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Research article

Non-invasive rehabilitation in Morbus Ledderhose disease, methods, techniques, efficiency

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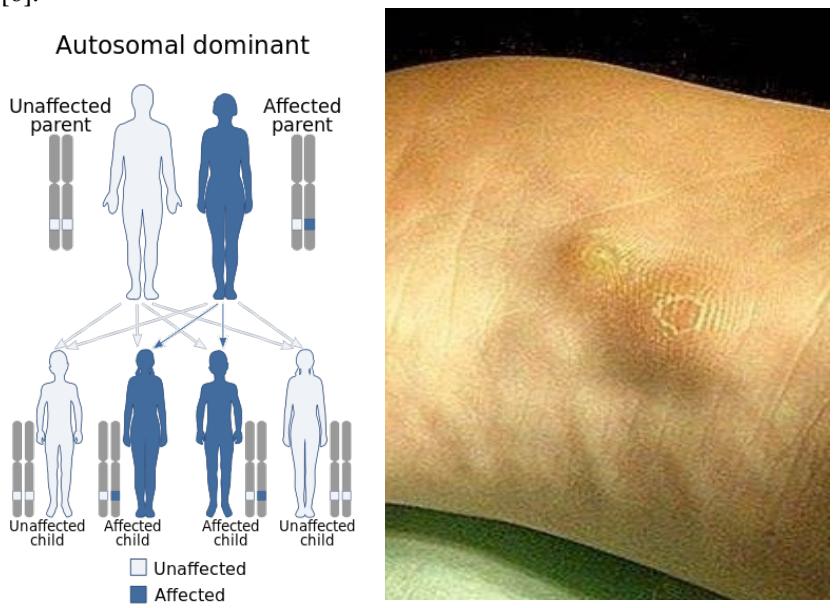
Abstract: The abnormal proliferation of the fibrous tissue in the plantar fascia, Morbus Ledderhose is a non-malignant thickening of the deep connective tissue of the foot, a relatively rare pathology that intensely affects patients through marked pain and functional impotence. Rehabilitation treatments are poorly presented in the literature. To apply a non-invasive physiotherapeutic treatment which leads to consistent results in reducing pain, reducing the size of nodules or even their disappearance, the functional resumption of the foot, an increase in the life quality of affected patients. In the study, patients were divided into 2 groups: G1 received treatment consisting of shockwave therapy complemented with SIS therapy, G2 received treatment consisting of ultrasound, laser therapy, kinesiotherapy, massage, excluding the application of shockwave therapy and SIS. Some of the patients associate comorbidities such as type II diabetes, Dupuytren's disease or, more rarely, with Peyronie's disease (penile fibromatosis). Important positive results have been obtained: a considerable decrease in the pain level of patients, the dissipation of consistency and decrease in the size of plantar nodules, an increase in the life quality of the patients with the resumption of productive activities. The treatment with shock waves and super inductive system has an increased efficiency both folowing the first cure and after various consecutive cures applied consistently at 6 months or maybe even faster, at 4-5 months, if necessary, if the pathology advances faster by intensifying fibrosis.

Keywords: fibromatosis, fasciitis, plantar, Morbus Ledderhose

1. Introduction

Plantar fibromatosis materialized in the abnormal proliferation of fibrous tissue in the plantar fascia of the foot is a relatively rare disease, with a long evolution, difficult to detect in the initial phases and difficult to treat in the advanced phases of the disease. It is also called the Morbus Ledderhose disease, taking the name of the German surgeon Georg Ledderhose who first described the pathology in 1894 and is defined as a gradual nodular growth in the central medial part of the plantar fascia with possible possibilities of sclerosis and contraction of the entire aponeurosis or, more rarely, contracture of the fingers, Dupuytren contracture [1]. Fibroblast proliferation is considered to be the basis for the formation of plantar nodules [2]. The phenomenon propagated over time induces the formation of fibrous masses or even nodules called Ledderhose nodules that cause accentuated and nagging discomfort and pain in orthostatism and in movement. The most frequently affected layer of the fibrous membranous aponeurotic formation is the medial layer, the plantar aponeurosis being a fibrous, very resistant membrane that covers the muscles and connects

them with the bones. Plantar aponeurosis originates on the anteromedial aspect of the calcaneus and inserts at the base of the metatarsals, consisting of three layers (central, medial, lateral). The causes of plantar fibromatosis have not been fully elucidated, but certain factors that favour the development of the pathology have been found: repeated foot injuries or overuse, genetic predisposition, chronic inflammation or, sometimes, association with other pathologies [3]. From a histopathological perspective, compared to palmar fibromatosis (Dupuytren's disease), the genetic aspects of plantar fibromatosis are uncertain, being associated with Dupuytren's disease in 25% of cases or, more rarely, with Peyronie's disease (penile fibromatosis) [4], all of which are part of a large group of fibromatoses based on a proliferation of collagen and fibroblasts [1]. As with Dupuytren's disease, the root cause of Ledderhose disease is not yet understood. It has been noted that it is an inherited disease and with variable occurrence within families, that is, the genes necessary for it can remain dormant for one generation or more and then appear in one individual or be present in several individuals of the same generation with variations [5]. The autosomal dominant hereditary inheritance presumed to have an incidence can be presented as in Figure 1 [6].

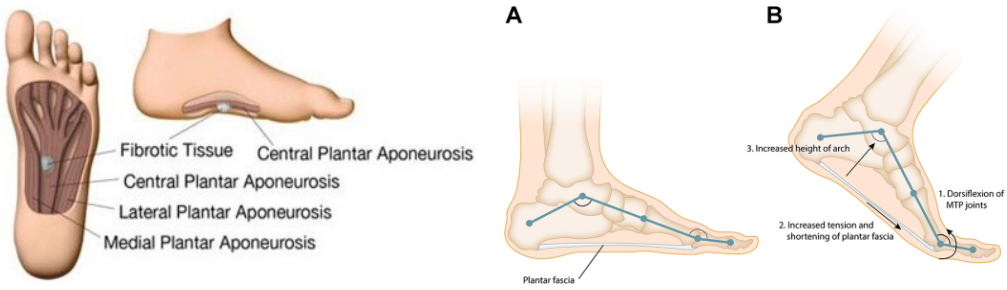


(**a**) (**b**)

Figure 1. (a) Autosomal dominant hereditary inheritance [6]; (b) clinical presentation of Morbus Ledderhose plantar nodules.

Plantar fibromatosis materialized by the presence of plantar nodules is the most common benign tumor formation of the foot, affecting mainly middle-aged to advanced male individuals, presenting bilateral localization in 25 – 50% of cases. The main risk factors are reflected in the male sex who have an increased risk of developing the disease, the Caucasian race is also more prone to the appearance of plantar fibromatosis, epilepsy, diabetes mellitus (usually associated in medical practice with diabetic neuropathy and peripheral atherocholerotic vascular pathologies), overuse and repeated trauma of the foot, alcoholism, chronic liver pathologies or other fibrosing diseases [4,5].

Frequently, the development of the pathology is asymptomatic in the initial phase, the patient occasionally discovering nodules in the sole. Sometimes, the patient may experience painful manifestations on the anteromedial aspect of the leg, rarely accompanied by a visible contracture of the toes.



(**a**) (**b**)

Figure 2. (a) Plantar fascia with a subcutaneous nodule [7]; (b) The plantar fascia and the longitudinal arch of the foot form a truss [8].

The presence of plantar nodules influences the plantar statics but above all, the vertebral statics, leading over time to serious postural imbalances at the level of the knees, pelvis, spine, shoulders, neck and even the cephalic extremity [9], possibly even inducing other muscular contracture or imbalances that will require additional treatments [10] thus increasing the health systems costs.

The diagnosis of plantar fibromatosis is a predominantly clinical one. The doctor will perform the detailed physical examination performed by palpating the heel area and the soles of the foot, insisting on the plantar arches in order to identify sensitive areas, painful points but also the presence of any fibromatous nodules. The personalized identification of the location of pain at the Lauge-Hansen point, in the area of insertion of the plantar fascia on the calcaneal bone is an eloquent sign of plantar fasciitis. At the same time, the doctor will perform an evaluation of the mobility of the leg and the posture of the body in order to identify any changes associated with the pathology [5,6].

At the same time, functional tests can be used in practice to evaluate the discomfort associated with plantar dysfunctions. Then, in order to confirm the diagnosis or due to the need to evaluate the extent of the lesions, the clinical diagnosis can be supported by imaging methods: ultrasound or MRI (magnetic resonance imaging). In other cases, an imaging diagnosis could be imposed from the perspective of detecting the pathology and diagnosis of leiomyomas, simple fibroids, liposarcomas, neurofibromas, etc., or supplementing the investigations with biopsy [11].

The absence of treatment or the neglect of Morbus Ledderhose disease can lead over time to the progression of plantar fibromatosis, generating complications of major impact on the individual's quality of life materialized in chronic, nagging pain, plantar or global postural static difficulties, movement difficulties, changes in the plantar arch [12]. At the same time, the incidence of recurrences is about 60% with the mention that the lesions and manifestations are much more aggressive. Prevention in plantar fibromatosis includes effective management of foot injuries by avoiding repeated exposure to trauma and early identification of manifestations and symptoms, adopting a healthy lifestyle with the promotion of mobilization and mobility, maintaining a body weight within normal limits and using protective orthoses and plantar supports when necessary. Plantar fascial fibromatosis is a complex disease that requires a multidisciplinary approach to address a correct and complete diagnosis and treatment. Understanding the risk factors, early diagnosis and approaching appropriate therapeutic interventions can bring a significant increase in the life quality of affected patients [13].

Ledderhose disease can develop at any age and is more common in adults and the elderly, especially in men with a prevalence ratio of 10:1 (men: women) [5].

The prevalence of Ledderhose disease covers a wide range from 0.2% to 56% of the adult population, the differences being due to variations in age, population group

and information collection methods. Northern Europe registers an increased incidence of the disease with a more aggressive evolution in men around the age of 50 [5].

Three stages have been observed in the evolution of plantar fascial fibromatosis: the proliferative phase materialized in the fact that the myofibroblasts proliferate developing nodules [14] that may be painful or sensitive to pressure or palpation, the involutional phase in which the disease spreads along the plantar fascia resulting in the development of specific cords and the residual phase in which the process continues to advance at the level of the fingers appearing induration of the cords, later progressing to contracture. At the molecular level, the contraction of myofibroblasts induces the transformation of type I collagen into type III scar collagen. At the same time, the atrophy of the local adipose tissue occurs, which turns into fibrous tissue [15]. The pretendinous cords continue their development by gradually affecting all three distinct structural components of the plantar aponeurosis: the medial component, the central component (plantar aponeurosis – the most prominent) and the lateral component.

As statistical studies reveal, as in the case of other pathologies [16], only a small number of the patients who experience the symptoms of Ledderhose disease go to the doctor for evaluation and an even smaller number benefit from appropriate treatment that will lead to the attenuation or even eradication of the bothersome manifestations and symptoms and to the slowing down of the evolution of the disease.

2. Results

2.1. Statistical evaluation of patients (age, gender, environment)

Table 1. Statistical evaluation of the study group

	No.	**Percentage (%)**	**Min/Max age (years)**	**MD±DS**
Gender (w/m)	2 women 15 men	11.76 % 88.23 %		
Age (years)			47 - 67	56.76 ± 5.73
Environment (U/R)	14 Urban 3 Rural	82.35 % 17.64 %		

2.2. Results obtained after using the treatment

The results obtained in the study are relevant and encouraging in the therapeutic approach to Morbus Ledderhose pathology and are presented graphically in the following figures.

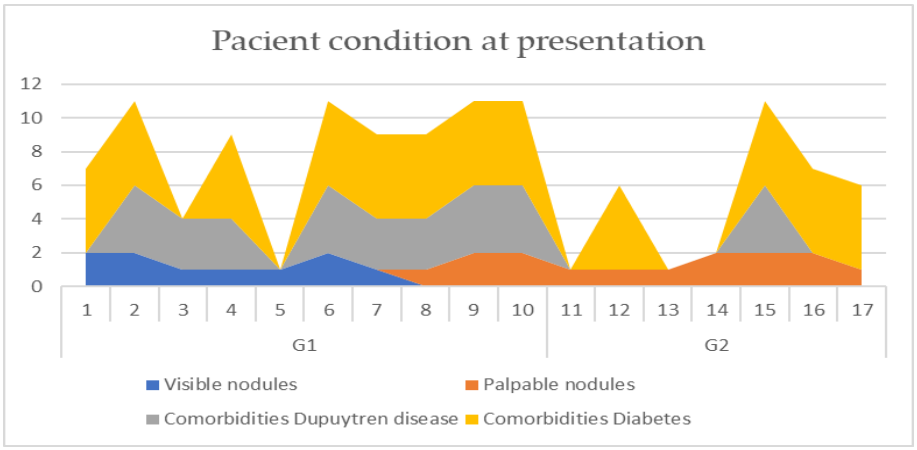
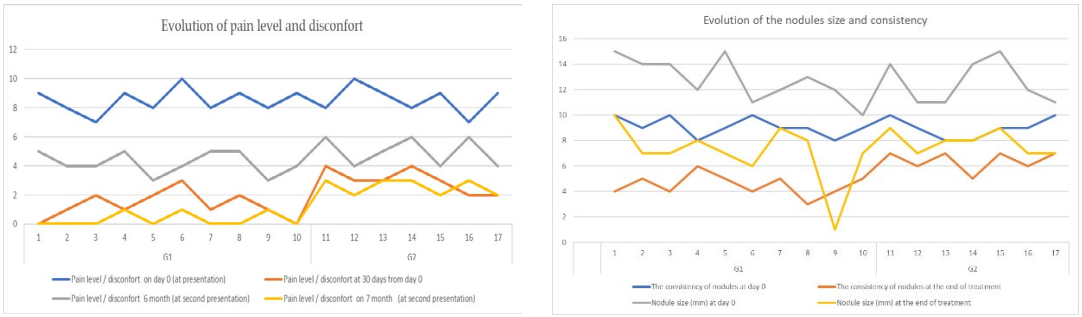


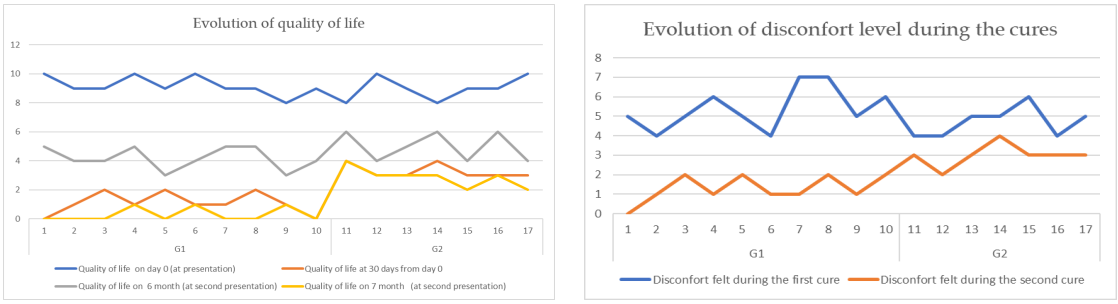
Figure 2. Patients' condition at presentation: presence of visible/palpable nodules, presence of comorbidities: Dupuytren's disease/Diabetes



(**a**) (**b**)

Figure 3. The evolution of the patients' condition measured at presentation, during and at the end of the treatment: **(a)** the evolution of the level of pain and discomfort**; (b)** the evolution of the size and consistency of the nodules.

Following the application of the physiotherapy treatment consisting of shockwave therapy and SIS therapy consecutively during the first course and subsequently, even after the first course of treatment, but especially after the application of the second course, we obtained a considerable decrease in the level of pain and discomfort of the patients included in the G1 group (patients 1-10 represented on the abscissa system), unlike the patients in the G2 group (patients 11-17 represented on the abscissa side) who registered a weak, less consistent evolution, with the persistence of painful manifestations, as can be seen in Figure 3. At the same time, the dissipation of the consistency and the decrease in the size of the plantar nodules were observed in the patients under study, a more substantial change in the patients in G1 (who received treatment with ESWT and SIS) compared to the patients in the G2 group whose change is greatly attenuated, evolutions revealed in Figure 3. Also, in a subjective evaluation of patients by evaluation from 1 to 10 (on the principle of the VAS pain scale) we measured and found the increase in the life quality of patients with the resumption of productive activities, as can be seen from the graphs presented in Figure 4.



(**a**) (**b**)

Figure 4. (a) Evolution of life quality measured at the beginning and end of treatment; (b) The evolution of the level of discomfort during the cures.

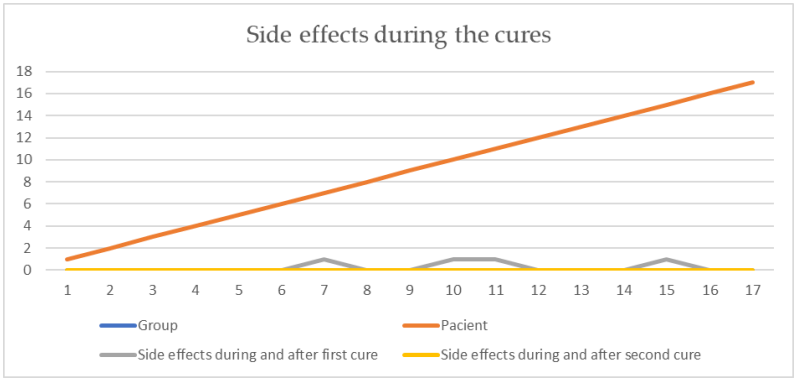


Figure 5. Evolution of the level of discomfort recorded during the cures and of the adverse effects following the cures

We also found the absence of adverse effects recorded when applying the therapies in both groups G1 and G2, both following the first course and after the second course of treatment. Discomfort of patients in the G1 group was found and recorded during the application of ESWT therapy, but its evaluation on the VAS scale of pain and discomfort was insignificant, as can be seen from the graph presented in Figure 5.

3. Discussion

We observe notable results obtained revealing the significant alleviation of pain in all patients included in the G1 group who received ESWT and SIS treatment compared to patients in the G2 group who received treatment consisting of laser, ultrasound, kinesiotherapy, massage. At the same time, we found a considerable decrease in the discomfort caused by pressure in orthostatism and gait, corroborated with a significant increase in the life quality of patients in the G1 group who received treatment with ESWT and SIS, compared to the G2 group, which registered weaker improvements.

Or, prior to any invasive surgical approaches, it is advisable to go through therapeutically or conservatively any other type of available therapies that offer notable, consistent results, that bring the patient to a stage of painlessness (or significant pain reduction)[10], to offer them comfort in walking and in carrying out their daily activities [9,12].

Continuing treatment in similar physiotherapy courses performed within a maximum of 6 months ensures patient comfort, eradication/alleviation of pain and, implicitly, stabilization over time of the results obtained following the first cure [10]. Most likely, the fibrosis process will resume, the hereditary genetic inheritance will continue its effects. The simultaneous use, within the same cure, of at least two types of effective non-invasive physiotherapeutic therapies represents the successful way in approaching plantar fascial fibromatosis, restoring to affected patients the correct

posture and gait, a significantly increased quality of life. Obviously, early arrival at the doctor for the correct evaluation, detection of the correct diagnosis and entry into regular effective non-invasive therapy is the key to success in the management of Morbus Ledderhose.

4. Materials and Methods

This is a longitudinal, interventional cohort study covering a period of 12 months. It was performed in the Rehabilitation Department of the "Domenico" Medical Center in Iasi between January 1 and December 31, 2019. It involved the diagnosis, treatment, evaluation and follow-up of the evolution of 17 patients, 15 men and 2 women from both rural areas (3 patients: 2 men and 1 woman) and urban areas (14 patients: 12 men and 2 women) during the 10 months of the study.

The 17 patients arrived at the rehabilitation centre presenting troublesome plantar pain and accentuated discomfort in orthostatism or movement, accusing the marked functional impotence from the perspective of the fact that their daily productive activity is significantly affected. 11 of the patients had visible nodules, the remaining 6 had nodules on palpation. Seven patients already had a diagnosis at presentation, but for safety, each of the patients included in the study received specialized medical consultation and evaluation, and MRI examinations were also performed for the detection and safety of the diagnosis. Nine patients had concomitant Dupuytren's disease, 4 unilateral palmar, 5 bilateral palmar, two of them having undergone palmar surgeries in history and now being in a situation of palmar recurrence.

Inclusion criteria in the study: patients who were diagnosed with Ledderhose plantar fibromatosis, who experienced localized plantar pain and discomfort in standing or walking.

Exclusion criteria: patients with pain manifested in the calcaneal area or who have revealed the existence of plantar osteophytes, patients with unclear diagnosis, patients who did not deny inclusion in the study.

Of the seventeen patients included in the study, twelve had already been diagnosed and treated for diabetes (ODA or insulin) at presentation, previously diagnosed by 8-12 years.

All patients received prior to the presentation drug approaches to pain therapy, but none of them found improvements in pain and discomfort in the medium or long term, the pain and discomfort reappearing within 48 hours after the administration of painkillers, regardless of whether they consisted of NSAIDs or corticotherapy.

The seventeen patients included in the study were divided into 2 groups, the G1 group consisting of 10 patients, the G2 group consisting of 7 patients. Group G1 received physiotherapy treatment consisting of application in two consecutive courses applied at an interval of 6 months consisting of shockwave therapy and SIS. Group G2 received ultrasound treatment, laser therapy, kinesiotherapy, massage, excluding the application of shock-wave therapy and SIS. Between therapy sessions, patients received conservative treatment consisting of adapted plantar supports inserted into shoes that fulfilled the role of reducing pressure in the nodule area and leaving the tissue space and time for recovery.

The shockwave therapy used was applied with a Gymna Shockmaster 300 device, from Belgium. The device has a frequency range between 0.5 and 17 Hz, in steps of 0.1 Hz and the maximum frequency with V-Actor of 31 Hz. The therapy was applied using evolutionary frequency steps, including the activation of the Burst module for sensitive patients to reduce their discomfort during the treatment. In extracorporeal shock wave therapy, the probe applicator, which is the electrohydraulic shock wave source, approaches the affected area. The energy concentration depends on the shape of the reflector, as shown in Figure 1.

(**a**) (**b**)

Figure 6. (a) ESWT Shockmaster 300 Gym Therapy Machine; (b) ESWT therapy probe-applicator.

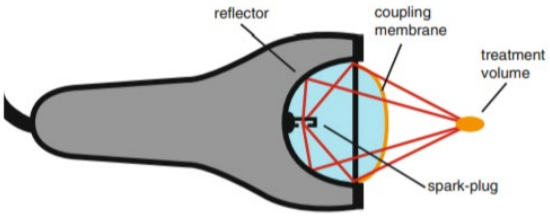


Figure 7. Working principle of shock-wave probe applicator

Extracorporeal shock wave therapy with radial pulses is a non-invasive alternative to orthopedic musculoskeletal surgery, for tendons, fascia, fibrosis or soft tissue damage, in order to stimulate healing and revascularization. Also called acoustic wave therapy, the extracorporeal shock wave used in therapy is a wave with a rapid intensification of pressure in a short period of time, subsequently registering a gradual reduction of pressure and a phase of negative pressure, of vacuum, causing the breakdown of calcium deposits, stimulating vascularization, collagen production, stimulation of the nutrition of the treated tissue. The cavitation effect produced excites the subdermal vascular plexus, thus stimulating the angiogenesis of the area under treatment. Thus, the regeneration of the granulation tissue and the establishment of an extracellular matrix with the superimposition of a phase of rapid maturation and collagen production are recorded. The subsequent effect recorded is pain relief, both in the short, medium and long term.

The shockwave effect from the cellular perspective translates into increasing the transmittance of the cell membrane by stimulating the activity of ion channels, stimulating cell division, the production of cellular cytokines, the stimulation of the production of new blood vessels in the area of muscles and tendons, increase of the concentration of growth factor beta1, chemotactic effect, chemo-tactic and mitogenic effect on osteoblasts. It stimulates metabolism, dissolves calcified fibroblasts, supports the production of repairing collagen, reduces tissue tension [10]. It intervenes on the bone system by healing and remodelling the bones. In addition, it has an analgesic effect. Shockwave has a success rate of 80% in the treatments applied in general and 74% for the applications of diabetic ulcerative pathologies. Being non-invasive, there is no risk of infection. It stimulates rapid healing, reduces the costs of long-term medical services.

Although ESWTs are still sound waves, the differences between ESWT and the therapeutic ultrasound are that they use high-frequency sound waves and can produce thermal or non-thermal effects, ESWTs use low-frequency sound waves and do not produce thermal effects.

There are also contraindications for the shockwave therapy: pregnant woman, coagulation disorders, hematological disorders, history of phlebitis, embolism, thrombosis, neurological pathologies, psychiatric, the patient's inability to cooperate,

the presence of local infections, wounds or open lesions in the treatment area, pacemaker or prosthesis wearers, any form of neoplasm. The device manual provides contraindications in the following cases: "coagulation disorders (haemophilia), use of anticoagulants, especially Marcumar, thrombosis, osteoporosis, neuropathy (for example; as a secondary disease to diabetes), tumour diseases, carcinoma patients, pregnancy, children in growth cortisone therapy up to 6 weeks before first treatment, heart pacemakers, stent implants." And, if initially, among the contraindications of the application of shockwave therapy were patients with diabetes, more precisely with diabetic neuropathy, subsequent research [17] reveals the effectiveness of the use of ESWT in patients with diabetes, with applications even on diabetic ulcers, with the adaptation of frequencies and number of pulses, revealing conclusive results, as will be mentioned below.

SIS (Super Inductive System) therapy is based on the high intensity of the electromagnetic field, acting by relieving chronic or acute pain, myorelaxation, myostimulation and joint mobilization. Pain management is based on three different theories of pain control, each varying in frequency spectrum, as revealed in Figure 4: 2-10 Hz – endogenous opioid system, 60-100 Hz – control gate, 120-140 Hz specific pattern. Myostimulation acts through the action of the electromagnetic field in the neuromuscular tissue, causing nerve depolarization and activation of physiological muscle contractions. Depending on the frequency of the stimulation selected, muscle facilitation or strengthening effects can be obtained. The reduction of spasticity is achieved by inhibiting increased muscle tone, influencing the control of muscle tone at the spinal cord level.

Figure 3. BTL 6000 Super Inductive System Elite

Figure 4. Theories for pain control. BTL 6000 SIS Elite device applicator probe

We consider this study to be a pilot one in the field of medical rehabilitation, a preliminary test that addresses the evaluation of its feasibility and the identification of possible aspects and potential problems before conducting a larger study on the non-invasive physiotherapy treatment that could be effectively used in the treatment of plantar fibromatosis.

In this study, the statistical analysis was carried out by using Office Excel 2021.

A careful investigation of the Medline/PubMed electronic database was performed for dates up to July 2024. The search terms used included "plantar fibromatosis" and "Morbus Ledderhose," "non-invasive treatment" or "non-surgical management." The existing literature on the treatment of plantar fibromatosis is poor, promoting especially invasive treatment approaches: steroid injections/infiltrations, blocking calcium channels or other invasive treatments in situ, excisions or vaporizations, irradiation or surgical approaches to treatment of the pathology. There are also few studies describing the effects of radiation therapy in patients with Ledderhose disease.

A study undertaken in 2008 by Seegenschmiedt et al. reveals the results obtained regarding a 44% decrease in the size of nodules as well as in the number of nodules following the application of radiotherapy. At the same time, important results were

recorded regarding the reduction of pain by 60% and the reduction of skin dryness by 11%. In the study, 36 legs belonging to 24 patients were irradiated [11].

Subsequently, in 2015, Schuster et al. studied 45 hands and 15 feet belonging to 33 patients using electron radiotherapy treatment. The results showed 81% improvement in pain and contracture, 70% improvement in pain at rest, 94% patient satisfaction and 25% toxicity and late dryness [13].

The most recent study undertaken on the treatment of Morbus Ledderhose disease found in our searches was conducted in 2023 by de Haan et al. on 67 patients followed medially for 49 months. The results revealed 41% complete pain response, 37% partial pain response, 0% positive pain regression, 78% patient satisfaction with 15% skin dryness and 3% erythema [7]. In fact, the dryness of the skin registered after irradiation negatively affects physical and mental health in the long term [11], in addition to many other unpleasant side effects [17,18].

Many of the existing materials address Morbus Ledderhose descriptively, displaying the anatomy and biomechanics of the plantar fascia, histology, epidemiology, clinical presentations, associated comorbidities and differential diagnosis.

A comparative study on the effectiveness of applying Kinesiology Taping versus therapeutic ultrasound in the management of plantar fasciitis was published in 2022 by Karishma et al. [19]. The study reveals the similarity of the efficiency of the two techniques used in obtaining results regarding pain reduction and improvement of foot functionality, without having cause-type approaches, but only acting on the effects and manifestations of the pathology.

Another analytical study published in 2023 by Panaet et al. included a group of 23 children with flat foot in the study, revealing the dependence of the foot's ability to evenly distribute body weight on the plantar areas, its purpose being to determine flat foot correlation - plantar pressure distribution under static conditions, the results recording significant correlations of strong intensity between the flat foot and the distribution of plantar pressure in the middle of the foot and that the flat foot significantly influences the values of the plantar pressure distribution in the middle of the foot and, obviously, the flat foot influences the values of the plantar pressure distribution in the medial area of the sole [20]. Flat foot in history is one of the factors favouring the subsequent development of plantar fibromatosis and characteristic nodules.

We can also consider studies that address treatments that involve the administration of mineral waters with potential in modulating biological processes [21], in the activity of fibroblasts, which synthesize the extracellular matrix and collagen, produces tissue stroma and has an important role in the healing process of lesions, enhancing skin health and offering new avenues for inflammatory and autoimmune disorders [21]. Published in 2023 by Munteanu et al., such a study paves the way for further new explorations and countless, perhaps even endless possible options for clinical applications.

For limiting the transmission of painful impulse and increase the quality of patients life, it could be used the electropuncture for pain therapy [9,10] in Ledderhose Morbus, but only on short time, probably a few days. Without acting directly on the nodules, the pain would reapearing in the next few days after stopping the electropuncture treatment, as specified in an article from 2024 published by Călin et al.[9].

Non-invasive physiotherapy treatment approaches for Morbus Ledderhose disease are non-existent in the literature, from the point of view of the use of Shockwave therapy and SIS therapy concomitantly.

From the perspective of the initial contraindications regarding the use of ESWT therapy in diabetic patients, since 2007 studies have been published on the effectiveness of ESWT even in the treatment of diabetic wounds, skin flaps, diabetic and non-diabetic skin ulcers and acute or chronic soft tissue wounds, obviously using different

frequencies and number of pulses per cm^2 adapted to the pathology and sensitivity of the area addressed.

Thus, in a study published in 2007, Schaden et al. reported the use of ESWT in the treatment of skin lesions in 102 patients with application on 104 diabetic feet, mentioning a success rate of 74% with complete healing and no recorded adverse effects [22].

In 2008 Saggini et al. revealed the application of ESWT in the management of chronic ulcers of the lower extremities including chronic posttraumatic, venous and diabetic ulcers [23]. The protocol reported to have been used reveals 100 pulses per 1 cm2 wound surface with an energy level of 0.037 mJ/mm2 each (Evotron, Lengwil, Switzerland). The focal volume therapy was 10-15 mm in diameter and the total energy applied for each pulse was 3.5 mJ, with a frequency of 4 Hz or 240 pulses/min. Results were reported consisting of 16 of the 32 wounds treated healed completely by applying six sessions of shockwave treatment.

In 2009, Wang et al. published a study of 72 patients with chronic diabetic foot ulcers, dividing them into 2 study groups: a group of 34 patients with 36 ulcers received ESWT treatment, while 36 patients with 36 ulcers received hyperbaric oxygen therapy (HBO) treatment. Patients in the ESWT group received 300 + 100/cm2 shockwave pulses with an energy flux density of 0.11 mJ/cm2 every 2 week for 6 weeks, while patients in the HBO group received daily treatment for 20 days (20 treatments). The results revealed 31% complete cures, improvements in 68% of cases but also unchanged in 11% of the ESWT group, compared to 22% complete cures, 50% improvements and 28% unchanged in the HBO group, thus revealing the superiority of the improved clinical results compared to the HBO group. At the same time, significant increases were found regarding "endothelial nitric oxide synthase, vessel endothelial growth factor, and proliferation cell nuclear antigen expressions and a decrease in transference-mediated digoxigenin-deoxy-UTP nick end-labelling expression than the HBO group, concluding in the end that ESWT appears to be more effective than HBO in chronic diabetic foot ulcers" [24].

The results of another study (Moretti et al.) that included treatment with ESWT every 72 hours for 3 sessions of 30 patients with neuropathic diabetic foot ulcer (DFU) was published in 2009 [25]. A therapeutic protocol was applied with 100 pulses on the surface of 1 cm2 of the wound with an energy flux density of 0.03 mJ/mm2. The results showed a percentage of 53.33% recorded in wound closure in the ESWT group, compared to 33.33% in the patients in the control group, revealing a healing time between 60.8 and 82.2 days for the ESWT group and the control group ($p<0.001$).

Omar et al. reported in another study published in 2014 a number of 38 patients and 45 chronic DFUs with random assignment in therapy [26]. The study included the application of a therapeutic protocol including the same 100 pulses/cm2 with an energy flux density of 0.11 mJ/mm2. The results were encouraging: 33.3% completely healed ulcers in 8 weeks and 54% completely healed ulcers in 20 weeks in the ESWT recipient group, comparable to the control group that recorded 14.28% complete healing in 8 weeks and 28.5% complete healing in 20 weeks. Also, a significantly shorter mean healing time was revealed in the ESWT group (64.5 8.06 days) vs. healing time in the control group (81.17 4.35 days, respectively $p<0.05$).

The latest study found by us, published in 2023, Jeong et al. confirms that the ESWT procedure significantly increases microcirculation in the treatment of DFU of grades I and II applied for a minimum of 2 weeks or more than 6 sessions [27]. At the same time, the study concludes that ESWT is an effective and safe method of treating diabetic foot, that it can be considered active as a standard treatment for diabetic foot ulcer.

All the mentioned studies concluded that ESWT therapy can be considered an effective treatment modality in the management of diabetic foot ulcers (DFU), without side effects worth considering.

In addition, the International Society for Medical Shockwave Treatment (ISMST) established in September 1997 has drawn up a list of contraindications for the application of ESWT (May 2019 version [28]. According to this official guideline, neither diabetes nor even the diagnosis of cancer is no longer specified as a contraindication.

5. Conclusions

It is important in plantar fascial fibromatosis, as in any other pathology, that the patient presents himself to the doctor as early as possible, without waiting for high intensification of pain, discomfort while walking or the notice of plantar nodules. The overdemanding environment but also the weight gain or sedentary lifestyle manifested by prolonged orthostatism imprint an increased discomfort on the quality of life of active patients in the second decade of life. Prevention can mean both the administration of mineral waters to attenuate the manifestations of exacerbation of autoimmune pathologies and attenuation of the impact of the soil or shoes with hard soles on the plantar fascia during daily activities and overloads. Early presentation at the consultation/diagnosis and implicitly entering treatment is the way to success towards a reduced level of discomfort felt both during daily activities and during the application of the shock wave and super-inductive system treatment, but also a minimal discomfort felt until the start of treatment. The shock wave treatment and the super inductive system has an increased efficiency both following the first cure and after consecutive cures applied consistently at 6 months or maybe even faster, at 4-5 months, if necessary, if the pathology advances faster by intensifying fibrosis. Patients should be advised to wear insoles in shoes, foot supports if necessary and/or even to orient themselves for the rest of their lives to wear shoes with soft soles, orthopedic as appropriate. The present study offers both viable options for the application of simple but effective treatments and the opening of research and study avenues for finding new treatment options or improving existing ones in order to increase the life quality of patients affected by plantar pathologies, especially Morbus Ledderhose, as well as significantly reducing the expenses of the health system registered with the treatment of these types of plantar pathologies that also affect postural statics.

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