Stroke rehabilitation conducted by PNF method, with and without the application of botulinum toxin – case reports

Rehabilitacja poudarowa metodą PNF, z zastosowaniem i bez zastosowania toksyny botulinowej – opisy przypadków

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Key words
spasticity, therapy, locomotion, amplitude, gait

Summary
One of the most common diseases of the nervous system is stroke. Its most frequently occuring kinetic symptoms are paresis or paralysis accompanied by an increase in muscular tension called spasticity. For patients and their carers these disturbances become a problem in many aspects of their everyday life, especially in locomotion. New ways need to be looked for to create therapies that could decrease or remove spasticity and restore the function which was disrupted. Therapy by botulinum toxin has been used as a method of decreasing spasticity to treat children with cerebral palsy having equines-varus foot, and it proves to be a breakthrough in the treatment of diseases with increased muscular tension. Owing to it, a range of mobility increases, for example in an ankle and knee joints, which facilitates locomotion. This improvement is caused by both pharmacological action, and assisted kinesitherapy. Proprioceptive Neuromuscular Facilitation (PNF) is considered to be especially effective rehabilitation method based on neuro-physiological mechanisms. This method in the therapy of adults, along with the application of botulinum toxin, seems to facilitate physical activity of the patient after stroke, which may be very important for secondary stroke prevention. The aim of the research was to assess the influence of the therapy by PNF method associated with a botulinum toxin application on the patients after stroke with spasticity in lower limbs. During gait the patients had the flexion of ankle and knee joints measured by means of VICON system with the special focus on the amplitude of angular values. All patients presented in this description of cases showed an improvement in most of the measured parameters, in both a four-week and a three-month period after the therapy. The results show a necessity to carry out further randomized control studies of larger groups.

Słowa kluczowe
spastyczność, terapia, lokomocja, amplituda, chód

Streszczenie
Jedną z częściej spotykanych chorób układu nerwowego jest udar mózgu. Do najczęstszych objawów ruchowych należą niedowłady bądź porażenia kończyn, z towarzyszącym wzrostem napięcia mięśniowego, zwanym spastycznością. Dla pacjentów oraz ich opiekunów zaburzenia te stają się problemem w wielu aspektach życia codziennego, między innymi w lokomocji. Wymaga to poszukiwania nowych dróg w tworzeniu terapii mogących zmniejszyć bądź znieść spastyczność i przywrócić zaburzoną funkcję. Terapia toksyną botulinową jako metoda obniżająca spastyczność, jest stosowana do tej pory w terapii dzieci z mózgowym porażeniem dziecięcym ze stopą końsko-szpotawą i przynosi przełom w leczeniu schorzeń przebiegających z nadmiernym napięciem mięśniowym. Uzyskuje się poprawę zakresu ruchomości, miedzy innymi w stawie skokowym, a poprzez to ułatwia lokomocję. Poprawa ta uzyskiwana jest zarówno poprzez oddziaływanie farmakologiczne, jak i prowadzoną równolegle kinezyterapię. Szczególnie skuteczne wydają się metody rehabilitacyjne oparte na mechanizmach neurofizjologicznych. Jedną z takich metod jest PNF. Zastosowanie terapii metodą PNF połączone z zastosowaniem toksyny botulinowej u dorosłych wydaje się ułatwiać aktywność ruchową pacjenta po udarze mózgu, co może być bardzo ważne w profilaktyce wtórnej udau mózgu. Celem pracy było przedstawienie możliwości połączenia i wpływu terapii metodą PNF skojarzoną z podaniem toksyny botulinowej u pacjentów po udarze mózgu ze spastyczną kończyna dolną. Dokonano w trakcie chodu pomiaru kąta ugięcia w stawie skokowym i kolanowym biorąc pod uwagę amplitudę ruchu, wykorzystując system VICON. U wszystkich przebadanych w niniejszym doniesieniu pacjentów odnotowano poprawę większości analizowanych parametrów, zarówno w okresie czterotygodniowym, jak i czteromiesięcznym. Przeprowadzone pomiary wskazują na konieczność wykonania randomizowanych, kontrolowanych badań na dużych grupach.

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Received 17.01.2005; accepted 11.04.2005

forming this exercise, muscles of the lower body part were strengthened; balance and coordination of pelvic girdle muscles were also exercised.

3. Combination of shoulder-blade and pelvis movement patterns – involving simultaneous raising the shoulder-blade and lowering the pelvis on the exercised side. In the second phase – the opposite movement is performed. This exercise serves as a preparation of the patient for the alternating effort of the shoulder and the pelvic girdles, used during gait;
4. From the sitting position on the couch, the feet resting on the floor – a movement of the body forwards, with separation of the buttocks from the coach. Therapist's arms initially assisted this movement, however, resisted it subsequently, stimulating patient's antigravitation muscles to a more intensive effort. During returning to the sitting position, eccentric inhibition by anti-gravitation muscles was exercised.
5. Stabilisation of the erect posture by approximation of the iliac crest. Therapist's arms exert a compression (approximation) to stimulate proprioception within the joints of the lower extremity, which induces an increased activity of the lower limb extensor muscles.
6. Shifting of the body weight during taking a step (balance). By loading the paretic extremity, its stability was trained and thus it was getting prepared for its supportive role during walking.
7. Walking forwards and backwards – by means of this exercise, correctness of particular gait phases was trained in the patient. Appropriate resistance exerted by therapist's arms aided or stimulated the effort of the pelvis.
8. Walking on steps. The patient was taught to correctly climb the steps, which also resulted in a stimulation of muscles of the lower limb up to the elevation phase and the supporting phase. It is important that the therapist constantly secures the patient from below.
9. Walking using the tripod – which the patient was taught the correct support-assisted locomotion with. During this exercise, attention was paid to a proper movement sequence (moving the tripod forwards, subsequent step with the paretic limb, finally – a step with the non-affected limb). Taking possibly greatest advantage of the previously trained elements is important in this activity: loading and moving the paretic extremity.

The rehabilitation was conducted by certified PNF therapists.

ASSESSMENT METHODS

The movement amplitude of the lower extremities and the angular changes in the knee joint and the ankle joint occurring during movement were assessed by means of a three-dimensional motion capture system VICON 250[A].

The VICON 250 system is used for spatial measurement and analysis of the motion of markers attached to the body of the evaluated subject at sites corresponding to characteristic bone points and joint axes. The device consists of five cameras linked to a computer – database. Each camera emits and receives the light of a visible-infrared borderline wavelength capturing a flat image of the marker, at a frequency of 120 Hz (possible regulation from 60 to 250 Hz). The computer generates a three-dimensional image and enables analysis of the collected study material using appropriate software. For the three-dimensional location of the markers, each of them has to be simultaneously captured by at least two cameras. Measurement space encompasses the space located within the cameras' fields of view. For capturing patients' gait, the length of this space was 10 metres. Each trial was repeated three times, both during the gait with the elbow crutch and the independent gait. The measurements were taken during barefoot walking. The most accurate of successively performed measurements were used for the description of each patient.

The testing procedures began with patient's preparation involving the attachment of the retro-reflective markers directly onto the skin at the following sites (marker symbols are given in parentheses):

- on the level of the upper border of the sacral bone (SACR),
- on both anterior superior iliac spines (LASI and RASI),
- at the lower 1/3, lateral surface of the thigh (LTHI and RTHI),
- on the lateral aspect of the rim of the knee joint (LKNEE and RKNEE),
- at the lower 1/3, lateral surface of the tibia (LTIB and RTIB),
- at the level of the ankle (talocrural) joint (LANK and RANK),
- at the level of the calcaneal tuber (LHEE and RHEE),
- at the level of the first metatarsal bone (LTOE and RTOE),
- at the level of the fifth metatarsal bone head (LMT5 and RMT5).

The testing was performed three times:

- prior to the therapy initiation,
- after termination of the four-week therapy,
- three months after therapy termination.

Given that lower limb spasticity can be the main cause of gait disturbances in the evaluated patients, motion of only the following markers: LASI and RASI, LKNEE and RKNEE, LANK and RANK and LTOE and RTOE, used for measurement of angular changes occurring during successive testing procedures in the ankle and knee joints, was subjected to the final analysis.

Data analysis was conducted in two phases. Preliminary preparation of the results and establishing the markers' trajectories were performed using the Work Station module[B]. Then, subsequent data processing was performed using the Body Builder[C] software. Angular changes were plotted again using the Work Station programme.

[A] System Vicon 250 – manufactured by Oxford Metrics Limited, 14 Minns Estate West Way / Minns Business Park West Way, Oxford OX2 0JB, United Kingdom
[B] Work Station – a system enabling conversion of images from infrared cameras and their presentation in a form of points moving within a space. Manufacturer: Oxford Metrics Limited, 14 Minns Estate West Way / Minns Business Park West Way, Oxford OX2 0JB, United Kingdom
[C] Body Builder – a computer programme enabling creation of mathematical models of human motor system and biomechanical analysis of the data obtained using the Work Station system. Oxford Metrics Limited, 14 Minns Estate West Way / Minns Business Park West Way, Oxford OX2 0JB, United Kingdom

INTRODUCTION

Despite constantly increasing knowledge, cerebrovascular diseases are still one of the leading causes of disability and also mortality[1]. The life of a person after stroke, as well as the life of his family and closest friends, changes dramatically because of disability of various degrees resulting from disturbed movement control and altered muscle tone. These phenomena, resulting from the upper motor neurone lesion, induce impairment of gait, development of pathological movement patterns and persistent contractures and joint deformations. Pathologically increased, spastic muscle tone, typical for the paretic (paralysed) body side, is present, thus leading to difficulties in performance of activities of daily living, locomotor activity, and in an independent self-service. Increased muscle tone is also associated with a more intense activity of the non-affected side undertaken to compensate for the loss of function. Functional problems are associated with the following domains: psychological, intellectual and social, and affect patient's quality of life to a greatest extent[2,3]. The multitude of problems requires multi-directional therapy and rehabilitation.

Physiotherapy is one of the components constituting the therapeutic process. Its role should involve limitation of movement deficits that occurred in the patient, including basic and complex motor functioning and self-service[4]. First of all, physiotherapy should be directed towards improving patients' quality of activities of daily living and patients' independence. Important component of such therapy should involve determining, in common effort with the patient, goals adequate to patient's abilities and current needs. Patients' problems occurring during post-stroke rehabilitation, e.g. the dynamics of spasticity changes, prompt to modify the therapy being carried out, to search for new paths, as well as to combine therapeutic concepts.

The presented case reports refer to a problem of combining two methods used in neurological rehabilitation – kinesitherapy using the PNF method and application of the botulinum toxin. In the presented paper, therapy during the late post-stroke period is described.

The PNF (Proprioceptive Neuromuscular Facilitation) is a method used in post-stroke treatment, where the functional therapy is a process of gradual restitution of patient's motor abilities[5,6,7]. It is a method of neuromuscular dysfunction treatment, primarily by means of facilitating the flow of information, mainly by the stimulation of proprioceptors[8]. Restoration of normal movement based on movement patterns, basic principles and techniques is directed towards normalisation of muscle tone[9].

Botulinum toxin therapy is a new pharmacological approach used in the treatment of spasticity. It is a method enabling, via direct effects on the spastic muscle, selective reduction of the increased muscle tone without occurrence of undesirable effects characteristic for oral myorelaxants. Botulinum toxin is frequently used in the therapy of children with cerebral palsy with talipes equinovarus[10,11]; however, it is more and more frequently applied in the adults in the treatment of diseases with muscular hypertonia[12,13,14,15]. In particular, persons in the late post-stroke period, with increasing muscle tone, require a search for both pharmacologic and physiotherapeutic methods[16] that can help to eliminate the strategy of compensation by the non-affected side and facilitate the functional rehabilitation of the paretic side. Reduction of spasticity in the foot and calf is an important domain of spasticity treatment in the adults[17]. The aim of botulinum toxin therapy is to achieve the improvement in qualitative parameters of gait by the elimination of pathological patterns[18].

One of possible modifications of the rehabilitation programme in the late post-stroke period is a combination of the PNF method with botulinum toxin therapy. Periodic reduction of muscle tone, resulting from the application of the preparation, should make the performance of motor exercises and tasks and maintenance of therapy effects easier for the therapist and the patient, and help in restoration of the correct movement pattern. The achievement of these goals may have a significant influence on the reduction of patient's problems in functioning.

Although theoretical premises for the combination of the PNF method with botulinum toxin application in the rehabilitation of post-stroke patients do exist, the information pertaining to the efficacy of such therapy is lacking in the literature on this topic. There are no descriptions of such management either.

In this study, cases of rehabilitation of four post-stroke patients are presented. In two of them, the PNF therapy with botulinum toxin application into the spastic muscles of the lower extremity was conducted, and in another two patients, the PNF method was used without concomitant botulinum toxin application.

REHABILITATION CONDUCTED ACCORDING TO THE PNF CONCEPT

Kinesitherapy in all four patients comprised a period of four weeks. The rehabilitation programme in each patient included exercises performed for 45 minutes 5 times a week. All persons came for the exercises independently, as outpatients.

The rehabilitation was conducted individually and adjusted to current needs and abilities of each of the patients. The therapeutic regime was the same for all participants.

It comprised the following elements (Table 1):
- initial position,
- basic principles,
- techniques,
- movement patterns.

The rehabilitation also included the introduction of additional activities such as:

1. Stabilisation of the sitting position – using the "feedback stabilisation" technique; trunk muscles responsible for the maintenance of the body in vertical position were stimulated and strengthened;
2. Asymmetrical movements of the pelvis back and forward, in the sitting position – the so-called "walking on buttocks", where the patient approaches the edge of the couch and then moves backwards. By per-

Table 1

Elements of therapy conducted by PNF method

Initial position	Basic principles	Techniques	Movement patterns
1. lying on the healthy side	– manual contact – verbal contact – manual resistance – movement patterns	– rhythmic movement initiation	– posterior lowering of the scapula – anterior lowering of the pelvis
2. supine	– manual contact – verbal contact – manual resistance – movement patterns	– rhythmic movement initiation	– flexion, abduction, external rotation (upper limb) – extension, abduction, external rotation (upper limb)
3. supine	– manual contact – verbal contact – visual contact – manual resistance – irradiation – movement patterns – diagonal movement	– movement reproduction	– flexion, abduction, external rotation (upper limb) – extension, abduction, external rotation (upper limb)
4. lying on the healthy side	– manual contact – verbal contact – visual contact – manual resistance – irradiation – movement patterns – diagonal movement	– movement reproduction	– posterior lowering of the scapula – anterior lowering of the pelvis
5. supine	– summation of stimuli – manual resistance – movement patterns	– combination of isotonic contractions	– flexion, abduction, external rotation (upper limb) – extension, abduction, external rotation (upper limb)
6. lying on the healthy side	– summation of stimuli – manual resistance – movement patterns	– combination of isotonic contractions	– posterior lowering of the scapula – anterior lowering of the pelvis
7. supine	– manual contact – verbal contact – manual resistance – movement patterns	– rhythmic movement initiation	– flexion, abduction, internal rotation (lower limb) – extension, abduction, internal rotation (lower limb)
8. supine	– manual contact – verbal contact – manual resistance – movement patterns	– movement reproduction	– flexion, abduction, internal rotation (lower limb) – extension, abduction, internal rotation (lower limb)
9. supine	– manual contact – verbal contact – manual resistance – movement patterns – change of normal movement sequence	– combination of isotonic contractions	– flexion, abduction, internal rotation (lower limb) (emphasizing the effort of the foot using stronger components) – extension, abduction, internal rotation (lower limb) (foot effort reversal)
10. sitting on a chair or couch	– manual contact – verbal contact – manual resistance – irradiation	– combination of isotonic contractions	– flexion, abduction, external rotation (upper limb) – extension, abduction, external rotation (upper limb)
11. sitting on a chair or couch	– manual contact – verbal contact – approximation – manual resistance	– feedback stabilisation	– maintenance of the correct sitting position – emphasizing scapular and pelvic patterns exercised in a low position
12. standing	– approximation – manual resistance – visual contact	– rhythmic movement initiation – movement reproduction	– learning to transfer from the sitting to standing position
13. standing	– approximation – manual resistance – visual contact	– feedback stabilisation	– exercises performed in order to emphasise the correct position assumed by the patient
14. standing	– manual contact – verbal contact – visual contact – manual resistance – irradiation – summation of stimuli	– rhythmic movement initiation – movement reproduction	– learning to move the limb up during walking – learning to load the limb during walking
15. standing	– manual contact – verbal contact – approximation – manual resistance	– feedback stabilisation	– learning to stably load the affected limb (primarily during the phase of full load.)

CASE REPORTS

Patient 1

A 60-year old man had a history of left hemisphere intracerebral haemorrhage. Non-systematically treated arterial hypertension had been reported previously. Early rehabilitation was started in the neurological ward on the 2nd day after the disease onset. Prior to the initiation of, during and after the four-week PNF + botulinum toxin therapy programme, the patient attended another rehabilitation centre, where physiotherapy was conducted by means of standard rehabilitation methods (active exercises of the lower limbs, active exercises during upper right and lower right limbs relief, active-passive exercises of the upper right extremity, exercises of the lower limbs using the rotor).

The rehabilitation according to the PNF concept with concomitant botulinum toxin application was conducted 1.5 years after the haemorrhagic stroke. Neurological examination performed before the four-week therapy revealed:

- right-sided spastic hemiparesis and the talipes equinovarus,
- right upper limb paresis of large degree,
- moderate right lower limb paresis,
- right-sided central facial weakness,
- slight sensorimotor aphasia,
- right lower limb spasticity within plantar flexors of the foot – grade 3 in the modified Ashworth scale[19].

The patient was independent; however, gait disturbances were present – the patient complained about problems with walking up and down the stairway. Sporadically, he used the elbow crotch.

Botulinum toxin was given with the aid of electromyographic identification of muscles' motor points. A total of 1500 units of Dysport were administered. The preparation was applied into the following muscles: gastrocnemius – 1000 units (4 injections), tibialis posterior – 300 units (2 injections), tibialis anterior – 200 units (2 injections). The patient received the BTX A for the first time in his life. No undesirable effects occurred. The relaxation effect was maintained for four months following administration of the medicinal product. The rehabilitation was started on the following day after botulinum toxin application. During the four-week kinesitherapy, a slight decrease in the paretic lower limb muscle tone was observed beginning with the 8th day of exercises, which enabled performance of the planned motor tasks with a greater range of motion. An improvement in patient's gait, both on a flat surface and on a stairway was observed. The patient began trials of walking on a stairway with an alternating gait.

Results of the testing

Knee joint range of motion (Figure 1)
In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:

- 32.9° (50.6% of the physiological range of motion during gait) during unsupported gait,
- 30.0° (46.2% of the physiological range of motion during gait) during supported gait,

These results indicate a significant reduction of the active movement in the knee joint.

In the second testing, the amplitude of angular changes was:

- 39.0° (60% of the physiological range of motion during gait) during unsupported gait – an increase by 18.5% as compared to the first testing,
- 41.1° (63.2% of the physiological range of motion during gait) during supported gait – an increase by 37% as compared to the first testing.

Use of the combined therapy was therefore associated with an improvement in the range of motion.

In the third testing, further increase in the amplitude of angular changes was observed:

- 42.4° (65.2% of the physiological range of motion during gait) during unsupported gait – an increase by 9.5% as compared to the second testing and by 28.7% in comparison to the first testing,
- 45.0° (69.2% of the physiological range of motion during gait) during supported gait – an increase by 9.5% as compared to the second testing and by 50% in comparison to the first testing.

During capturing the unsupported gait, the patient showed great hesitation during moving the limb up, whereas using the elbow crotch support allowed the patient to move according to the learned motion pattern.

Ankle joint range of motion (Figure 2)
In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:

- 18° (60% of the physiological range of motion during gait) during unsupported gait,

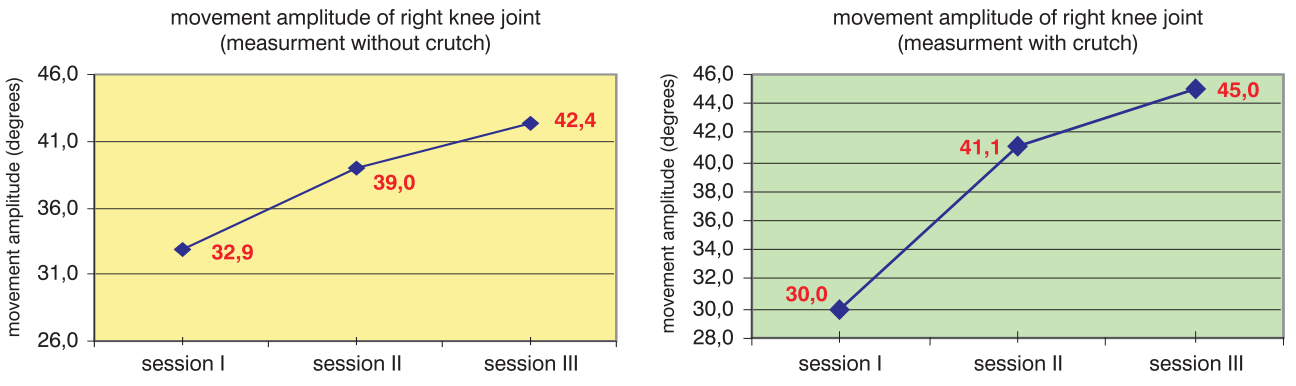


Figure 1
Results of measurements based on amplitude of angular changes in knee joint – Patient 1

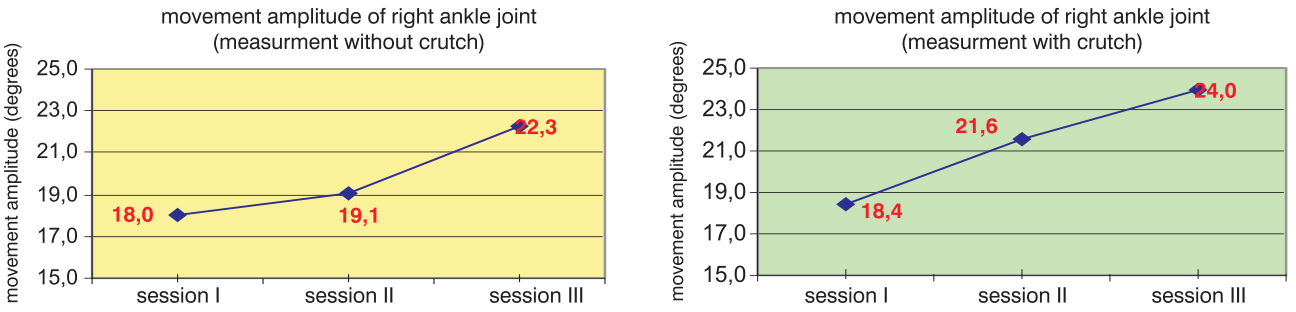


Figure 2
Results of measurements based on amplitude of angular changes in ankle joint – Patient 1

– 18.4° (61.3% of the physiological range of motion during gait) during supported gait.

In the second testing, the amplitude of angular changes was:

– 19.1° (63.7% of the physiological range of motion during gait) during unsupported gait – an increase by 6.1% as compared to the first testing,
– 21.6° (72% of the physiological range of motion during gait) during supported gait – an increase by 17.4% as compared to the first testing.

Use of the therapy was associated with a slight improvement in the range of motion.

In the third testing, further increase in the amplitude of angular changes was observed:

– 22.3° (74.3% of the physiological range of motion during gait) during unsupported gait – an increase by 16.8% as compared to the second testing and an increase by 23.9% in comparison to the first testing,
– 24° (80% of the physiological range of motion during gait) during supported gait – an increase by 11.1% as compared to the second testing and an increase by 30.4% in comparison to the first testing.

Patient 2

A 67-year old man had a history of ischaemic stroke in the territory of the right middle cerebral artery; and a history of paroxysmal atrial fibrillation, prostatic hypertrophy, and glaucoma. Early rehabilitation was started in the neurological ward on the 2nd day after the disease onset. Prior to commencing the four-week PNF + botulinum toxin therapy programme, and after its termination, the patient was irregularly subjected to rehabilitation according to standard methods (active exercises of the relieved left lower limb, exercises of the lower extremities using the rotor, assisted exercises during upper limbs relief, active-passive exercises of the paretic limbs). During the four weeks of therapy, the patient did not have any rehabilitation treatment in other centres.

The rehabilitation according to the PNF concept with concomitant botulinum toxin administration was conducted 2 years after the ischaemic stroke. Neurological examination performed before the four-week therapy revealed:

– left-sided spastic hemiparesis,
– left upper limb paresis of large degree,
– slight left lower limb paresis with talipes equinovarus,
– significant disturbances within the shoulder and elbow joints due to contractures induced by spasticity and pain,
– left lower limb spasticity within plantar flexors of the foot – grade 2.5 in the modified Ashworth scale[19].

The patient was independent, using the elbow crotch during walking. During the maximum limb-loading phase of the gait, hyperextension in the knee joint was present.

Botulinum toxin was administered with electromyography-assisted identification of muscles' motor points. A total of 1500 units of Dysport were administered. The preparation was applied into the following muscles: gastrocnemius – 1000 units (4 injections), tibialis posterior – 300 units (2 injections), tibialis anterior – 200 units (2 injections). The patient received the BTX A for the first time in his life. No undesirable effects were present. The relaxation effect was maintained for four months following administration of the preparation. The rehabilitation was started on the following day after botulinum toxin application. During the four-week kinesitherapy, a slight decrease in spasticity of the paretic lower limb was observed beginning with the 12th day of exercises. The dorsal flexion of the paretic foot was facilitated. Patient's gait was improved both on a flat surface and on a stairway. The hyperextension of the paretic limb in the knee joint was still present during the maximum limb-loading phase.

Results of the testing

Knee joint range of motion (Figure 3)

In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:

– 28.8° (44.3% of the physiological range of motion during gait) during unsupported gait,
– 24.8° (38.2% of the physiological range of motion during gait) during supported gait,

The results indicate a significant reduction of the active movement in the knee joint.

In the second testing, the amplitude of angular changes was:

– 31.6° (48.6% of the physiological range of motion during gait) during unsupported gait – an increase by 9.7% as compared to the first testing,
– 29.2° (44.9% of the physiological range of motion during gait) during supported gait – an increase by 17.7% as compared to the first testing

During the therapy, gait-associated motion range improved.

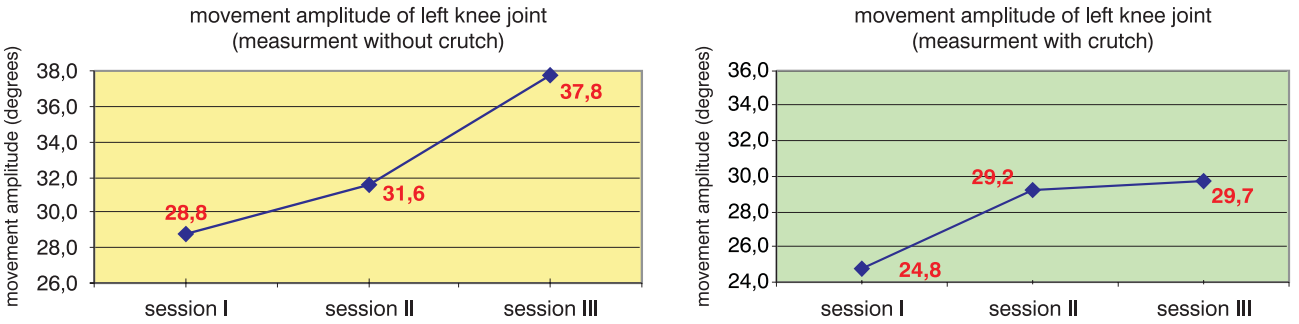


Figure 3

Results of measurements based on amplitude of angular changes in knee joint – Patient 2

In the third testing, further increase in the amplitude of angular changes was observed:

- 37.8° (58.2% of the physiological range of motion during gait) during unsupported gait – an increase by 19.6% as compared to the second testing and an increase by 31.3% in comparison to the first testing,
- 29.7° (45.7% of the physiological range of motion during gait) during supported gait – an increase by 1.7% as compared to the second testing and an increase by 19.8% in comparison to the first testing.

Ankle joint range of motion (Figure 4)

In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:

- 13.7° (45.7% of the physiological range of motion during gait) during unsupported gait,
- 15.5° (51.7% of the physiological range of motion during gait) during supported gait.

In the second testing, the amplitude of angular changes was:

- 15.3° (51% of the physiological range of motion during gait) during unsupported gait – an increase by 11.7% as compared to the first testing,
- 14.9° (49.7% of the physiological range of motion during gait) during supported gait – a decrease by 3.9% as compared to the first testing.

In the third testing, a significant increase in the amplitude of angular changes was observed:

- 19.4° (64.7% of the physiological range of motion during gait) during unsupported gait – an increase by 26.8% as compared to the second testing and an increase by 41.6% in comparison to the first testing,
- 24.6° (82% of the physiological range of motion during gait) during supported gait – an increase by 65.1% as compared to the second testing and an increase by 58.7% in comparison to the first testing.

Patient 3

A 67-year old man had a history of ischaemic stroke in the territory of the right middle cerebral artery; and a history of paroxysmal atrial fibrillation and arterial hypertension. Rehabilitation was started in the neurological ward on the 1st day of the disease. Prior to the initiation of the four-week PNF therapy, the patient had physiotherapy in a rehabilitation ward (a four-week hospitalisation) according to standard rehabilitation methods (self-assisted exercises, exercises during relief, passive exercises, active-passive exercises, learning to walk with the tripod), and subsequently, he had a periodic rehabilitation according to the PNF concept conducted at patient's home. After termination of the four-week therapy, the rehabilitation was continued at patient's home according to the principles of the PNF method. During the four weeks of the therapy, the patient did not attend other rehabilitation centres.

The four-week PNF rehabilitation cycle was started 9 months after the ischaemic stroke. Botulinum toxin was not used. Neurological examination before the initiation of the four-week therapy revealed:

- left-sided spastic hemiparesis,
- severe distal spasticity in the left upper limb,

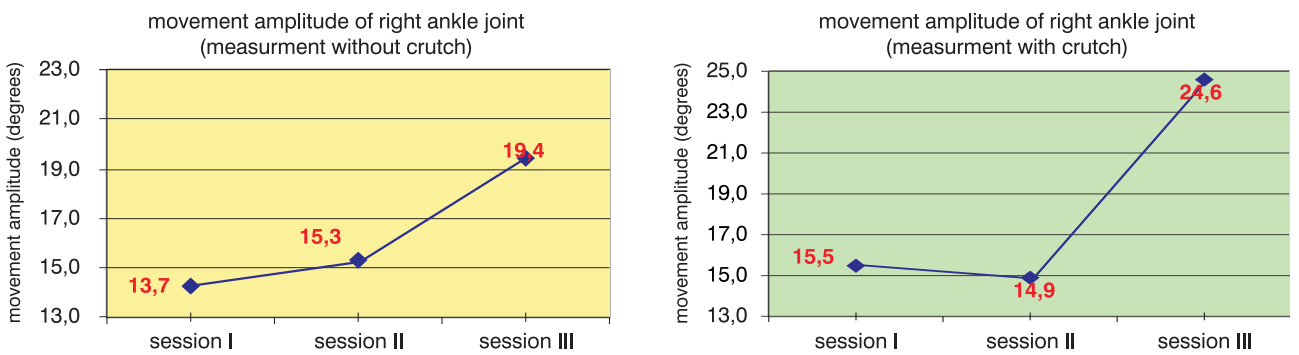
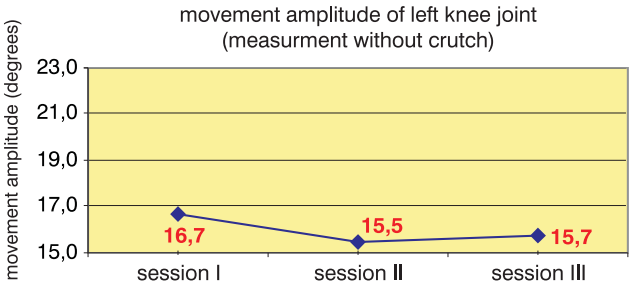


Figure 4

Results of measurements based on amplitude of angular changes in ankle joint – Patient 2



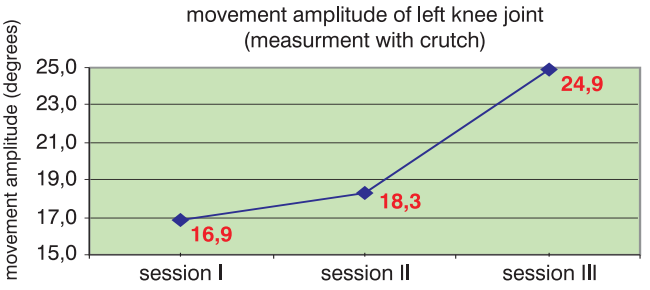


Figure 5
Results of measurements based on amplitude of angular changes in knee joint – Patient 3

– left upper limb paresis of large degree,
– moderate left lower limb paresis,
– aggravated spasticity within the plantar flexors of the toes, particularly during walking,
– left lower limb spasticity within plantar flexors of the foot – grade 3 in the modified Ashworth scale[19].

The patient was independent, using the elbow crotch during walking.

The foot was secured from dropping by means of the DAFO[D] device. Most pronounced gait disturbances were observed in the patient during the phase of moving the paretic limb up.

Results of the testing

Knee joint range of motion (Figure 5)
In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:
– 16.7° (25.7% of the physiological range of motion during gait) during unsupported gait,
– 16.9° (26% of the physiological range of motion during gait) during supported gait.

In the second testing, the amplitude of angular changes was:
– 15.5° (23.8% of the physiological range of motion during gait) during unsupported gait – a decrease by 7.2% as compared to the first testing,
– 18.3° (28.2% of the physiological range of motion during gait) during supported gait – an increase by 8.3% as compared to the first testing.

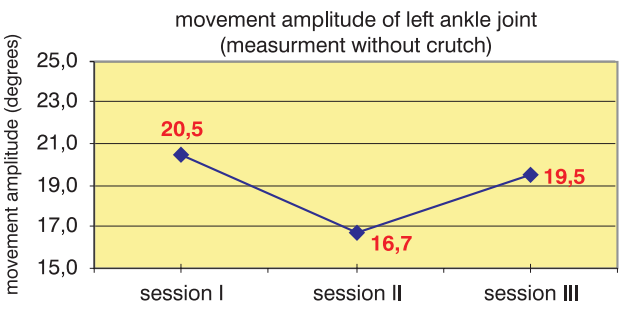
In the third testing, the amplitude of angular changes was:
– 15.7° (24.2% of the physiological range of motion during gait) during unsupported gait – an increase by 1.3% as compared to the second testing and a decrease by 6% in comparison to the first testing,
– 24.9° (38.3% of the physiological range of motion during gait) during supported gait – an increase by 36.1% as compared to the second testing and an increase by 47.3% in comparison to the first testing.

Trials performed when the patient was using crotch support, demonstrated the highest increment in the knee joint range of motion.

Ankle joint range of motion (Figure 6)
In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:
– 20.5° (68.3% of the physiological range of motion during gait) during unsupported gait,
– 21.9° (73% of the physiological range of motion during gait) during supported gait.

In the second testing, the amplitude of angular changes was:
– 16.7° (55.7% of the physiological range of motion during gait) during unsupported gait – a decrease by 18.5% as compared to the first testing,
– 23.4° (78% of the physiological range of motion during gait) during supported gait – an increase by 6.8% as compared to the first testing.

In the third testing, an improvement was observed and the amplitude of angular changes was:
– 19.5° (65% of the physiological range of motion during gait) during unsupported gait – an increase by 16.8% as compared to the second testing and a decrease by 4.9% in comparison to the first testing,
– 26° (87% of the physiological range of motion during gait) during supported gait – an increase by 11.1% as compared to the second testing and an increase by 18.7% in comparison to the first testing.



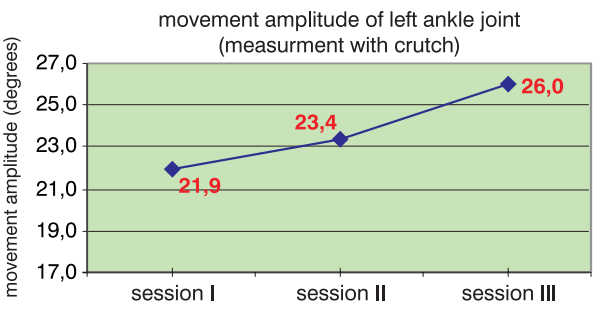


Figure 6
Results of measurements based on amplitude of angular changes in ankle joint – Patient 3

[D] DAFO device – a polypropylene shell preventing foot drop, used as a shoe insert

Patient 4

A 43-year old man with a history of surgery due to a DNT (dysembryoblastic neuroepithelial tumour) brain tumour of the left temporal lobe, complicated by an ischaemic stroke in the territory of the left anterior choroid artery. He also had a history of complex partial seizures. Early rehabilitation was started in a hospital ward on the 1st day of the disease. Rehabilitation was conducted according to the NDT-Bobath and the PNF concepts. Prior to commencing the four-week PNF therapy programme, the patient had had physiotherapy in a private rehabilitation office 3 times a week according to the PNF concept. After termination of the four-week therapy, the rehabilitation was continued in a rehabilitation ward and in an outpatient clinic. During this period of time, elements of the PNF and classical methods (exercises in relief, self-assisted exercises, active-passive exercises, manipulation exercises of the upper extremity) were used in the therapy. During the four weeks of the therapy, the patient did not have rehabilitation in other centres.

The four-week cycle of the PNF rehabilitation was started 6 months after the ischaemic stroke. Botulinum toxin was not used. Neurological examination performed before the initiation of the four-week therapy revealed:

- right-sided spastic hemiparesis,
- moderate paresis of the upper limb,
- voluntary movement attempt-induced spasticity aggravation in the hand,
- slight paresis of the lower limb,
- right lower limb spasticity within plantar flexors of the foot – grade 2 in the modified Ashworth scale[19].

The patient was hardly able to dorsiflex his paretic foot. Periodically, he reported occurrence of increased spasticity within the plantar flexors of the foot. He was able to walk independently. When assisted by an accompanying person, the patient was able to walk on a stairway with an alternating gait. Hyperlordosis was observed during gait, and excessive flexion of the paretic limb in the knee joint was seen during the maximum limb-loading phase.

During the measurements, the patient was moving without the crotch all the time.

Results of the testing

Knee joint range of motion (Figure 7)

In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:

- 18.7° (28.8% of the physiological range of motion during gait) during unsupported gait.

In the second testing, the amplitude of angular changes was:

- 24.5° (37.7% of the physiological range of motion during gait) during unsupported gait – an increase by 31% as compared to the first testing.

In the third testing, further improvement of the motion range was observed:

- 28.1° (43.2% of the physiological range of motion during gait) during unsupported gait – an increase by 14.7% as compared to the second testing and an increase by 50.3% in comparison to the first testing.

Ankle joint range of motion (Figure 8)

In the first testing, performed before therapy initiation, the amplitude of angular changes in the joint was:

- 25.9° (86.3% of the physiological range of motion during gait) during unsupported gait.
- 21.9° (73% of the physiological range of motion during gait) during supported gait.

In the second testing, the amplitude of angular changes did not change significantly in comparison to the previous measurement and was:

- 25.4° (84.7% of the physiological range of motion during gait) during unsupported gait – a decrease by 1.9% as compared to the first testing.

In the third testing, the amplitude of angular changes was:

- 30.5° (102% of the physiological range of motion during gait) during unsupported gait – an increase by 20.5% as compared to the second testing and an increase by 18.1% in comparison to the first testing,

DISCUSSION

During the therapy, re-education of patients' gait was especially emphasised. Using the PNF method, an attempt was made to achieve the planned effect via a reduction of spasticity and an improvement in movement coordination. Additionally, two patients were given botulinum toxin injections. In the conducted evaluations, we tried to determine simple markers that could enable estimation of therapy effectiveness both immediately after termination of rehabilitation and after a longer period of time following particular therapeutic actions. The recorded changes in the range of motion in the lower limb joints during walking may serve as a parameter of gait quality evaluation. It was observed that gait quality expressed as amplitude of angular changes in the knee and ankle joints, obtained during the four-week PNF

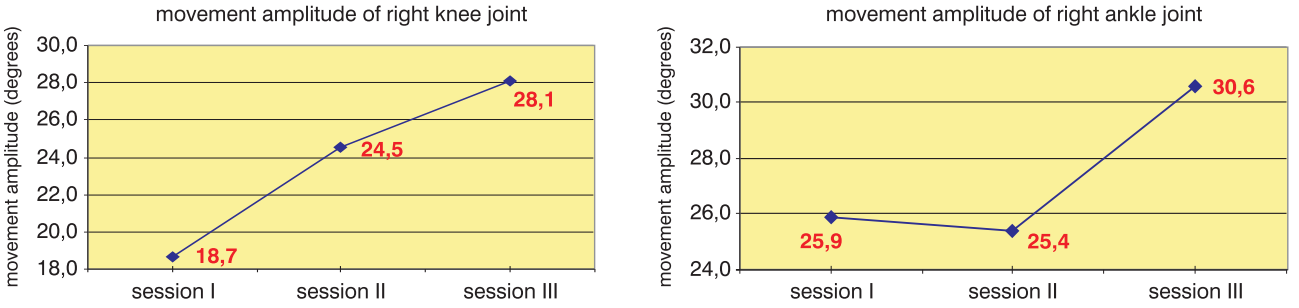


Figure 7, 8
Results of measurements based on amplitude of angular changes in knee joint – Patient 4

therapy programme, was maintained on a similar level or increased during 3 months following the therapy. This may be indicative of an educational effect of the conducted rehabilitation, thanks to which patients were able to introduce the skills learnt during the programme to their every-day activities thus achieving an improvement in their locomotion.

In other studies[5,20,21,22], improvement of gait was demonstrated by means of such factors as gait speed, relative step length or symmetry index, apart from the angular changes in the articulations. In this study, to estimate patient's functional disturbances and to assess the effects of the methods aimed at reducing muscle tone and improving coordination, we focused on the quality and correctness of gait mechanics, whereas gait velocity and step length receded into the background. The elbow crotch-supported gait was also compared to the unsupported gait because of a possible influence of pathological motion patterns, occurring with a greater activity of the non-affected side, on patient's locomotion.

For a more complete picture of changes occurring as a result of the PNF therapy and the combined therapy with concomitant botulinum toxin injection, other markers of patients' functional status, such as e.g. the Barthel index, as well as muscle tone scales such as the modified Ashworth scale[10,19,23] should also be considered.

In this study, a possibility of combining the botulinum toxin and the PNF therapies was presented. Normal course of patients' rehabilitation process and a gradual improvement in the range of motion in the knee and ankle joints was presented. There were no marked differences across the case reports. Unequivocal effects of the combination of the methods were not observed. Theoretical data allow assumption that the combination of botulinum toxin administration and the PNF method is a plausible management[9,12,13]. Application of the combined therapies is supposed to facilitate patient's and therapist's efforts towards the re-education of the lost motor function via a temporary reduction in spasticity. Expectations associated with the combination of these therapies include mainly the possibility to maintain and consolidate the effect of rehabilitation involving reproduction of normal motion patterns, reduction of pathological movements induced by spasticity of the paretic limbs, and an improvement in patients' quality of life by reducing disturbances of functioning.

As there are no clinical studies on the effects of the combined PNF and botulinum toxin therapy on the adult post-stroke patients' rehabilitation process, in the future, it is necessary to plan large, randomised, controlled clinical studies, comparing patients subjected to the PNF method with patients in a similar neurological state treated with the botulinum toxin, and the patients, in whom both methods were used concomitantly. Clinical trials, conducted according to the above assumptions, can allow unequivocal evaluation of and drawing conclusions from such therapy, as well as determine a rehabilitation model that would be of use in comprehensive therapy of stroke sequelae.

Based on the reported cases, conclusions regarding the efficacy of the combined PNF and botulinum toxin therapy cannot be drawn; however, the performed observations may facilitate planning clinical studies on the effects of these methods on the rehabilitation process during the late post-stroke period.

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