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THE TOE SPREAD OUT EXERCISE IN PATIENTS WITH HALLUX VALGUS – PRESENTATION OF TWO CASES

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SUMMARY

Introduction

Hallux valgus (HV) is a common foot disorder which can be a cause of functional disability, including foot pain, stiffness, walking difficulties and shoes wearing. The precise etiology of hallux valgus is unknown. The deformity is multifactorial in origin and includes some intrinsic and extrinsic factors. Some studies suggest that the hallux valgus deformity can be caused by muscle imbalance between abductor hallucis muscle (AbdH) and adductor hallucis muscle (AddH) and that the activity of AbdH muscle during abduction in first metatarsal joint is significantly reduced in patients with hallux valgus compared to healthy people. Therefore, it is recommended to strengthen the AbdH muscle, particularly in mild deformity. The toe spread out exercise is the one of the method to achieve this effect.

Aim

The aim of this study is to present the preliminary results of applying of toe-spread-out exercises in patients with hallux valgus based on neurophysiological study results.

ĆWICZENIE TOE SPREAD OUT U PACJENTÓW Z PALUCHEM KOŚLAWYM – PREZENTACJA DWÓCH PRZYPADKÓW

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STRESZCZENIE

Wstęp

Paluch koślawy (hallux valgus, HV) jest częstym zniekształceniem stóp, które może być przyczyną niepełnosprawności funkcjonalnej, w tym dolegliwości bólowych stóp, sztywności, trudności z chodzeniem i noszeniem obuwia. Dokładna etiologia tego schorzenia jest nieznana. Patogeneza tej deformacji jest wieloczynnikowa i obejmuje szereg czynników wewnętrznych i zewnętrznych. Niektóre badania sugerują, że koślawość palucha może być spowodowana brakiem równowagi mięśniowej pomiędzy odwodzicielem (abductor hallucis, AbdH) a przywodzicielem palucha (adductor hallucis, AddH). Istnieją doniesienia potwierdzające, iż u pacjentów z tym zniekształceniem aktywność odwodziciela palucha podczas ruchu odwodzenia w pierwszym stawie śródstopno-paliczkowym jest znacznie zmniejszona w porównaniu do ludzi zdrowych. W związku z tym zaleca się wzmacnianie tego mięśnia, szczególnie w przypadkach łagodnych deformacji. Jedną z metod dążących do tego efektu jest ćwiczenie toe spread out (TSO).

Cel

Celem niniejszej pracy jest przedstawienie wstępnych wyników dotyczących zastosowania ćwiczenia *toe spread out* u pacjentów z paluchem koślawym na podstawie wyników badań neurofizjologicznych.

Patients and methods

The preliminary study involved two cases of patients with diagnosed hallux valgus who underwent the therapy of toe-spread-out exercise. The patients were examined twice, before and after 14 days of rehabilitation. They did the exercise only unilaterally with 200 repetitions a day. Apart from examinaA tion using goniometer, surface electromyography study (sEMG) recorded from abductor hallucis muscle and electroneurography study (ENG) of motor fibers of tibial nerve and sensory fibers of sural nerve function were performed. The sEMG recordings of maximal voluntary contraction of abductor hallucis muscle were performed three times, during the three consecutive phases of toe-spread-out exercises.

Materiał i metody

Badania wstępne objęły dwa przypadki pacjentów ze zdiagnozowanym paluchem koślawym, którzy poddani zostali terapii z zastosowaniem ćwiczenia TSO. Pacjenci badani byli dwukrotnie, przed i po 14-dniowym okresie rehabilitacji. Wykonywali oni ćwiczenie z częstotliwością 200 powtórzeń dziennie. Poza badaniem z użyciem goniometru wykonywane było także badanie elektromiografii powierzchniowej (sEMG) rejestrowanej z mięśnia odwodziciela palucha oraz badanie elektroneurografii (ENG) oceniającej funkcję włókien ruchowych nerwu piszczelowego oraz włókien czuciowych nerwu łydkowego. Zapisy maksymalnego skurczu mięśnia odwodziciela palucha rejestrowane były trzykrotnie – w trakcie trzech następujących po sobie faz ćwiczenia TSO.

Results

Conduction of nerve impulses in the tibial and sural nerves in both patients was proper and comparable during the ENG study in two stages of observation. In sEMG study the slight increase of the value of amplitude and more significant increase of the motor units recruitment during maximal contraction of left (the exercised side) abductor hallucis muscle have been recorded in the first patient after the therapy. The result of sEMG study in the second patient drew attention to asymmetry in bioelectrical activity of muscles with reduced interference pattern in the right abductor hallucis muscle only in the first test and in the first two phases of TSO exercise. The marked improvement of the interference pattern and symmetry of muscle contraction in the three phases of TSO exercise have been presented in the second stage of observation.

Wyniki

W badaniu ENG obydwóch pacjentów nie zaobserwowano zmian w zakresie funkcji nerwu piszczelowego oraz nerwu łydkowego pomiędzy pierwszym a drugim badaniem. W badaniu sEMG pierwszego pacjenta zarejestrowano po terapii nieznaczny wzrost amplitudy zapisu oraz zwiększenie rekrutacji jednostek ruchowych podczas maksymalnego skurczu ćwiczonego lewego mięśnia odwodziciela palucha. W wynikach badania sEMG drugiego pacjenta zwraca uwagę asymetria w zakresie czynności bioelektrycznej mięśni na niekorzyść prawego odwodziciela palucha jedynie w pierwszym badaniu i w dwóch pierwszych sekwencjach ćwiczenia TSO. W badaniu drugim obecna jest wyraźna poprawa zapisu interferencyjnego oraz powrót symetrii czynności bioelektrycznej mięśni w trzech sekwencjach ćwiczenia TSO.

Conclusions

The preliminary results can confirm necessity of providing studies on the TSO exercise in activating the AbdH in patients with hallux valgus based on results of sEMG study.

Wnioski

Rezultaty wstępne mogą potwierdzać konieczność kontynuowania badań nad zasadnością stosowania ćwiczenia toe spread out u pacjentów z paluchem koślawym pod

There were no differences in the function of the lower extremity nerves studied before and after 14-days interventions of TSO exercises. Conduction velocity as well as the value of the compound action potential amplitude were similar in two periods of observation in ENG study. The further researches including a greater number of subjects and research method such as pain assessment or range of motion are required.

względem aktywizacji mięśnia odwodziciela palucha. Nie zaobserwowano różnic w funkcji nerwów kończyny dolnej porównując okres przed i po 14-dniowej terapii z użyciem ćwiczenia TSO. Badania ENG wykazały, iż szybkość przewodzenia oraz wartość amplitudy złożonego potencjału wywołanego na dwóch etapach obserwacji były podobne. Potrzebne są dalsze badania obejmujące większą liczebność grup badanych, które wykorzystywać będą dodatkowo takie metody badawcze jak ocena bólu i zakres ruchu w stawach palucha.

Keywords: hallux valgus, toe spread out exercise, abductor hallucis muscle, electromyography, electroneurography

Słowa kluczowe: paluch koślawy, ćwiczenie *toe spred out*, odwodziciel palucha, elektromiografia, elektroneurografia

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Introduction

Hallux valgus (HV) is a common foot disorder which can be a cause of functional disability, including foot pain, stiffness, walking difficulties and shoes wearing. It is described as lateral deviation of the great toe at the metatarsophalangeal joint. However, hallux valgus involves frequently a deviation of the first metatarsal bone towards the longitudinal axis of the foot, a deformity on the phalangeal bone and interphalangeal joint, and pronation of the big toe with sesamoid subluxation (Lee *et al.* 2012).

The diagnosis of hallux valgus deformity is based on clinical assessment and X-ray evaluation taking into account the hallux valgus presence when the hallux abductus angle (angle formed between the longitudinal bisections of the first metatarsal and proximal phalanx) is greater than 15° on the anterior-posterior projection (Hardy and Clapham 1951; Piggott 1960; D'Arcangelo *et al.* 2010).

The meta-analysis showed that prevalence of this deformity is 23% among adults aged 18 to 65 years. It increased with age (36% in elderly people aged over 65 years) and is higher in females (30%) compared to males (13%) (Nix *et al.* 2010).

The precise etiology of hallux valgus is unknown. The deformity is multifactorial in origin and includes some intrinsic and extrinsic factors such as high-heeled narrow shoes, excessive weight-bearing, genetic factors, ligamentous laxity, metatarsus primus varus, pes planus, functional hallux limitus, sexual dimorphism, age, abnormal metatarsal morphology, first-ray hypermobility and tight Achilles tendon (Perera *et al.* 2011).

There are a lot of interventions, which can relieve patients with hallux valgus. They are divided into conservative and surgical treatment with over 150 different procedures (Wülker and Mittag 2012). The non-operative treatment includes apart from physical therapy following methods: exercises (Schuh *et al.* 2009; Jedynak 2009; Bayar *et al.* 2011; Kim *et al.* 2013; Kim *et al.* 2015), manual therapy (Bek and Kurklu 2002, Schuh *et al.* 2009, du Plessis *et al.* 2011), gait training (Schuh *et al.* 2009), taping (Jeon *et al.* 2004; Bayar *et al.* 2011)

and orthosis (Bek and Kurklu 2002; du Plessis *et al.* 2011). The available researches reported their beneficial effects in hallux valgus therapy and the most frequently observed results were reductions in pain and improvements in function.

There are also reported (Eustace *et al.* 1996; Incel *et al.* 2003) that the hallux valgus deformity can be caused by muscle imbalance between abductor hallucis (AbdH) and adductor hallucis (AddH). Some studies (Iida and Basmajian 1974; Incel *et al.* 2003) suggest that the bioelectrical activity of AbdH muscle during abduction in first metatarsal joint was significantly reduced in patients with hallux valgus compared with a control group. Therefore, it is recommended to strengthen the AbdH muscle, particularly in mild deformity (Groiso 1992; Incel *et al.* 2003). This insintric muscle participates in the abduction and less in flexion of the great toe and supports medial longitudinal arch. The AbdH stretches medially along the border of the sole, from the medial process of posterior calcaneal tuberosity and flexor retinaculum to the medial aspect of base of proximal phalanx of big toe via medial sesamoid (Chittoria *et al.* 2015).

In literature and practice of physiotherapy and sport a lot of exercises for strengthe ening the foot intrinsic muscles are known and applied, for example: short foot exercise, toe towel curls, catching and moving the objects with feet, tearing a piece of paper, toe-spread-out exercise. A few researches refer to assess the exercises in patients with hallux valgus and their effect on activity of AbdH muscle. Jung *et al.* (Jung *et al.* 2011) showed that the activity of the AbdH muscle in the short foot exercise was significantly greater than during a toe curl exercise. On the other hand, Kim *et al.* (Kim *et al.* 2013) compared short foot exercise with toe curl exercise and received significantly greater activation of the AbdH during toe spread out exercise than during the short foot exercise.

Aim

The aim of this study is to present the preliminary results of applying the toe-spread-out exercises in patients with hallux valgus based on neurophysiological study results.

Material and methods

The research material included patients from Daily Rehabilitation Ward in Wiktor Dega Orthopaedic and Rehabilitation Clinical Hospital in Poznań. The preliminary study involved two patients with diagnosed hallux valgus who underwent the therapy of toe-spread-out exercise. Action aimed to increase the number of groups is still in progress.

The inclusion of the patient to the research group took place on the basis of the Manchester scale and clinical examination using a goniometer. The Manchester scale includes 4 standard photographs (A, B, C, D) which allow to diagnose the severity of hallux valgus. The investigator assesses which photography is the most similar to the subject. The photograph "A" shows the lack of distortion and others ("B", "C", "D") indicates the increasing degrees of valgus. A clinical examination using a goniometer was performed in the standing position of the patient. The examiner measured the angle of hallux valgus applying arms of the goniometer to the medial edge of the big toe and the medial edge of the foot.

The inclusion criterion in the research group was the degree of deformity assessed in the Manchester scale as "B", "C" or "D", confirmed by the hallux valgus angle measurement using a goniometer with result above 15°. In order to unify the group and to exclude people having other illnesses which could have influence on the weight-bearing patterns of the foot, the following exclusion criteria were established: grade A in Manchester scale, angle equal or below 15° result in the measurement using goniometer, serious injury or underwent surgery of the lower limb, the presence of pain from disc disease on the background

of the disco radicular conflict, neuropathy, myopathy, rheumatoid arthritis, psoriatic arthritis, connective tissue diseases, stroke or other neurological diseases in history.

After inclusion in the research group the patient and its deformity were evaluated on the basis of X-ray images taken in weight-bearing conditions in a standing position in the anterior-posterior projection. The result above 15 degrees of hallux valgus angle confirmed diagnosis of hallux valgus and the result below this value was another criterion for exclusion from the research group.

Two subjects with hallux valgus were rehabilitated by toe-spread-out exercises which lasted 14 days. This exercise was performed under the supervision of a qualified physiotherapist. The starting position of the toe-spread-out exercise was sitting position with the knee joint and hip bent 90 degrees. The exercise consisted of 3 consecutive phases (Figure 1): dorsiflexion of the toes keeping the metatarsal heads and the heel on the ground, moving the fifth toe down and to the lateral direction, moving the great toe down and abduction. The final position should be maintained for 5 seconds. The whole was repeated in the number of 200 a day.

The patients were examined twice: before and after 14 days of rehabilitation. Apart from examination using goniometer, surface electromyography study (sEMG) recorded from abductor hallucis muscle and electroneurography study (ENG) of motor fibers of the tibial nerve and sensory fibers of the sural nerve function were performed.

For this purpose, the KeyPoint System (Medtronic A/S, Skovlunde, Denmark) and appropriate to the type of neurophysiological studies set of electrodes (surface electrodes, bipolar stimulating electrode, grounding electrode) are used.

In the ENG the following parameters of CMAP (compound muscle action potential) from the tibial nerve and of SNAP (sensory nerve action potential) from the sural nerve are analysed: amplitude (measured from negative inflection to baseline in mV or in μV), latency (measured in ms) and conduction velocity (measured in m/s). During ENG examinations the time base on 5ms/D and sensitivity of recordings on 2mV/D are set. 10Hz upper and 10kHz lower filters of recorder amplifier are used.

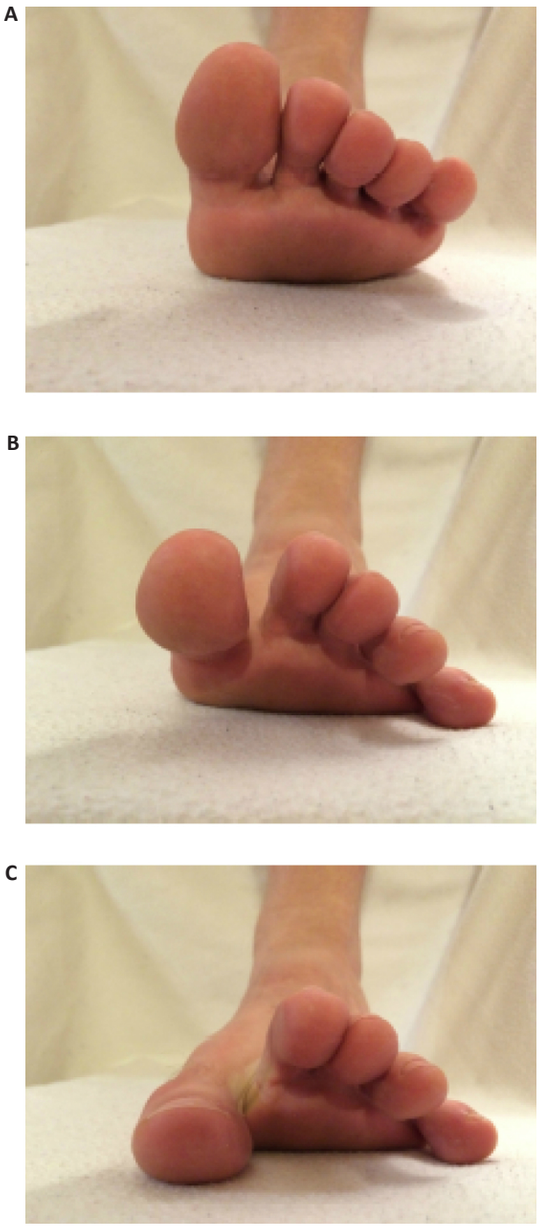

Figure 1. The phases of TSO exercise. A – dorsiflexion of the toes keeping the metatarsal heads and the heel on the ground, B – moving the fifth toe down and to the lateral direction, C – moving the great toe down and abduction.

In order to record the compound muscle action potentials (CMAP) evoked from abductor hallucis muscle, standard (Ag/AgCl) surface electrodes are used. The active electrode is placed on the muscle belly, while the reference electrode over the great toe. The electrical stimulation of the tibial nerve is applied in two points: below medial malleolus and in the popliteal fossa. The ground electrode is located in the plantar part of the foot. Single rectangular stimuli with a duration of 0.2ms are deliv0 ered via bipolar electrode at 1Hz frequency while their intensity ranged from 30mA to the value evoking the supramaximal cm AP. For recordings of SNAP from sural nerve antidromic and repetitive electrical stimulation with intensity of 20mA is required. Recording electrodes are placed near lateral malleolus while stimulating point is 15 cm proximally at the external border of Achilles tendon (Stålberg and Falck 1993).

For the analysis of bioelectrical activity of the selected muscle standard disposable Ag/AgCl surface electrodes with the active surface 5mm² are used. The active electrode (cathode) is applied on the muscle belly of the abductor hallucis muscle and the reference electrode (anode) is located 3 cm distally to the active electrode. During sEMG examinations the time base on 80ms/D and sensitivity of recordings on 0.5mV/D are set. Upper 10kHz and lower 20Hz filters of recorder amplifier are used. The sEMG recordings are performed three times: during the three consecutive phases of toe-spread-out exercise. These tests are aimed to analyze the following parameters: value of amplitude during maximal muscle contraction (measured in mV), the frequency of recruitment of motor unit action potential (MUAP) during maximal contraction of muscle (interference pattern) and the symmetry of muscle activity during maximal muscle contraction in three phases of TSO. For the calculation of amplitude value (range and standard deviation) results from three values of MUAP amplitude recorded in one representative trial are analyzed.

Results

The preliminary results of this study are based on outcome of two patients with diagnosed hallux valgus. The first is a womg an, 28 years old, with hallux valgus angle: 16° on the left foot and 21° on the right (measured on the base of X-ray image in anterior-posterior projection). The patient did the toe-spread-out exercise only on left foot. The results of ENG and sEMG study are showed in Figure 2 and 3 respectively.

In the ENG study no change in neural transmission of the tibial and sural nerve between the first and the second tests have been observed (Figure 2). The sEMG study shows significant asymmetry of bioelectrical activity of muscles with lower amplitude and reduced interference pattern on the left side (Figure 3). It was presented at both stages of observation in all sequences of TSO exercise. In the second study a slight increase of the amplitude value and more significant increase in the recruitment of motor units during maximal contraction of left abductor hallucis muscle have been recorded.

The second patient is a 64 years woman, with hallux valgus angle: 30° on the left foot and 38° on the right (measured on the base of X-ray image in anterior-posterior projection). The patient did the toe-spread-out exercise only on right side. The results of ENG study did not deviate from the norm and were comparable in two stages of observation. The results of sEMG study are shown in Figure 4.

The sEMG study draws attention to asymmetry in bioelectrical activity of muscles with lower value of amplitude and reduced interference pattern in the right abductor hallucis muscle only in the first period of observation (Figure 4A) and in the first two phases of TSO exercise (Figures 4A 1, 2). In the second study a marked improvement of muscle maximal contraction (increase

ENG studies – Tibial Nerve

	Right				Left		
1	dLAT/CV	AMP	AREA		dLAT/CV	AMP	AREA
	3.4	20.5	32.9	Ankle	4.0	19.0	33.5
	55.3 m/s	-13 %	-8 %		46.6 m/s	-15 %	-8 %
	11.0	17.7	30.4	Knee	12.8	16.1	30.9
2							
	3.5	20.1	44.3		3.5	25.5	50.8
	55.7 m/s	-11 %	-7 %		49.4 m/s	-42 %	-33 %
	10.5	18.0	41.0		11.8	14.8	34.2

ENG studies – Sural Nerve

	LAT	CV	AMP	LAT	CV	AMP
1	3.1	66.7	18	3.0	56.2	17
2	2.3	72.7	25	2.4	57.8	21

Figure 2. Example of data of ENG study obtained from one of the patient. 1 – the first examination before exercises, 2 – the second examination after therapy.

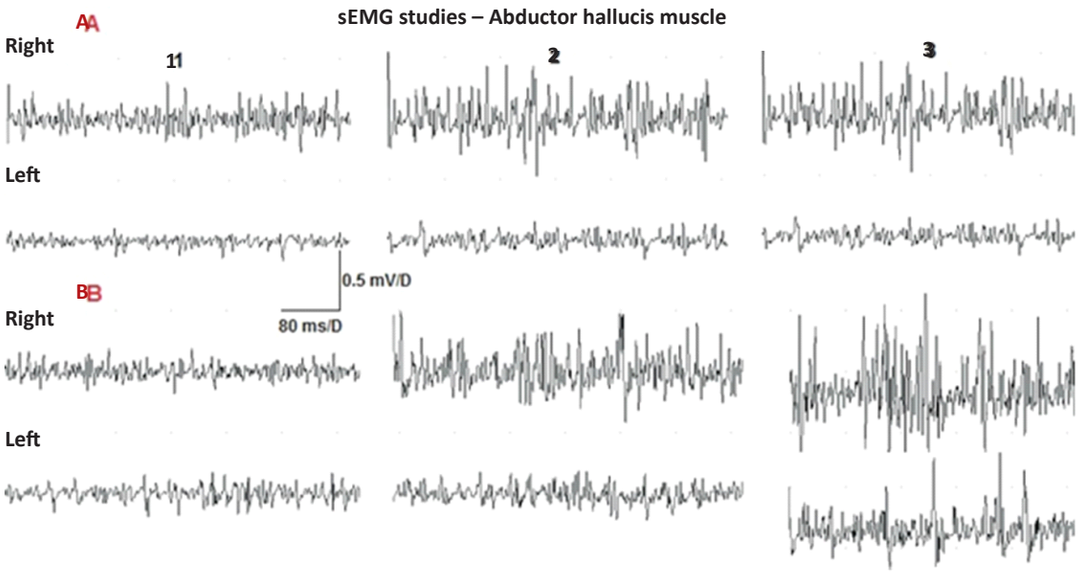

Figure 3. Examples of sEMG recordings performed in first patient at subsequent stages of observation. A – the first examination before exercises, B – the second examination after therapy, 1–3 – the phases of TSO exercise).

amplitude and full interference pattern) and symmetry in the three phases of TSO exercise have been observed. In addition, notes also the improvement the function of the AbdH muscle on the left side in second periods of observation as the example of muscle synergy.

Discussion

Action aimed to increase the number of group is still in progress, also taking into account the control groups including patients without the deformity (doing exercises) or patients with hallux valgus without the implementation of any therapy.

Current results do not yet allow to perform advanced inference but these two presented cases initially indicate the direction of research on the TSO exercise in activating the AbdH in patients with hallux valgus. That agrees with study results of Kim *et al.* (Kim *et al.* 2013). As it was expected, there was no difference in ENG results between the first examination and after 14 days of exercises.

Interesting fact is that after doing exercise unilateral, the amplitude and the frequency of MUAP increased also on the untreated side. It was observed that in some subjects during recording of the unilateral activation of AbdH the opposite side demonstrated bioelectrical activity.

The authors of this article realize that in order to talk about the assessment of the effectiveness of TSO exercise other research methods must be taken into account. It would be worthwhile to check after doing exercises the change in range of motion in the first MTP, hallux valgus angle, pain or comfort in wearing shoes. The EMG and ENG studies should be only part of assessment.

There is a study (Kim *et al.* 2015) which showed the effectiveness of TSO exercise in reduction of the hallux valgus angle as well as in the hallux valgus angle during active abduction. These researchers noted also increase in the cross-sectional area of the abductor hallucis muscle. However, the authors perceived the limitation in their study. The subjects were relatively young (mean age = 23 years) and had only mild to moderate HV. Therefore, additional research examining the effects of TSO exercise on different age groups, and in severe HV cases, is required.

Another work (Goo *et al.* 2014) refers to EMG activity of the AbdH during TSO exercise using different weight bearing postures. The results of this study suggests that a weight bearing posture such as standing is the most effective method of increasing the EMG activity of AbdH in the TSO exercise.

The TSO exercise was recommended not only in patients with hallux valgus. It can be used for strengthening the medial longitudinal what reports Heo *et al.* (Heo *et al.* 2011).

This article was also intended to present an interesting kinesiotherapy method as a kind of conservative treatment of hallux valgus. Even if a physiotherapist knows which exercise can be used in patients with hallux valgus, he should know what is its effectiveness and if it is confirmed by evidence based medicine. It can be problematic cause of a small number of prospective randomized trials assessing conservative treatments (Wülker and Mittag 2012). Presumably it is a reason that conservative treatment is treated with neglect and its effectiveness in hallux valgus deformity is often ignored.

Conclusions

- The preliminary study can confirm necessity of providing studies on the TSO exercise in activating the AbdH in patients with hallux valgus based on results of sEMG study.
- There were no differences in the function of the lower extremity nerves studied before and after 14-days interventions of TSO exercises.
- The further researches including a greater number of subjects and research method such as pain assessment or range of motion are required.

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