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Prevention and Rehabilitation

Mobilization of the neurodynamic system using proprioceptive neuromuscular facilitation decreases pain and increases mobility in lower extremities and Spine-A case report

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A B S T R A C T

Introduction: Different approaches are used in physical therapy when treating patients with peripheral nerve paralysis and pain syndrome, such as neuro-mobilization techniques, manual therapy, muscle strengthening, active mobilization and relaxation techniques. Proprioceptive neuromuscular facilitation (PNF) seems to be a promising therapy for mobilizing the neurodynamic system. This case report illustrates the clinical reasoning and feasibility of applying PNF based neuromobilization to a patient not responsive to standard physical therapy.
Case description: A 66-year-old male was diagnosed with neurofibrosarcoma grade II, paravertebral L4-L5 left (L) side. After laminectomy of the transverse process L4 and L5 L side and stent in the lumbar region, the patient presented pain and peripheral nerve paralysis. The patient's complaints 13 years later were chronic lower back, buttock and leg pain and weakness in the L leg.
Patient management: Six treatment sessions with follow-up were provided during 3.5 months. The PNF-based-rehabilitation-approach applied the PNF philosophy, specific techniques, and facilitating principles and procedures using manual guidance in 3-dimensional PNF movement patterns in various positions, aiming to mobilize the neurodynamic system to decrease pain and achieve trunk and leg mobility.
Discussion and conclusion: The PNF-based-rehabilitation-approach led to improvement in pain, nerve mobility and balance beyond or close to clinical relevance. This approach had positive effects, by supplying oxygen to the nerves, increasing nerve mobility and decreasing pain, hence restoring altered movement patterns, which all improved the patient's activities-of-daily-living. In a situation, where standard strengthening and mobilization techniques are not effective, PNF seems a feasible alternative to decrease chronic pain.

1. Introduction

Different active and passive approaches such as neuro-mobilization techniques (Butler 2000; Shacklock 2005), manual therapy (Balthazard et al., 2012), muscle strengthening, active mobilization (Jensen et al., 2012) and relaxation techniques (Ozsoy et al., 2019), are used in physical therapy to treat patients with peripheral nerve paralysis and pain syndrome (Butler and Moseley 2003).

Mobilization of the neurodynamic system, also called neuro-mobilization or neurodynamics, is an approach to treatment of pain that relies on influencing pain physiology via mechanical treatment of neural tissues and the surrounding non neural structures (Butler and Moseley 2003; Basson et al., 2017). Neurodynamics is the clinical application of mechanics to the physiology of the nervous system as they relate to each other and are connected with musculoskeletal function (Shacklock 2005). The nervous system has the natural ability to move and withstand mechanical forces that are generated by movements in daily life. It must be able to withstand tension, slide in its ensheathment, and be compressible. Mechanical modifications by compression and tension can alter blood flow and lead to inflammation and mechanical sensitivity of the nervous system. This can be caused by clinical features such as disc protrusion, peridural scarring, joint instability, high intra-muscular pressure and overuse. These disorders may create stress

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by mechanical alteration on nearby neural structures and may result in pain and disability (Butler 2000). Pain not only is a marker of tissue damage or disease but also signals a perceived need to protect body tissue according to the biopsychosocial model of pain (Butler and Moseley 2003).

For several years, neuromobilization using proprioceptive neuromuscular facilitation (PNF) has been proposed in practical clinical work (Butler 2000; Shacklock 2005; Wolny et al., 2010).

PNF is a rehabilitation based approach developed by Dr. Hermann Kabat in the 1940s. It is a physical therapy concept allowing simultaneous assessment and treatment of neuromuscular dysfunction. The concept is based on the PNF philosophy, facilitating principles and procedures and specific techniques. The "philosophy" emphasizes the potential of the patient, by starting with the non-affected part achieving reinforcement by employing the stronger muscles, using repetitions of functional movements and stressing intense training with the aim of improving function and activity. The "procedures" such as the therapist's dynamic body mechanic and movement patterns are used as basic tools to support the "facilitating principles". These principles encompass guided movement with manual contact, traction used for elongating weak muscles and verbal and visual stimuli for encouraging smoother and quicker movement (Adler et al., 2014). PNF has been continuously developed under the guidance of the International PNF Association (IPNFA) and modern PNF has integrated the principle of motor learning. Its clinical approach is in line with the International Classification of Functioning (ICF) (World Health Organization, 2013), which addresses impairments in body function and structure as well as disabilities of activities to restore participation in society, from hands-on to hands-off approaches (IPNFA 2019). PNF is characterized by 3-dimensional (3D) movement patterns (Adler et al., 2014) based on synergist muscle elongation and contraction within a body's muscle chain.

Comparing the PNF pattern with the defined "neurodynamic test" (Butler 2000; Shacklock 2005), it allows assessing whether one component of the PNF pattern differs from that in the "neurodynamic test", thus protecting the corresponding nerve from reaching the maximal level of tension. The neurodynamic test evaluates the length and mobility of various components of the nervous system, progressively applying more tension on the component that is being tested. In this case report, nerve mobility was tested by straight leg raise (SLR) and the corresponding nerves (spinal cord + sciatic nerve) in the supine and slump long-sitting (Slump LS) positions (Butler 2000; Boyd 2005; Shacklock 2005). One of the PNF lower extremity patterns contains the hip in flexion/adduction/lateral rotation (F/ADD/LR), the knee in extension (E), the ankle in dorsiflexion (Df) and the foot in inversion (In). The SLR, which elongates the sciatic nerve, has its major component in hip F and knee E, with reinforcement in hip ADD and medial rotation (MR), ankle Df and foot Eversion (Ev) (SLR + tibial neurodynamic test [TNT]). The two different components the hip LR and foot In make it possible to mobilize the nerve within the above-mentioned PNF pattern without reaching maximal tension.

The aim of this case report, on a male adult suffering from chronic pain and peripheral nerve paralysis for 13 years, was to illustrate the clinical reasoning and the feasibility of applying PNF-based neuromobilization.

2. The case/patient characteristics

The patient's complaints were lower back, buttock and leg pain on the left (L) side, expressed as generally experienced pain, and weakness in the L leg.

The complete diagnosis after surgery (in 2006) was neurofibrosarcoma grade II paravertebral L4-L5 L side; post laminectomy of the transverse process L4 and L5 L side; lumbar plexus lesion L3 L side; plegia of L quadriceps, iliopsoas and anterior tibial muscles; sciatica on disc herniations L4-S1 L side and stent in the lumbar region. The patient is a physical active person, who swims regularly, deep-dives for 6 weeks in autumn and is often gardening, which provokes pain from time to time. He walks independently, with a knee orthosis for short distances and with one or two crutches for longer distances, depending on the general state.

The patient is married, 66 years old and self-employed, lives in a house, and has an active social life and a positive attitude.

In the past, the patient had been treated with conventional exercise therapy and manual therapy, focusing on muscle strengthening and joint mobility. This resulted in changes in the intensity of the complaints, but no long-lasting relief was achieved.

3. Timeline

The timeline of the PNF interventions was running from T0 (baseline) to T1 and consisted of 6 sessions in total over a period of 3 weeks. Each therapy session focused on neuromobilization and lasted 45 min. Follow-up was made at T2, which was 3.5 months later.

4. Patient management

4.1. Initial assessment and monitoring

The patient's assessment revealed a clear neurodynamic component. Therefore, a neuromobilization strategy was defined, using clinical reasoning integrating the PNF philosophy, facilitating principles, procedures and specific techniques (Adler et al., 2014; Smedes et al., 2016).

The effectiveness of this approach was monitored by measuring pain, nerve mobility of the lower extremities and spine, functional mobility, balance, fall risk and gait parameters.

For measuring the patient's specific complaints (PSC), the average result for the lower back, buttock and leg pain was used (Breivik et al., 2008). Pain was monitored with a Numeric Rating Scale (NRS) (0 = no pain and 10 = worst imaginable pain on an 11-point scale); the intraclass correlation coefficient (ICC) was excellent at 0.95 and the minimal detectable change (MDC) was 1.33 (Alghadir et al., 2018).

To evaluate the patient's level of physical function, spine and leg mobility were evaluated with neurodynamic tests, monitored with the Range Of Motion (ROM) of hip F, and assessed with a goniometer similar to the protocol of Herrington et al. (2008). This protocol showed a SLR test with an intratester reliability of 0.93 and a standard error of measurement (SEM) of 2.5°, and a slump test with an intratester reliability of 0.88 and an SEM of 1.8°. The MDC for SLR was 5.7° according to Ekedahl et al. (2012).

Neurodynamic quantities were monitored by SLR + TNT and a slump test, which are recommended, although their sensitivity and specificity are under debate (Scaia et al., 2012).

In the supine position, the sciatic nerve was tested on the right (R) side by active SLR (L side not possible due to weakness) (Butler 2000); passive tests were executed on both sides as follows: passive SLR, SLR + hip ADD, and SLR + hip ADD + hip MR; tibial nerve with ankle and foot in Df/Ev + SLR; common fibular nerve with ankle and foot in plantar flexion (Pf)/In + SLR; and sural nerve with ankle and foot in Df/In + SLR.

In the sitting and long-sitting positions, the spinal cord and sciatic nerve were tested by slump and Slump LS (Butler 2000; Herrington et al., 2008; Shacklock 2016).

In the standing position, the spinal cord and the sciatic and tibial nerves together were tested by forward bending, imitating Slump

LS, measured in centimeters with the fingertip-to-floor test (FTF); its intra- and interrater reliability was excellent with an ICC of 0.99 (Perret et al., 2001) and an MDC of 4.5cm (Ekedahl et al., 2012).

The patient's balance was monitored with the functional reach test (FRT); its interrater reliability was almost good with an ICC of 0.73 and an MDC of 9 (Steffen and Seney, 2008). The test was measured with the patient barefoot.

The patient's functional mobility, balance and fall risk were evaluated with a Timed Up and Go test (TUG). The TUG's interrater reliability was good with an ICC of 0.85 and an MDC of 11 (Steffen and Seney, 2008). The test recorded walking time, with the patient barefoot without a crutch.

The patient's activity of walking, with shoes on, was assessed with the Gait Up system (Mariani et al., 2013). Measuring gait parameters, the interrater reliability demonstrated good-to-excellent agreement with ICC of 0.83–0.97. The MDC for stride length was 0.11 on the R leg and 0.17 on the L leg; the MDC was 0.17 for speed and 13 for cadence (Nair et al., 2012). The measurements were done with foot-worn inertial sensors, which detect temporal events within the gait cycle; their validity and reliability have been demonstrated by Mariani et al., (2013). The corridor for testing was 50 m long.

The measurements were done by an experienced physical therapist. Each measurement was performed twice and the best result was recorded. A total overview of interrater and intratester reliability with ICC and SEM values is provided in Table 1.

4.2. Physical treatment and intervention

The objective of the treatment was to address the patient's problems such as pain, walking and balance. Based on clinical reasoning, the symptoms, considering the ICF in terms of impaired nerve mobility, resulted in diminished activities of daily living. PNF movement patterns and specific techniques were applied to improve nerve flexibility and decrease pain. The PNF facilitating principles and procedures were exerted in various positions using the knowledge about neuromobilization (Coppieters and Butler 2006; Singh et al., 2017). Depending on symptoms, first the distal part, then the proximal part of the specific nerve was mobilized together with the spinal cord (Talebi et al., 2010). The therapist focused on either the entire nerve or a segment thereof. The mobilized nerve was never fully elongated, thus preventing it from reaching maximal tension (Vidhi et al., 2014).

In accordance with the PNF philosophy, the treatment began each time on the non-painful R side (Adler et al., 2014; Shacklock 2016). This had the advantage for the patient to be able to perceive and integrate the movement while emphasizing conscious breathing with the aim to relax, which was quasi an indirect way to help decrease the pain level (Adler et al., 2014; Butler 2000).

The PNF specific techniques were (1) "rhythmic initiation" (RI), a technique characterized by a passive, an active assisted, a resisted and an active non guided phase of agonistic muscle activity exercising a specific movement; (2) "dynamic reversal" (DR), defined as successive concentric muscle contractions of agonists and antagonists within a diagonal of two opposing PNF movement patterns; and (3)

"combination of isotonics" (CoI) focusing on combined agonistic muscle contractions in concentric, eccentric and stabilizing muscle work, without relaxation. The PNF basic procedure "Timing for Emphasis" (TfE), is defined as facilitating one specific sequence within a complete movement pattern (Adler et al., 2014; Smedes et al., 2016), aiming to mobilize the nerve. To obtain increased nerve mobility, a so-called slider technique was applied. A slider is a neurodynamic maneuver with the purpose of producing a sliding movement of neural structures relative to the adjacent tissue. The effect of a neural slider is to create significant movement in the nerve, within a painless range, without generating tension or compression. To perform a slider, longitudinal force is applied at one end of the nerve tract whilst tension is released at the other (Shacklock 2005).

The PNF movement pattern of lower extremity F/ADD/LR with knee E, ankle Df with foot In, was used in the supine position to address the neurodynamics of the sciatic, tibial and sural nerves. The patient was placed in a relaxed position, with a cushion under the head and the upper part of the table put at 10° of F. The PNF basic procedure "TfE" was applied with emphasis on knee E, with the thigh lying on the treatment bench, using the specific techniques "RI" and "CoI" (Adler et al., 2014; Smedes et al., 2016).

The approach progressed with "TfE" on ankle Df with foot In, making several repetitions while keeping the knee in F and the hip in E.

A combination of knee E, ankle Df with foot In, with the pattern F/ADD/LR versus knee F, ankle Pf with foot Ev, with the pattern E/Abduction (ABD)/MR used the specific technique "DR".

The same procedure as described above was implemented on the L, affected side (see Fig. 1). On this side, knee E was maximally assisted and facilitated by the therapist's dynamic body mechanics and by using "traction," as the L quadriceps was extremely weak. "Traction" helped to elongate the weak quadriceps, thereby getting an increased muscle response. The therapist added tactile stimulation to the muscle and asked the patient to think of and visualize the movement of knee E and ankle Df with foot In.

The PNF facilitating principles of "traction," tactile, verbal and visual stimulation, and guided movements, as well as the therapist's dynamic body mechanics, movement patterns, and repetition of slow movements, assisted in supplying oxygen to the nerves (Butler 2000). These tools helped increasing the patient's awareness of muscle contraction by indirectly sliding and broadening the flexibility of the nerves, thus decreasing the pain level.

To obtain a mobilizing effect on the sciatic nerve from the proximal and distal parts, the patient sat upright on a table with hand support, one leg placed in long-sitting with a cushion under the knee, the other leg supported in hip ABD with the lower leg hanging by the side (see Fig. 2). The above described pattern (F/ADD/LR with Knee E, ankle Df with foot In), specific techniques and procedures were repeated in this position both on the R and the L side.

Addressing the spinal cord, the patient sat on the table leaning forward with his forearms on a cushion block placed on two chairs, imitating a slump position; his feet were first placed flat on the floor in front of the knees, then a cushion was placed under each foot to increase ankle Df, imitating a slump position with an

Table 1
Overview of interrater and intratester reliability with ICC and SEM.

Tests	Interrater reliability/ICC	Intratester reliability	SEM
NRS	0.95		
SLR		0.93	2.5°
Slump		0.88	1.8°
FTF	0.99	0.99	
FRT	0.73		
TUG	0.85		
Stride length R leg	0.89		
Stride length L leg	0.83		
Speed	0.97		
Cadence	0.97		

Reliability values: moderate 0.5–0.75, good 0.75–0.90, excellent 0.91–1.0.
ICC = intraclass correlation coefficient, SEM = standard error of measurement.
NRS = Numeric Rating Scale, SLR = straight leg raise, FTF = fingertip-to-floor test.
FRT = functional reach test, TUG = Timed Up and Go test, R = right, L = left.

Fig. 1. With the patient in supine position, the therapist activates the lower left extremity in flexion/adduction/lateral rotation with guided movement, using the procedure "Timing for Emphasis" on knee extension (red arrow), mobilizing the sciatic nerve from the distal part. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 2. With the patient in adapted longsitting with hand support, one leg hanging by the side, and with increased load on the spinal cord, the therapist activates the left lower extremity in flexion/adduction/lateral rotation with guided movement, using the procedure "Timing for Emphasis" on knee extension (red arrow), mobilizing the sciatic nerve from the distal part. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 3. With the patient in the sitting position, supported on his forearms and with both ankles in dorsiflexion, the therapist activates the pelvis by "anterior elevation/posterior depression" with guided movement using the procedure "Timing for Emphasis" on "anterior elevation" (red arrow) mobilizing the sciatic nerve and spinal cord. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 4. With the patient in the half-kneeling position, the therapist activates the pelvis by "anterior elevation/posterior depression" with guided movement, using the procedure "Timing for Emphasis" on "anterior elevation"(red arrow) mobilizing the sciatic, common fibular and femoral nerve with the spinal cord. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Overview of the PNF intervention.

Nerve mobilized	Positions	PNF procedures for facilitation	PNF principles for facilitation	PNF techniques
Sciatic Tibial Sural Femoral Common fibular	Supine	Lep: F/ADD/LR + knee E TfE: - knee E - ankle Df/foot In E/ABD/ MR + knee F TfE: - knee F - ankle Pf/foot Ev	Exteroceptive stimuli: - tactile - verbal - visual Proprioceptive stimuli: - traction - guided movement	Rhythmic Initiation (agonist technique) Dynamic Reversals (antagonist technique) Combination of Isotonics (agonist technique)
Sciatic Tibial Sural Femoral Common fibular	Long-sitting: - one leg hanging by the side of the table - trunk with hand support	Lep: F/ADD/LR + knee E TfE: - knee E - ankle Df/foot In E/ABD/ MR + knee F TfE: - knee F - ankle Pf/foot Ev	Stimuli: - tactile - verbal - visual - traction - guided movement	Rhythmic Initiation Dynamic Reversals Combination of Isotonics
Spinal cord Sciatic Tibial Sural Femoral Common fibular	Sitting supported on forearms: - knee F ~30° - ankle Df - a cloth placed under the foot facilitating movements of the knee	Pp: anterior elevation/posterior depression TfE: - anterior elevation Lep: F/ADD/LR + knee E TfE: - knee E/F - toe E, foot and ankle Ev/Df, knee E E/ABD/MR + knee F TfE: - toe F, foot and ankle In/Pf, knee F	- tactile - verbal - visual - traction - guided movement	Rhythmic Initiation Combination of Isotonics Dynamic Reversals
Spinal cord Sciatic Femoral	Quadruped: - tall-kneeling with neck-F/E	Pp: anterior elevation/posterior depression TfE: - anterior elevation	- tactile - verbal - visual - traction - guided movement	Rhythmic Initiation Combination of Isotonics
Spinal cord Sciatic Common fibular Femoral	Quadruped: - half-kneeling with neck-F/E	Pp: anterior elevation/posterior depression TfE: - anterior elevation	- tactile - verbal - visual - traction - guided movement	Rhythmic Initiation Combination of Isotonics
Spinal cord Sciatic Tibial	Standing up from half-kneeling		- tactile - verbal - guided movement	

Lep = lower extremity pattern, F = flexion, ADD = adduction, LR = lateral rotation, E = extension, ABD = abduction, LR = lateral rotation, MR = medial rotation, TfE = Timing for Emphasis, Df = dorsiflexion, In = inversion, PF = plantar flexion, Ev = eversion, Pp = pelvis pattern.

SLR + TNT, a position of extended nerve tension (see Fig. 3). The therapist stimulated the pelvis in slow movements using the PNF pattern "anterior elevation" and "posterior depression," diagonally to the R and L side, applying neck F for "anterior elevation" and neck E for "posterior depression" and achieving an increased sliding effect on the spinal cord. The PNF techniques "RI" and "CoI," applying "TfE" for "anterior elevation" of the pelvis, further stimulated the mobility of the upper lumbar nerve roots (Butler 2000).

By using "TfE" on knee E and knee F, with a cloth placed under the moving foot, the ankle moved into Pf and back into Df, sliding, from the distal part, the sciatic and common fibular against the femoral and tibial nerves.

The therapist then facilitated, by **"TfE,"** toe E, foot and ankle Ev/Df and knee E versus toe F, foot and ankle In/Pf and knee F, thus sliding the sciatic, tibial and sural against the femoral and common fibular nerves.

Increased neurodynamics were required for the spinal cord and sciatic nerve, comprising mobilization in the quadruped position and a closed-chain situation, such as adapted tall-kneeling and half-kneeling, adopted from the PNF matt program (Adler et al., 2014). Rocking exercises were facilitated with guided movements via the pelvic patterns "anterior elevation" and "posterior depression," combining neck F with "anterior elevation" and neck E with "posterior depression," thereby obtaining an increased sliding effect combined with conscious breathing. The specific techniques used were "RI" and "CoI".

In the half-kneeling position, with the weight on the R "stance leg" (see Fig. 4), the pelvis was facilitated into "anterior elevation," mobilizing the femoral nerve on the R side, and then into "posterior depression," the front L leg moving into knee E, thereby mobilizing the sciatic and common fibular nerves on the L side. A cushion was placed between patient and therapist as a supportive treatment environment. The exercise was repeated on the L side.

The treatment finished with the patient standing up from half-kneeling, changing into the "downward-facing dog" position, imitating a Slump LS position, then coming to stand with the help of the arms on the legs, thus mobilizing the lumbar part of the spine in F and sliding the spinal cord and sciatic and tibial nerves towards increased tension. A total overview of the PNF intervention is provided in Table 2.

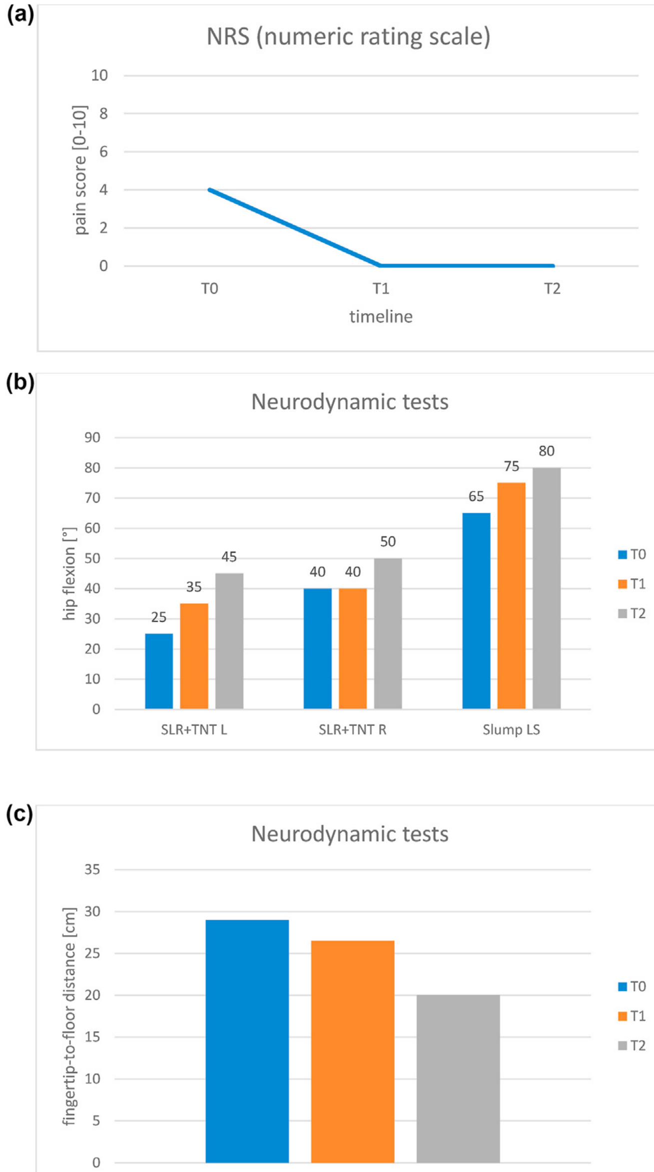

Fig. 5. Graph and charts:
Fig. 5a Pain decreased from T0 to T1 and remained 0 at T2.
Fig. 5b Hip flexion increased in SLR + TNT L and R as well as in Slump LS.
Fig. 5c Fingertip-to-floor distance decreased from T0 to T2.
Fig. 5d Reach distance while bowing forward increased from T0 to T2.
Fig. 5e Performance time decreased as gait speed increased, from T0 to T2.
Fig. 5f Stride length increased from T0 to T1 and was still better at T2 compared to T0.
Fig. 5g Speed increased from T0 to T1 and was still better at T2 compared to T0.
Fig. 5h Cadence increased from T0 to T1 and was still better at T2 compared to T0.

5. Results

The patient's ability to move with less pain improved, as illustrated by different tests.

On the NRS**,** the PSC pain, situated in the lower back, buttock and leg on the L side, ameliorated from 4 to 0 points, without the need for regular pain medication (see Fig. 5a).

Improved nerve mobility was achieved as shown by the following neurodynamic tests results (see Fig. 5b):

SLR + TNT extended the ROM of hip F by 20°(from 25° to 45°) on the L side and R side by 10° (from 40° to 50°) on the R side.

Slump LS with hand support extended the ROM of hip F by 15° (from 65° to 80°).

Slump LS without hand support extended the ROM of hip F, from “not possible due to pain” to “possible without pain” with hip F at 75° (see Fig. 6).

The FTF in the forward-bending position showed an improvement in reach by 9 cm (from 29 to 20 cm) between finger-tip and floor (see Fig. 5c).

The FRT showed an improvement in balance outcomes by 8 cm, (from 12.5 to 20.5 cm) (see Fig. 5d).

The TUG was completed in almost half the time compared to

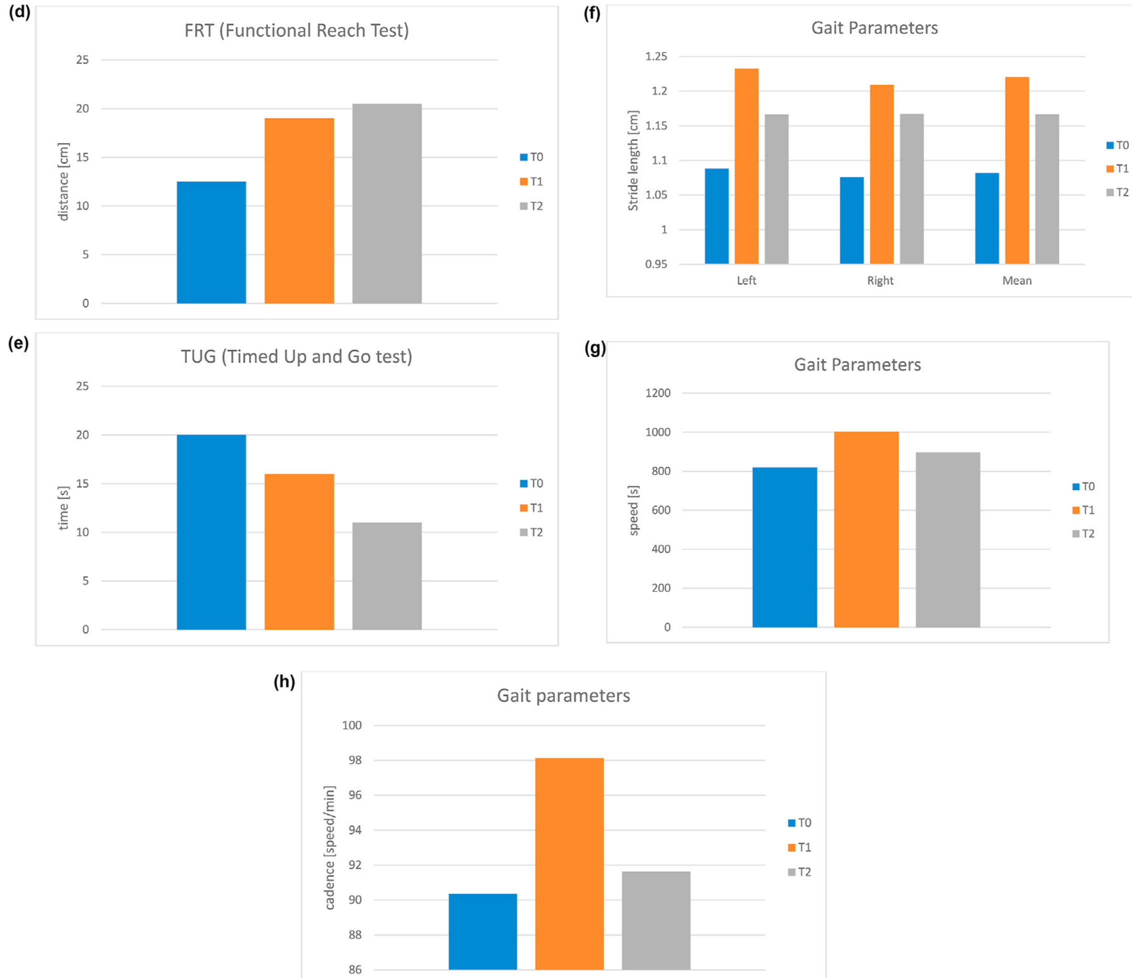

Fig. 5. (*continued*).

before therapy (11 vs. 20 s) (see Fig. 5e).

Gait parameters displayed improvements in stride length, speed and cadence – in stride length, on the R leg, by +0.091 cm from 1.076 to 1.167 cm and on the L leg, by +0.078 cm from 1.088 to 1.166 cm (mean value by +0.085 cm, from 1.082 to 1.167 cm) (see Fig. 5f); in speed, by +0.075 m/s from 0.819 to 0.894 m/s (see Fig. 5g); and in cadence, by +1.26 steps/min from 90.36 to 91.62 steps/min (see Fig. 5h).

Monitoring took place at T0, T1 and T2.

A total overview of the results from T0 to T2 is provided in Table 3.

6. Discussion

6.1. Clinical reasoning

The hypothesis for the treatment set-up was that the patient's symptoms were linked to resection of the tumor in the lumbar spine. As a consequence of surgery and disc herniations, the patient had developed symptoms such as chronic lower back, buttock and leg pain on the L side, decreased lower back and leg mobility on the L side, and reduced strength in the L leg. This resulted in a loss of nerve mobility, potentially in all directions (Talebi et al., 2010).

The patient's assessment revealed a clearly adverse neurodynamic component. Therefore, a neuromobilization strategy was defined that combined neurodynamics with the PNF approach.

This strategy was shown to be successful in this case report, since the patient's function, activity and participation level increased.

The NRS showed excellent results concerning pain alleviation. Our hypothesis was that the general decrease in muscle tension linked to conscious breathing and slow repetitive dynamic movements (Michaeli et al., 2017; Di Trani Lobacz 2015) helped stimulate oxygen flow to the nerves (Butler and Mosley 2003). Furthermore, starting with facilitating the requested movement on the non-painful side, supported the patient in perceiving and integrating the correct movement and had an indirect effect on mobilizing the lumbar plexus and sciatic nerve on the opposite side (Butler 2000).

Gilbert (2015) showed that slow repetitive movements aiming to mobilize the sciatic nerve had a positive impact by decreasing edema in the lumbar spine and thus reducing pressure and the level of pain.

Slump LS had a beneficial effect on lower back pain, as described by Nagrale et al., (2012).

Approaching mobilization from the distal end, as with the knee moving in E or the foot in Df, revealed a good effect on the mobility of the sciatic nerve (Castellote-Caballero 2013; Sharma et al., 2017).

In our case, Slump LS had improved from not possible with hand support to possible without hand support. This was related to increased nerve mobility in the spine and lower extremities due to better nerve gliding, as seen by enhanced hip flexion (see Table 2). Slump LS showed the most notable improvement in the patient.

Fig. 6. With the patient in the slump longsitting position, without hand support, with hipflexion by 75° and without pain, mobility of the sciatic nerve and spinal cord is tested.

Likewise, the FTF results improved because of increased gliding of the spinal cord and the sciatic and tibial nerves, and the SLR + TNT showed improvements in mobility due to increased gliding of the sciatic nerve.

The choice of a non-weight-bearing (i.e., supine) position minimized the mechanical stress on the lumbar spine (Ebraheim 2017).

However, challenging weight-bearing positions, such as sitting, tall-kneeling and half-kneeling, demanded active balance control of the movements of the lower extremities and trunk; therefore, a supportive treatment environment with manual guidance was important to engage the patient in collaboration without fear. Moving the pelvis addressed the flexibility of the lumbar spine, and thereby the mobility of the lumbar intervertebral joints and nerve roots through the foramina (Shacklock 2005). Mobilizing the patient's sciatic nerve and lower lumbar spine demanded precautions, as the trunk and neck reacted in a sensitive way. This sensitivity might be explained by the biomechanics of lateral F of lumbar spine induced by the pelvic patterns. The pattern "anterior elevation" results in narrowing of the intervertebral foramen on the ipsilateral side while simultaneously requiring the contralateral side to elongate the nerve roots of the lumbar plexus (Butler 2000).

The sensitivity could also have been related to an expected instability of the lumbar spine due to laminectomy of the transverse process L4 and L5 L side.

The patient's improvement in balance could be related to generally decreased muscle tension, relaxed breathing, decreased pain and enhanced nerve gliding due to repeated dynamic movements in weight bearing positions.

The time to complete the TUG shortened and the FRT distance lengthened, which was related to an enhanced balance and functional mobility.

Gait parameters such as stride length, speed and cadence improved slightly (Amir Rachedi Bonab M et al., 2020). The enhanced balance during walking was associated with the decreased pain and increased mobility of the spine and lower extremities.

6.2. Clinical perspective

The provided therapy required a complete integration of clinical reasoning to obtain a personalized intervention addressing the different components of function and structure influencing the patient's activity and participation level as defined in the ICF.

The following gait parameters improved clinically relevantly from T0 to T1: stride length, R leg, by 0.133 cm (MDC 0.11) and speed by 0.184 m/s (MDC 0.17) (see Table 3). One of the tests that had improved results at T2, the follow-up session, was the NRS, the score of which decreased from 4 to 0 points (MDC 1.33). The NRS score was essential for assessment of the treatment outcome, and the excellent result stimulated the patient. At T0, he had been on pain medication (2x/day Ponstan 500 mg, 3x/day Ibuprofen 600 mg). At T2, the patient no more required any regular pain medication for the first time in 12 years. His spouse was positively surprised, and the two of them went to the cinema for the first time since several years (increased participation level according to the ICF).

Another test with enhanced results was the TUG, and the improvement was close to clinical relevance, i.e., from 20 to 11 s, with a result of 9 s (cutoff 10, MDC 11).

Furthermore, the FRT showed amelioration close to clinical relevance, from 12.5 to 20.5 cm, with a result of 8 cm (cutoff 8, MDC 9).

The SLR + TNT, Slump LS and FTF results improved clinically relevantly as follows: (1) the SLR + TNT for the L side showed extension of the ROM of hip F by 20° from 25° to 45° (MDC 5.7), and the SLR + TNT for the R side showed extension of hip F by 10° from 40° to 50° (MDC 5.7); (2) Slump LS with hand support displayed extension of the ROM of hip F by 15° from 65° to 80°, and Slump LS without hand support had an improvement in ROM of hip F from not possible due to pain to possible without pain of 75°, the patient's most notable improvement; the FTF distance decreased from 29 to 20 cm, with a result of 9 cm (MDC 4.5).

All this led to meaningful improvement in function, activity and participation level with the patient achieving.

- reduced pain;
- increased mobility of the spine and lower extremities;
- secure walking; and
- increased quality of life.

The PNF specific based rehabilitation approach of neuromobilization proved to be an excellent tool for manual treatment of this patient with chronic pain and peripheral nerve paralysis. Mobilizing the sciatic nerve using slow, dynamic and repetitive 3D PNF movement patterns in different positions and practicing selected PNF specific techniques led to reduced pain and increased mobility in the lower extremities and spine of this patient.

Clinical reasoning should undoubtedly target PNF for mobilization of the neurodynamic system in physical therapy practice.

This specific approach was tested on a single patient and it needs to be validated on a larger scale before being applied as standard therapy to similar patients.

To date, there has not been much research done in this field (Shacklock 2005).

6.3. Patient perspective

The patient stated that his wish regarding treatment was to

Table 3
Overview of patient monitoring.

Outcome measurements	T0	T1	T2	T2-T0 Difference	MDC[a]/Cutoff point#
NRS (points) lower back, buttock and leg pain	4	0	0	−4	1.33[a]
SLR + TNT L (hip F in °)	25	35	45	+20	5.7[a]
SLR + TNT R (hip F in °)	40	40	50	+10	5.7[a]
Slump long-sitting (hip F in °)	65 with HS, not possible w/o HS due to pain	75 with HS, 75 possible w/o HS and w/o pain	80 with HS, 75 possible w/o HS and w/o pain	+15 with HS, 75 w/o HS and w/ o pain	patient's most notable improvement
FTF (cm)	29	26.5	20	+9	4.5[a]
FRT (cm)	12.5	19	20.5	+8	9[a]/8#
TUG (s)	20	16	11	−9	11[a]/10#
Gait parameters: stride length	1.082	1.220	1.167	+0.085	0.17[a]
(cm)	1.088	1.232	1.166	+0.078	0.17[a]
M	1.076	1.209**	1.167	+0.091	0.11[a]
L leg					
R leg					
speed (m/s)	0.819	1.003**	0.894	+0.075	0.17[a]
cadence (steps/min)	90.36	98.12	91.62	+1.26	13[a]

[a] MDC = minimal detectible change, T0 = baseline, T1 = 3 weeks post baseline, T2 = follow-up 3.5 months post baseline, NRS = Numeric Rating Scale, SLR = straight leg raise, TNT = tibial neurodynamic test, L = left, R = right, F = flexion, HS = hand support, w/o = without, FTF = fingertip-to-floor test, M = mean value, FRT = functional reach test, TUG = Timed Up and Go test, # = Cutoff point, ** = MDC from T0 to T1: stride length R leg .133cm, speed .184 m/s.

decrease his pain and to walk better for a longer period of time.

He said that the therapist's advice to listen to his body, not to ignore his pain but take it seriously, and to alternate phases of activity with resting or sports such as swimming was of great importance to be able to change his behavior and to deal with his pain.

The patient also appreciated that a specific home program was proposed which emphasized the importance of slower movements with several repetitions of PNF movement patterns. He said that his personal physiotherapist integrated this PNF approach focusing on neuromobilization, so that he was able to make slow and pain-free global active movements in daily life.

The patient stated that he was satisfied with the therapy outcome, was filled with vitality, and hoped to be able to handle the pain, and he requested further physical therapy applying PNF, focusing on neuromobilization.

7. Conclusion and take-home message

The patient's function, activity and participation level improved to a degree close to or beyond clinical relevance, and the PSC pain disappeared over a period of 3.5 months. His walking pace was slightly quicker. The patient walked with less effort, displayed better balance and felt more secure, which all in all had a positive effect on his quality of life, with no need for regular intake of painkillers.

PNF with the focus on neuromobilization revealed to be a feasible therapy for decreasing pain, increasing SLR + TNT and Slump LS outcomes, and improving walking ability.

8. Informed consent

Written informed consent was obtained by the patient, allowing the anonymous use of treatment and assessment data and images for publication.

CRediT authorship contribution statement

Karin Jeanbart: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Cornelia Tanner-Bräm:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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