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Specialized Manual Therapy Techniques Which Can Improve Neuromotor Outcome in Patients with Foot-Drop Syndrome

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Abstract: ***Introduction:*** *Functional rehabilitation of foot-drop syndrome due to lumbar disc herniation it is a problem that concerns many researchers. Study objective was to investigate if specialized manual therapy techniques and functional electrical stimulation alone and combined can influence the overall neuromotor outcome.*
Methods*: 90 subjects were randomized to 3 groups, 30 subjects allocated to control group (CG) which received physical therapy, 30 subjects in functional electrical stimulation group (FES) and 30 subjects in combined FES with manual therapy techniques (FES-MT). All groups received a number of 20 sessions. We evaluated nerve conduction study, dynamometry, goniometry, functional ankle disability index (FADI), Oswestry Disability Index (ODI) and Numeric Rating Scale (NRS).*
Results: *For Compound muscle action potential we have found significant modifications when comparing FES-MT vs CG ($p<0.011$). For dynamometry we registered as follows: FES-MT vs CG (0.0001), FES-MT vs FES ($p<0.003$). ODI and FADI scores were more significant in FES-MT and FES compare with CG.*
Conclusions: *Manual therapy techniques utilized for increasing the excitability of neuromuscular spindle can increase the overall functionality of the tibialis muscle in case of foot drop syndrome. The combination between FES and MT showed better functional results than physical therapeutic exercises and FES alone.*

Keywords: *Manual therapy, electrical stimulation, foot-drop, nerve regeneration.*

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Introduction

The main cause of lower back pain is intervertebral disc degeneration and herniation, Corniola et al. (2014). This pathology occurs when nucleus pulpous degenerates, losing its physical properties and moving to the spine channel, compressing a nerve root, Selkirk and Ruff (2016). Is one of the causes of disability for people over 40 years and the most affected discs are L4-5 due to the fact that they take over and support most of the body weight. Obesity can be a factor that seriously affects long-term health, Mocanu et al. (2023). Treatments are focused on the symptoms alleviation, but finally is indicated lumbar discectomy surgery.

Rehabilitation program that follows after surgical procedure requires a multidisciplinary team, being a complex process, which aims to improve the mobility of the spine, increase the muscular strength of the lower limb and improve ability to walk.

M**anual physical therapy** (MPT) is a method in which physical therapist uses his hands to manipulate joints for reduction muscles tension; restoring spine mobility and provide back pain relief. In general, the techniques are performed over the dermatome or the muscle that needs to be treated. Such techniques comprise in various gestures that are trying to increase the neural excitation of alpha motoneurons by means of activating peripheral reflex arches. The increased excitation of peripheral α motoneuron is perceived by the central nervous system and the patient is able to recover the control over the periphery, Ferreira et al. (2007). The following manual therapy techniques that can influence the excitability of a muscle: brushing, muscle belly tapping, stretch release, repeated stretch.

Beside physical therapy, in some cases, functional electric stimulation (FES) may be appropriate for rehabilitation. FES is a new technique which involves the external activation of the neuromuscular complex with an electric stimulation. The result is a functional act that could not be achieved before. Unlike direct muscle stimulation, FES requires lower stimulus intensities and allows much better adjustments in the level of excitation obtained. Improvements concern both walking parameters (especially speed and energy consumption), as well as more complex aspects such as normalization of kinetic chains and walking symmetry (Melo et al., 2015). Theoretically, FES contributes to increased agonist shrinkage force, increased joint motion freedom, weight distribution improvement, retraining walking (Thrascher & Popovic, 2008).

The aim of this clinical study was to investigate if specialized manual therapy techniques used in neuromuscular rehabilitation practice can influence the overall outcome of patients with foot-drop syndrome.

Methods

The study was carried out in accordance with the Helsinki Declaration. The guide for reporting this randomized control study is in accordance with CONSORT reporting guidelines (Figure 1). An informed consent was obtained from every patient.

Ninety (90) patients with foot drop after surgical decompression of the sciatic nerve were enrolled in our study. The patients were selected after applying the following inclusion criteria's: foot drop syndrome after discectomy; muscular manual force test (MMT) ≤ 3; capacity of signing the informed consent. The exclusion criteria were foot drop syndrome by other etiology.

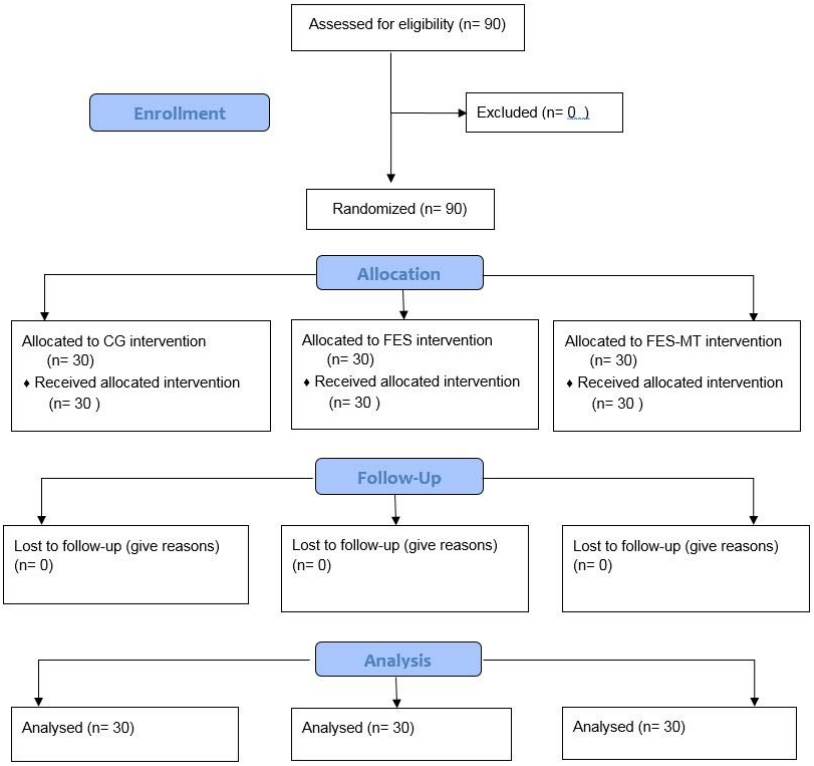

Figure 1. Flow chart of the trial selection process

The participants were allocated randomly in three groups. The randomization was made using a computer number sequencer program. First group (control group = CG) of 30 patients received physical treatment by means of physical therapeutic exercises. The second group of 30 patients beside the standard treatment like control group they received FES triggered by electromyography (EMG). EMG-FES was applied using module from the Chattanooga Intellect Advanced Combo manufactured in United States by DJO Chattanooga in 20 physiotherapy sessions as follows: once a day for 30 minutes during 5 consecutive days for 4 weeks (Sardaru et al., 2018). The third group (FES-MT) of 30 patients beside the standard treatment and EMG-FES they received treatment by manual therapy techniques. The FES-MT group received treatment for 20 sessions (5 days for 4 weeks) consisting in functional electrical stimulation during walking followed by manual therapy techniques. The manual therapy techniques sessions consisted in: fast brushing technique, muscle belly taping, stretch release technique, repeated stretch and a combination of muscle belly taping with repeated stretch technique.

Brushing technique has been described by Margaret Rood as a modality to activate the muscle spindle via the anterior horn cell and the gamma loop. Generalized or local brushing which can be performed manually or electrically may improve muscle activity and patient perception of the muscle group (Metcalfe & Lawes, 1998; Page et al., 2012). The fast-brushing technique was applied over the tibialis anterior muscle and peroneus brevis and longus muscles for five minutes in intervals of 5 second stimulation followed by 30 second pause and then repeated. During the 30 seconds pause the patient was asked to concentrate and activate the dorsiflexion. The tapping on a muscle belly can be a facilitator technique. This determines a localized quick stretching of the muscle fibers that stimulates the myotatic reflex and therefore augments the contractility of the muscle (Stokes & Stack, 2011).

For some authors the tapping technique works by stimulating the sensory receptors in the tissues (such as mechanoreceptors) thereby producing a protective contraction of the muscle being manipulated. This protective contraction is a reflex contraction (Rattray & Ludwig, 2000). When incorporated in the manual therapy session it is advised to be performed for short duration because excessive stimulation may lead to muscle fatigue which can be counterproductive (Caessar, 1999). Another working mechanism for the muscle belly tapping is stretch reflex stimulation which can facilitate a contraction of the muscle when is applied to the belly or to the tendon (Fritz, 2017; Turcaninov, 2000; Casanelia & Stelfox, 2010).

The muscle belly tapping technique was applied over the same area of muscles for five minutes in order to excite an answer from the muscles being stimulated. The sequence of stimulation comprised of three brisk hits with the fingers, asking the patient to concentrate over the area being stimulated.

The stretch release techniques performed by placing the fingertips over the belly of muscles and briefly spreading the fingers in order to stretch the skin and the underlying muscle. To temporarily deform the soft tissue in order for the cutaneous receptors and the afferent fibers to produce facilitation for the targeted muscle it is necessary for a firm stretch, (Umphred et al., 2013). The stretch release technique was also employed for five minutes. The skin over the muscle to be stimulated was first compacted and then was performed a rapid and deep stretch of the underlying muscle fibers (Figure 2).

Repeated stretch is a technique that is part of the proprioceptive neuromuscular facilitation (PNF) concept developed by Herman Kabat and his collaborators. Basically, the physiotherapist tries to stimulate the Ia afferent fibers in order to produce the myotatic reflex. The brief tensioning response of the muscle is enhanced by an appropriate resistance from the hands of the physiotherapist, Hindle et al. (2012). The repeated stretch technique was repeated during five minutes. The ankle was positioned in a manner that pre-elongated the tibialis and peroneus muscles and then performed a rapid stretch in order to excite the neuromuscular spindle. The technique was also combined with muscle belly taping. After stimulation the patient was asked to activate de muscles and perform ankle dorsiflexion with a small opposition from the therapist (Figure. 3). All the techniques were applied by a PNF trained physiotherapist.

Figure 2. The stretch release technique. **A.** The skin is being wrinkled in order to prepare the maneuver. **B.** The rapid and deep stretch of the skin and underlying muscle

Figure 3. Repeated stretch technique combined with muscle belly tapping. During the rapid repeated stretch movement, the muscle belly is being briefly tapped to increase afferent stimulation.

For nerve conduction study we used the electromyograph Neuro–MEP Micro. We evaluate motor nerve conduction velocity (NCV –m/s) and the amplitude of compound muscle action potential (CMAP-mV) **of** peroneal nerve. The method was explaine elsewere (Sardaru et al., 2018).

Muscle force (Kgf) was tested using the Baseline® hydraulic push-pull dynamometer.

Ankle dorsiflexion range of motion was evaluated with a standard goniometer with the subject in a sitting position with the knee flexed to 90°, Norkin and White (2009).

For the evaluation of the perceived functional capabilities of the ankle we used the Functional Ankle Disability Index (FADI). This is an important clinical tool because it is a region-specific self-report outcome measure related to activities of daily living. FADI evaluates functional mobility, gait, occupational performance, pain, sleep and strength (Eechaute et al.,2007).

Numeric Rating Scale (NRS) was used to have a direct and clear idea of the general pain. This is a one-dimensional pain measurement clinical tool at which the subjects can reply briefly by selecting a hole number (0 - 10) that best reflects the intensity of their pain (Hawker et al., 2011).

The overall functional status was evaluated with the Oswestry Disability Index (ODI) which measure disability and quality of life in a person with low back pain (De Kroon et al., 2005; Jeremy et al., 2000).

Statistical Analysis

The statistical analysis of the results was performed using the BioStatAnalystSoft software package. Because we have only a limited number of patients, we tested the normality of the distributions and we used the Shapiro-Wilk normality test. In our study all data was normally distributed except for gender. In the case of gender analysis, we opted for the nonparametric Chi-square test.

Table I. Data analysis before and after the treatment

	Control N=30	**FES N=30**	**FES-MT N=30**	**p CG vs FES**	**p CG vs FES-MT**	**p FES vs FES-MT**
Mean age (years)	43.16 ± 8.05	41.96 ± 6.79	44.80 ± 6.21	0.221	0.479	0.124
VNC (m/s)						
initial	43.10 ± 4.11	44.77 ± 3.93	43.03 ± 4.55	0.315	0.733	0.125
final	45.21 ± 3.68	46.24 ± 4.57	45.25 ± 3.93	0.576	0.824	0.375
Δ	1.9 ± 1.74	1.46 ± 1.59	2.10 ± 1.59	0.317	0.523	0.082
CMAP (mV)						
initial	1.44 ± 0.41	1.42 ± 0.43	1.39 ± 0.34	0.244	0.115	0.780
final	1.81 ± 0.42	1.79 ± 0.43	1.82 ± 0.37	0.672	0.813	0.800
Δ	0.31 ± 0.10	0.38 ± 0.14	0.43 ± 0.15	**0.040**	**0.001**	0.158
Dynamometry (Kgf)						
initial	10.27 ± 2.51	11.13 ± 3.32	9.80 ± 2.49	0.548	0.215	0.084
final	11.36 ± 2.25	12.80 ± 3.56	12.06 ± 2.28	0.221	0.702	0.347
Δ	1.48 ± 0.95	1.66 ± 0.75	2.26 ± 0.74	**0.007**	**0.0001**	**0.003**
ODI score						
initial	34.53 ± 6.42	33.12 ± 6.03	36.00 ± 5.71	0.510	0.263	**0.052**
final	27.58 ± 6.40	26.26 ± 6.10	27.83 ± 6.28	0.162	0.688	0.642
Δ	5.18 ± 2.14	6.73 ± 2.36	8.16 ± 1.98	**0.021**	**0.0001**	**0.013**
FADI score						
initial	55.26 ± 5.05	56.36 ± 6.57	53.86 ± 5.41	0.640	0.211	0.113
final	60.18 ± 4.25	62.83 ± 6.28	62.46 ± 5.89	0.112	0.165	0.816
Δ	4.82 ± 2.25	6.46 ± 2.89	8.60 ± 2.26	**0.020**	**0.0001**	**0.002**
NRS score						
initial	5.94 ± 0.95	5.70± 1.05	5.86 ± 1.04	0.315	0.522	0.111
final	4.15 ± 1.25	3.50 ± 1.33	3.16 ± 1.46	**0.017**	**0.002**	0.360
Δ	1.61 ± 0.95	2.20 ± 0.94	2.70 ± 0.85	**0.050**	**0.0001**	**0.042**

The results were expressed as mean standard deviation for normally distributed continuous variables. To determine the differences between the groups we used Test t-Student for normally distributed continuous variables, and the chi-square test for categorical variables. The values $p < 0.05$ were considered statistically significant.

Results

In our study the control group was made up of 30 patients (15 males and 15 females), with mean age of 43.16 ± 8.05 years old, received standard therapy, the second group of 30 patients (16 males and 14 females), with mean age of 41.96 ± 6.79 years old received FES triggered by a foot-floor contact transmitter placed bellow the heel, and the third group of 30 patients (15 males and 15 females), with mean age of 44.80 ± 6.21 years old received

FES and manual therapy. We did not find any statistical differences in gender (Chi-square test, $p = 0.7624$) and age between the groups (Table I).

The results for all groups of nerve conduction velocity were not statistically significant. However, in the analysis made on CMAP we found differences between CG and FES (CG Δ 0.31 $\pm$ 0.10 mV vs FES Δ 0.38 $\pm$ 0.14 mV), with $p<0.040$, also between CG and FES-MT (CG Δ 0.31 $\pm$ 0.10 mV vs FES-MT Δ 0.43 $\pm$ 0.15 mV), with $p<0.001$ (Table I).

The Dynamometry results were Δ 1.48 $\pm$ 0.95 Kgf for CG vs Δ 1.66 $\pm$ 0.75 Kgf for FES with $p < 0.007$ and for FES-MT Δ 2.26 $\pm$ 0.74 Kgf vs CG, $p <0.0001$. We found a statistically significant difference between FES group and FES-MT group with $p< 0.003$.

For the ODI score we found a statistically significant difference for the FES-MT group when we compared it with FES with $p<0.052$. The difference between initial and final score ODI was different in the 3 groups with $p<0.021$ when compare CG vs FES, $p<0.0001$ CG vs FES-MT, and $p<0.013$ FES vs FES-MT (Table I).

In the analysis made on FADI score we found differences between CG and FES (CG Δ 4.82 $\pm$ 2.50 vs FES Δ 6.46 $\pm$ 2.89), with $p<0.02$, also between CG and FES-MT (CG Δ 4.82 $\pm$ 2.5 vs FES-MT Δ 8.60 $\pm$ 2.26), with $p<0.0001$, and between FES vs FES-MT, $p< 0.002$.

For NRS score we found a statistically significant difference for final data when comparing CG vs FES, $p<0.017$ and for CG vs FES-MT, $p<0.002$. Also, for Δ NRS values we found difference between the groups such as CG vs FES $p<0.050$, CG vs FES-MT $p<0.0001$, and between FES vs FES-MT $p <0.042$ (Table I).

Discussions

In the present study we compared the efficiency of FES alone and FES combined with specialized manual therapy techniques versus therapeutic physical exercises for the treatment of foot drop syndrome post lumbar laminectomy. There is a plethora of studies that are exploring the effects of FES in cases of central nervous system foot drop caused by stroke, Ferrante et al. (2016), but the literature is lacking in evidences for FES applied in foot drop from peripheral conditions.

The results from our study showed that FES applied on foot drop had better results that physical therapy exercises alone. From the point of view of functional nerve recovery, we have seen in our FES and FES-MT groups increased values of the CMAP in comparison to CG group. This means that the number of viable nerve fibers and active motor unites increased in numbers (Jerath & Kimura, 2019; Sardaru & Pendefunda, 2013).

But the group with FES-MT did not have any significant increase in CMAP amplitude compared with FES alone. From this we can conclude that nerve regeneration was achieved by functional electrical stimulation. The effect of nerve regeneration by applying electric current stimulation it is known in the scientific literature, Miranda de Assis et al. (2014) but also, we had shown this in a previous scientific paper (Sardaru et al., 2015).

In the FES-MT group, aside from FES stimulation we had employed specialized manual therapy techniques. This are known to stimulate the excitability of the motoneuron-units and increase the motor control over the muscle group area. Because we wanted to find out what effect could this have on a foot-drop syndrome after lumbar laminectomy we compared it with the CG and FES groups.

Muscle fore was tested in our clinical trial with a push-pull dynamometer (Baseline®). This permitted us to collect reliable data for the mechanical work of the tibialis muscle involved in the dorsiflexion control of the ankle. This test for muscle force allows less interpretation than the MMT technique which is a manual sensitive dependent test.

From the functional point of view the FES-MT group registered the best results. We have seen the dynamometry score higher in the group in which we utilized specialized manual therapy techniques (Δ 2.267 $\pm$ 0.740). The FES-MT had better results when compared to CG ($p<0.0001$) and FES alone ($p<0.003$). In this case we are hypothesizing that the combination of exogenous muscle contraction my FES an endogenous muscle contraction when using repeated stretching techniques increased the excitability of the neuromuscular spindle. Furthermore, the resistance opposed to the muscle after every manual therapy technique had the role increase the number of motor units.

Moreover, we found interesting correlations between the increased muscle force in the groups FES and FES-MT, and the FADI score that we used to quantify the functionality of the ankle. FADI is a region specific and self-report 34 item questionnaire designed to asses functional limitations related to ankle and foot disabilities. Ankle functionality was a very important outcome for our study. Significant statistically improvements were seen in all groups compared to the CG. Very interesting also is that the FES-MT group registered higher statistically power significance when compared to CG ($p<0.0001$) and the FES group ($p<0.0024$).

Evaluation for subjective pain was done with the NRS scale which is a one-directional measure for pain in adults. Scientific literature established that a difference of 2 points modification is the minimal clinical important difference (MCID). This is an important criterion for the correct evaluation

NRS scale. According to this interpretation of the NRS score only the FES (2.200 ± 0.997) and FES-MT (2.700 ± 0.877) groups registered clinically important results in the modification of pain. Hypothesized that the stimuli from electric stimulation and cutaneous stimulation from manual therapy techniques activated the defense mechanism of endorphin secretion for modulation of the pain.

Conclusions

Specialized manual therapy techniques utilized for increasing the excitability of neuromuscular spindle can increase the overall functionality of the tibialis muscle in case of foot drop syndrome. The combination between FES and MT showed better functional results than physical therapeutic exercises and FES alone.

The recommendation for clinical practice in foot drop syndrome is to start with FES and MT and only after the sufficient muscular strength is reached, the therapist should integrate physical therapeutic exercises according to the level of motor function of subject.

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Institutional Review Board Statement: The study was conducted in accordance with the principles set out in the Declaration of Helsinki. Written informed consent was obtained from all participants. The ethical opinion granted by the ethics commission U.M.F. "Grigore T. Popa" Iaşi under which this study was carried out is registered with the number 3110/2021.

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References

Caessar M. (1999). *Handbook of Massage Therapy: A Complete Guide for the Student and Professional Massage Therapist*. Butterworth-Heinemann, 37 – 86.

Casanelia L., Stelfox D. (2010). *Foundations of Massage* (3rd ed.). Churchill Livingston, 100 – 134.

Corniola M. V., Tessitore E., Schaller K., Gautschi O.P. (2014). Lumbar disc herniation – diagnosis and treatment. *Rev Med Suisse, 10*(454). 2376-82.

De Kroon J. R., Ijzerman M. J., Chae J., Lankhorst G. J., Zilvod G. (2005). Relation between stimulation characteristics and clinical outcome in studies using electrical stimulation to improve motor control of the upper extremity in stroke. *J Rehabil Med, 37*, 65–74.

Eechaute C., Vaes P., Aerschot L. V., Asman S., Duquet W. (2007). The clinimetric qualities of patient-assessed instruments for measuring chronic ankle instability: A systematic review. *BMC Musculoskeletal Disorders, 8*. doi: 10.1186/1471-2474-8-6.

Ferrante S., Bejarano N. C., Ambrosini E., Nardone A., Turcato A. M. et all. (2016). A personalized multi-channel FES controller based on muscle synergies to support gait rehabilitation after stroke. *Neurosci, 10*, 425.

Ferreira M. L., Ferreira P. H., Latimer J. et al. (2007). Comparison of general exercise, motor control exercice and spinal manipulative therapy for chronic low back pain: A randomized trial. *Pain, 131*(1-2). doi: 10.1016/j.pain.2006.12.008.

Fritz S. (2017). *Mosby's Fundamentals of Therapeutic Massage* (6nd ed.). St. Louis: Mosby, 78 – 132.

Hawker G. A., Mian S., Kendzerska T., French M. (2011). Measures of adult pain. *Arth Care Res, 63*, 240 – 252.

Hindle K. B., Whitcomb T. J., Briggs W. O., Hong J. (2012). Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function. *J Hum Kinet, 31*.

Jerath N., Kimura J. (2019). *Clinical neurophysiology: Basis and technical aspects. In Handbook of Clinical Neurology*. Elseier, 225 – 239.

Jeremy C. T., Fairbank M. D., Pynsent R. P. (2000). The Oswestry Disability Index. *Spine, 25*, 2940–2953.

Melo P. L., Silva M. T., Martins J. M., Newman D. J. (2015). Technical developments of functional electrical stimulation to correct drop foot: sensing, actuation and control strategies. *Clin Biomech, 30*(2).

Metcalfe A. B., Lawes N. (1998). A modern interpretation of the Rood Approach. *Phys Ther Rev, 3*(4). doi.org/10.1179/ptr.1998.3.4.195.

Miranda de Assis D. C., Lima Ê. M., Teixeira B. G., Cavalcanti J. Z., Paixão A. B. et all. (2014). The parameters of transcutaneous electrical nerve stimulation are critical to its regenerative effects when applied just after a sciatic crush lesion in mice. Biomed Res Int., 2014:572949.

Mocanu, G. D., Postelnicu, M. G., Adam, A. M., Murariu, G. & Potop, V. (2023). Body composition analysis for non-athlete urban schoolgirls in the pubertal stage. *Pedagogy of Physical Culture and Sports*, *27*(3), 254-266.

Norkin C. C., White D. J. (2009). *Measurement of Joint Motion. A guide to goniometry*. F. A. Davis Company, 263 – 316.

Page P., Frank C. C., Lardner R. (2012). Assessment and Treatment of Muscle Imbalance: The Janda Approach. *J Can Chiropr Assoc, 56*(2).

Rattray F., Ludwig L. (2000). *Clinical Massage Therapy: Understanding, Assessing and Treating over 70 Conditions*. Talus Inc. 19 - 75.

Sardaru D. P., Matei D., Zaharia-Kezdi D., Pendefunda L. (2018). Effects of biofeedback versus switch-triggered functional electrical stimulation on sciatica-related foot drop. *J Back Musculoskelet Rehabil, 31*(2). doi: 10.3233/BMR-169578.

Sardaru D., Pendefunda L. (2013). Neuro-proprioceptive facilitation in the re-education of functional problems in facial paralysis. A practical approach. *Revista Medico-chirurgicala a Societatii de Medici si Naturalisti din Iasi, 117*(1), 101-106.

Sardaru, D. P., Zaharia-Kezdi D., Andruseac G. G. and Pendefund L. (2015). Electrical stimulation of sciatic nerve after decompression. Does the time of intervention counts? *E-Health and Bioengineering Conference (EHB)*, 1-4, doi: 10.1109/EHB.2015.7391544.

Selkirk S. M., Ruff R. (2016). Low back pain, radiculopathy. *Handb Clin Neurol. 136*. 1027-33.

Stokes M., Stack E. (2011). *Physical Management for Neurological Conditions*. (3rd ed.). Churchill Livingstone; 134 – 162.

Thrascher T. A., Popovic M. R. (2008). Functional electrical stimulation of walking: function, exercise and rehabilitation. *Ann Readapt Med Phys, 51*(6).

Turcaninov R. (2000). *Therapeutic Massage: Scientific Approach*. Aesculapius Books, 42 – 75.

Umphred D. A., Lazaro R. T., Roller M. L., Burton G. U. (2013). UMPHRED'S Neurological Rehabilitation (6th ed.). Mosby Elsevier, 191 – 250.