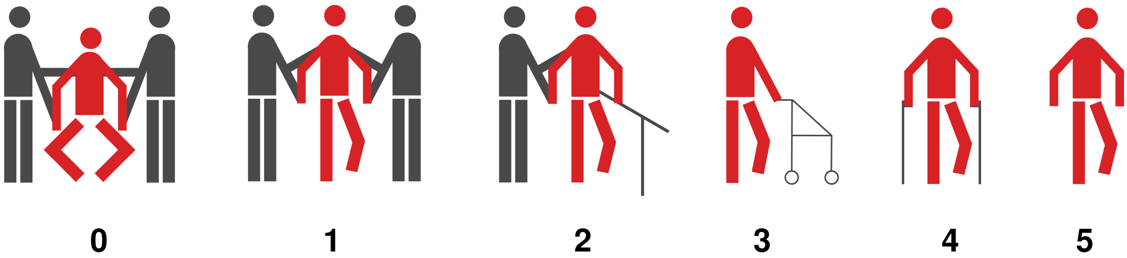
FIM does not even distinguish between locomotion with and without wheel chair.

For these reasons and to adopt to the progress in walking we may achieve with LB therapy we have suggested 2 new assessments.
Functional Classes (0 to 5; Wernig-scale see Hicks et al 2005**)** which cover the whole range of locomotion (not capable of walking even with help of 2 therapists to free walking without devices) and dissociates between patients who are independent or dependent on other persons for walking. Validity of the test is obvious (test walking by walking performance), reliability is high (0.84, Maegele et al. 2002)
For muscle function we propose a **Cumulated Muscle Index (CMI EU muscle).**

7.1.1 Functional Classes (0 – 5) for locomotion: Minimum distance: 5 m

Dependent: 0: not capable of walking even with help from two therapists; 1: capable of walking with moderate help from 2 therapists; 2: walking at the railing with one therapist. **Independent**: 3: rollator or reciprocal frame; 4: Regular crutches; 5: without devices. The classes graphically:

Functional Classes SCI:



7.1.2 . The amount of ***voluntary muscle activity*** may be evaluated from the force and range of single joint movements evokable upon verbal command in defined resting positions (horizontal and sitting), avoiding readily evokable spastic extension or flexion patterns (**Kendall *et al.*,1971**). Under these rating conditions, values were defined as follows: 0=no muscle contraction visible or palpable; 1=muscle contraction visible and/or palpable, no movement of limbs; 2=some joint angle movement with passive support by the therapist balancing gravity; 3=full range of joint angle movement against gravity; 4=full movement plus maintenance of position against moderate applied resistance; 5=like 4, against maximal applied resistance. Values in between were allowed and valued as 1/2 points. **Cumulated Muscle Index:** Glutaeus maximus, Glut.med. and min., Iliopsoas, Sartorius, Quadriceps fem., Ischiocrurales, Tibials ant., Triceps surae.

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7.1.3 Assessments for clinical scientific trials

For a study with different interventions to improve locomotion in SCI persons to compare, the following schedule might be practical.

ASSESSMENTS for SCI persons

Every 2 weeks till end of therapy and at 6, 12 months:

1. Walking capability: FIM-walking (not locomotion or stairs), EU-walking (Functional Classes, Wernig et al. 1995)
2. Muscle activity scores for lower limbs: EU-muscle (8 functionally important lower limb muscles per side) . ASIA –muscle (key muscles of lower limbs only; as long as the score is in use and EU-muscle is not yet in general use, both should be done)
3. Ashworth Spasticity Scale, Antispastic medication

At the beginning and end of therapy and at 6 and 12 months:

4. Endurance: Distance walked in 6 min
5. Time to walk 10 m

PLEASE NOTE: Definition of the treatment given to the **control group** is obviously important. It appears that more and more researchers (e.g. Nilsson et al 2001; Kosak et al 2000) choose to give the control group a very intensive locomotor training, which was not done a few years ago, when non-ambulating patients were rather discouraged to consider walking as a primary goal rather than to try the borders. We realise that this shift in attitude very much comforts our new dogma: **If one wants to walk again one needs to exercise upright walking** (Wernig et al 1991, 1992). If our previous work has contributed to this dramatic shift in therapeutic approach, much has already been achieved. However, it blurs the definitions of such trials. Now not any longer intensive upright walking (on the treadmill) is compared to "conventional" physiotherapy (with limited stress on training of walking for non-ambulating patients), but **different ways to train upright walking**. This shift then necessarily causes a shift in the scientific questions to ask from a trial. Rather than asking whether LB therapy is superior to conventional physiotherapy, the question now is for the **efficacy** of the therapeutic approach: This includes therapy time, amount of effort therapists need to put into walking the patient (walking on the treadmill with the patient secured by a harness and body weight supported versus walking over ground also with non-ambulating patients), number of therapists necessary to support the training, time to reach independent ambulating and so on.

7.2 Hemiplegia

For hemiplegia the Functional Ambulation Category (FAC) has been convincing for classification of locomotion, the Motricity Index may be used to assess muscle function

7.2.1 Functional Ambulation Category (FAC): Holden et al 1984, Phys Ther 64, 35-40.

0: Patient cannot walk, or needs help from 2 or more persons
1: Patients needs firm continuous support from 1 person who helps carrying weight and with balance
2: Patient needs continuous or intermittent support of one person to help with balance and coordination.
3: Patient requires verbal supervision or stand-by help from one person without physical contact
4: Patient can walk independently on level ground, but requires help on stairs, slopes or uneven surfaces
5: Patient can walk independently anywhere

7.2.2 Motricity Index to test motor strength (both sides)(Demeurisse et al 1980, Eur Neurol 19, 382-389.): Pinch grip, elbow flexion, shoulder abductíon, ankle dorsiflexion, knee extension, hip flexion.

7.2.3 Scientific trial

In preparing a European multicenter trial to study the effect of LB therapy, the following general assessments have been suggested for hemiparetic persons.

Assessments (including Video):

1. FAC every week during period of therapy; 6, 12 months.
2. Rivermead Motor Score Assessment (**Gross function, Leg and Trunk**) at the end of therapy; 6, 12 months.
3. Walking speed tested over 10 m, at the end of intervention; 6, 12 months.
4. Endurance test: Measure distance walked within 6 min. At the end of intervention; 6, 12 months.

For later stratification:

1. Scand. Stroke Scale: at the time of randomization.
2. CT topographic assessment
3. CT-small vessel disease (Lacunar Infarct) /CT-large vessel disease (Territorial Infarct)/CT normal
4. Motricity Index to test motor strength (both sides)(Demeurisse et al 1980, Eur Neurol 19, 382-389.): Pinch grip, elbow flexion, shoulder abductíon, ankle dorsiflexion, knee extension, hip flexion. At the beginning and end of therapy period.
5. Reduction in proprioception (tested manually at digit 1) every 2 weeks
6. Balance Scale (Bohannon). Every week
7. Ability to maintain a vertical position while sitting unsupported (inclination of trunk measured in sagittal and lateral directions). Every 2 weeks during

therapy.

8. Zung Self-rating Depression Scale (Zung, Arch Gen Psych 1965, 12, 63-70). Every 2 weeks
9. Total Comorbidity (respiratory, heart and circulation problems)

8. APPENDIX II. References and suggested reading

LB therapy is a classical example for the development of new therapies in medicine. In the beginning there were basic researchers working in animal research discovering spinal motor centers for locomotion in lower vertebrates. Another typical event is the fact that spinal locomotion in the cat was found 100 years ago, but no consequences were drawn for the human SCI patient. This is hard to understand since infant stepping always told us that also the human spinal cord works with such motor programs. Some 20 – 30 years ago the rules of spinal locomotion were found and it was clear that proprioceptive key inputs were important to maintain the flow of correct efferent signals which all melted into one enormous event: Walking. Among the many researchers who contributed to this knowledge some names to remember are Grillner, Lundberg, Shik, Hultborn... However, it took another amazing finding which finally ignatated the spark for the transfere into therapy for humans: The isolated spinal cord can learn, found Edgerton in Los Angeles and Rossignol in Montreal. The first attempts with paraplegics were done independently in Canada by Barbeau and our group in Germany. It was 1995 that the first and so far only controlled study involving some 150 SCI patients appeard in print. Soon LB therapy spread to hemiplegia and other diseases with motor deficits.
The references below provide original information on these aspects, additional references can be taken from the quotations. They will give a good start for those among you who want to go the roots but also additional practical knowledge.

Barbeau, H. and Blunt, R. (1991) A novel interactive locomotor approach using body weight support to retrain gate in spastic paretic subjects. In A. Wernig (Ed.), *Plasticity of Motorneuronal Connections. Restorative Neurology,* Vol. 5, Elsevier, Amsterdam, pp. 461-474.

Barbeau, H. and Rossignol, S. (1987) Recovery of locomotion after chronic spinalization in the adult cat. *Brain Res.*, 412: 844-895.

Dobkin, B.H., Harkema, S.J., Requejo, P.S. and Edgerton, V.R. (1995) Modulation of locomotor-like EMG activity in subjects with complete and incomplete spinal cord injury. *J. Neurorehab.,* 9: 183-190.

Edgerton, V.R., Roy, R. R., Hodgson, J.A., Gregor, R.J. and de Guzman, C.P. (1991) Recovery of full weight-supporting locomotion of the hindlimbs after complete thoracic spinalization of adult and neonatal cats. In A. Wernig (Ed.), *Plasticity of Motoneuronal Connections. Restorative Neurology,* Vol. 5, Elsevier, Amsterdam, pp. 405-418.

Eidelberg, E., Walden, J.G. and Nguyen, L.H. (1981) Locomotor control in macaque monkeys. *Brain,* 104, 647-663.

Gossard, J.P. and Hultborn, H. (1991) On the organization of spinal rhythm generation in locomotion. In A. Wernig (Ed*.), Plasticity of Motorneuronal Connections. Restorative Neurology,* Vol. 5, Elsevier, Amsterdam, pp. 385-404.

Grillner, S. (1981) Control of locomotion in bipeds, tetrapods, and fish. In J. E. Brookhart, V. B. Mountcastle, V. B. Brooks and S. R. Geiger (Eds.), *Handbook of Physiology*, Section 1, Vol. 2, Part 2, American Physiological Society, Bethesda, MD, pp. 1127-1236.

Harkema, S.J., Requejo, P.S., Hurley, S.L., Patel, U.K., Dobkin, B.H. and Edgerton, V.R. (1997) Human lumbosacral spinal cord interprets loading during stepping. *J. Neurophysiol.,* 77: 797-811.

Harms, J. (1992) Screw-threaded rod system in spinal fusion surgery. *Spine: State of the Art Reviews,* 6: 541-575.

Hesse, S.T., Bertelt, C., Schaffrin, A., Malezik, M. and Mauritz, K.H. (1994) Restoration of gait in nonambulatory hemiparetic patients by treadmill training with partial body weight support. *Arch. Phys. Med. Rehabil.,* 75: 1087-1093.

Jorgensen H.S., Nakayama H., Raaschou H.O. and Olson T.S.. Recovery of walking function in stroke patients: The Copenhagen stroke study. Arch Phys Med Rehabil 78, 27-32, 1995.

Kendall, H.O., Kendall, F.P. and Wadsworth, G.E. (1971) *Muscles - Testing and Function*, Williams and Wilkins, Amsterdam.

Kosak MC, Reding MJ (2000). Comparison of partial body weight-supported treadmill gait training versus aggressive bracing assisted walking post stroke.. *Neurorehabil Neural Repair 2000;14(1):13-19*

Lovely, R.G., Gregor, R.J., Roy, R.R. and Edgerton V.R. (1986) Effects of training on the recovery of full weight-bearing stepping in the spinal adult cat. *Exp. Neurol.,* 92: 421-435.

Maegele, M., Müller, S., Wernig, A., Edgerton, R. and Harkema, S. (2002). *J Neurotrauma 19, 1217-29,.*

Nilsson et al (2001). Walking training of patients with hemiparesis at an early stage after stroke: a comparison of walking training on a treadmill with body weight support and walking training on the ground. *Clin Rehabil 2001 Oct;15(5):515-27.*

Richards, C. L., Malouin, F., Wood-Dauphinee, S., Bouchard, J.P. and Brunet, D. (1993) Task specific physical therapy for optimization of gait recovery in acute stroke patients. *Arch. Phys. Med. Rehabil,* 74: 612-620.

Visintin, M. and Barbeau, H. (1989) The effects of body weight support on the locomotor pattern of spastic paretic patients. *Can. J. Neurol. Sci.,* 16: 315-325.

Wernig, A. and Müller, S. (1991) Improvement of walking in spinal cord injured persons after treadmill training. . In A.Wernig (Ed.), *Plasticity of Motoneuronal Connections. Restorative Neurology,* Vol. 5, Elsevier, Amsterdam, pp. 475-486.

Wernig, A. and Müller, S. (1992) Laufband locomotion with body weight support improved walking in persons with spinal cord injuries. *Paraplegia,* 30: 229-238.

Wernig, A., Müller, S., Nanassy, A. and Cagol E (1995) Laufband therapy based on "rules of spinal locomotion" is effective in spinal cord injured persons. *Eur. J. Neurosci.*, 7: 823-829.

Wernig, A., Nanassy, A. and Müller, S. (1998). Maintenance of locomotor abilities following Laufband (treadmill) therapy in para- and tetraplegic persons: follow up studies. *Spinal Cord,* 36: 744-749.

Wernig, A., Nanassy, A. and Müller, S. (1999). Laufband (treadmill) therapy in incomplete paraplegia and tetraplegia. *J.of Neurotrauma*, 16: 719-726.

Wernig, A. (2005). Letter to the Editor. *Spinal Cord, in press*

9.APPENDIX III.
FILM TEXT (CD available upon request. Cover charge € 15)

9.1 MOUNTING OF THE HARNESS

We have been developing this harness over almost 10 years and we are sure to continue doing so. However, the principle will remain. The harness is constructed to be used for severely paralysed patients. **It is the only harness that can be mounted while the patient is sitting in the wheel chair**.

PICTURE 1: SCHEMATIC DRAWING OF THE HARNESS

There is a chest part (**D**) and a pelvis part (**A**), they come separated as shown (for combining parts of different sizes to fit unusual body shapes; rarely necessary) or usually firmly connected at **C**.
The harness is available in 3 different sizes, the small size is suitable also for children

FILM 1: THE HARNESS DEMONSTRTED BY SABINE MÜLLER

FILM 2: MOUNTING OF HARNESS ON PATIENT WHO CANNOT STAND UPRIGHT BUT CAN LIFT HIS BODY AND CONTROL HIS RUMP

Patient bends forward: Bring the harness below the body as far as possible

Therapist stands in front of the patient: Fix chest part of harness loosely

Patient lifts his body: Pull harness further down and towards you: secure the patient with your knees while pulling
Pelvis part should at least be at trochanter femoris or below
Before connecting straps **A** with buckle at **A** (pelvis part) pull straps up to symphysis and MAKE SURE THAT STRAPS DON'T JEOPARDIZE MALE GENITALS OR THE URINAL TUBES:
Close leg straps (**A**) firmly.
Now also close chest part tightly

FILM 3: DE-MOUNTING OF HARNESS (SAME PATIENT)

FILM 4: PATIENT HAS LITTLE/NO CONTROL OF HIS RUMP AND POOR/MISSING ARM FUNCTIONS

Follow steps as described under FILM 2; note that the patient needs to be carefully secured by the therapist as shown in the film.

Tilt patient to the side you are standing, pull down pelvis part of the harness if necessary (note shown in the film) and adjust leg straps. Then same procedure for the other side.

FILM 5: DE-MOUNTING; SAME PATIENT AS IN 4

FILM 6: MOUNT SEVERELY PARALYZED PATIENT IN THE SUSPENSION SYSTEM

Bring patient directly under the suspension
Breaks of the wheel chair need to be closed
Put feet on the ground

FILM 7: ADJUST FRAME

Estimate your patient s body size and adjust height

FILM 8: UP-RIGHT POSITION

Secure patient with your knees if necessary

FILM 9: RUBBER BANDS

Considerably helpful to stabilize the pelvis. Fine-adjust height of the frame in order for the bands running as shown. Frontal rubbers may be brought up higher and can be fixed with help of the straps on the chest part (Klett, not shown)

FILM 10: END OF SESSION

Make sure that the patient does not miss the wheel chair when lowered: bring chair below the suspension and patient in front, hold your knees against the patient s if necessary.
Open lower buckles to relieve the patient

FILM 11:

Dont forget to pull down the trousers, again to relieve tension and avoid pressure problems when the patient is sitting.

9.2 HELPS PROVIDED BY THERAPISTS (same CD)

The different manual aids provided when patients walk and train on the Laufband. Differently paralysed patients are simulated.