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REVIEW

Rehabilitation through movement in diabetic foot

Rehabilitación a través del movimiento en pie diabético

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ABSTRACT

One of the consequences of Diabetes Mellitus is diabetic foot, which we will address in this scientific manuscript. The diabetic foot is the product of a laceration of the foot which is a consequence of the chronic disease diabetes where the healing time is altered and extended, generating greater risk in life, a decrease in the person's quality of life and a greater cost to the health system. The treatment carried out for the diabetic foot becomes extensive and affects the mobility of the ankle joint, leaving it rigid, which is called ankle ankylosis, losing the functionality of the joint, which causes gait dysfunction. The proposal of this manuscript is to demonstrate the importance of movement in rehabilitation, generating a global approach to the person, encompassing prevention and treatment.

Keywords: Diabetic Foot; Ulcers; Rehabilitation; Movement; Diabetes; Ankle Ankylosis.

RESUMEN

Una de las consecuencias de la Diabetes Mellitus es el Pie diabético. El pie diabético es producto de una laceración del pie el cual es consecuencia de la enfermedad crónica diabetes en donde el tiempo de cicatrización se ve alterado y extendido, generando mayor riesgo en la vida, disminución en la calidad de vida de la persona y un mayor costo al sistema de salud. El tratamiento realizado para el pie diabético llega a ser extenso y afecta a la movilidad de la articulación del tobillo dejándolo rígido lo que se conoce como anquilosis de tobillo, perdiendo la funcionalidad de la articulación, lo que provoca una disfunción en la marcha. La propuesta de este manuscrito es demostrar la importancia del movimiento en la rehabilitación generando un enfoque global de la persona abarcando la prevención y el tratamiento.

Palabras clave: Pie Diabético; Úlceras; Rehabilitación; Movimiento; Diabetes; Anquilosis de Tobillo.

INTRODUCTION

The pathology to be developed in this manuscript is the diabetic foot (DF). It is a chronic and potentially serious complication affecting people with diabetes. It occurs as a result of elevated blood glucose levels that, over time, can damage the nerves and blood vessels in the feet. This damage reduces sensation and the ability of the feet to heal wounds, which increases the risk of developing ulcers, infections, and other serious complications.

People with diabetes should pay special attention to the health of their feet and take preventive measures to reduce the risk of developing diabetic foot. This includes keeping blood glucose levels under control, leading a healthy lifestyle that consists of a balanced diet and regular exercise, and checking feet daily for any signs of injury or skin changes.

Before fully introducing the subject to be developed in this manuscript, we will make a brief anatomical

and histological review of the structures affected in this pathology.

Regarding the anatomical aspect, we will focus specifically on the lower limb, particularly its distal part, known as the foot.

A study highlights the importance of the foot for quality of life, noting that "The ankle and foot generate a stable and flexible platform for standing, walking".

Also, research indicates that "the bones of the foot are twenty-six, which are divided into three groups, where going from back to front we find: the tarsal bones, the metatarsal and phalanges of the toes".

On the other hand, a study lists the muscles found in the foot: short toe flexor, plantar square, four lumbrical, three plantar interosseous, four dorsal interosseous, medial group: big toe abductor, big toe adductor, short toe flexor.

Likewise, that study describes the tibioperoneal astragalar joint as the connection between the leg skeleton and the talus and tarsal bones; it is a trochlear-type synovial joint, also known as a hinge. The primary function of this joint is plantar flexion and dorsal flexion. The muscles that perform these movements are: gastrocnemius, soleus, plantar, tibialis anterior, extensor hallucis longus, third peroneus, and extensor digitorum longus.

The foot can generate movements of dorsal flexion and plantar extension, inversion and eversion, and rotation. Therefore, the association of these movements causes circumduction. A study mentions that "these movements are going to allow a controlled synchronization for gait".

On the other hand, a subject of great importance in this context is the skin, since it is one of the most affected organs in this pathology.

We will approach it with the book "Principles of Anatomy and Physiology", where the authors state that "the skin is the easiest system to examine and is the most exposed to infection, disease and injury".[1] So it is of great importance to remember what its composition looks like.

Junqueira, L.C. et al.[2] explains in their book that:

The skin is one of the largest organs of the body. It fulfills several functions, including protection through sensory nerve endings that receive information, collaboration with the body's thermoregulation, and the formation of vitamin D3 by the action of ultraviolet radiation from the sun. Additionally, it stores blood, excretes waste, and absorbs substances.

Regarding the above, Tortora GJ et al.[1] notes that the skin is composed of two distinct portions: an avascular epithelial portion, called the epidermis, and a vascularized portion, called the dermis. According to the thickness of the dermis, we distinguish thin skin and thick skin, which we can find in the palm of our hands, on the soles of our feet, and at the height of some joints. After the dermis is the hypodermis, which is not part of the skin; it is a lax connective tissue that may contain many adipocytes and constitutes the adipose panniculus.

Having clarified that this condition occurs in the foot and mainly affects the skin, we will begin to define this disease, quoting different authors and entities.

Within the generalities of diabetes, Arroyo LD et al.[3] explains that:

Diabetes is a metabolic disease, non-communicable, characterized by increased blood glucose levels (hyperglycemia) due to the dysfunction of the pancreas, which is responsible for the secretion of insulin and transporting sugar to the cells. It is an incurable and irreversible chronic syndrome, but treatable, that leads to a degenerative process of the human being and leads to complications that can produce death or conditions that affect the quality of life not only of those who live with diabetes, but also of their family and social environment.

Regarding the above, the Royal Spanish Academy defines chronic disease as follows: "Said of a disease: long".

On the other hand, the World Health Organization and the Pan American Health Organization[4] indicates that non-communicable (or chronic) diseases are conditions of long duration with a generally slow progression.

Here, it becomes interesting what the National Institute of Health explains about chronic diseases, stating that:

They are diseases for which there is still no known definitive solution, and the therapeutic success consists of palliative treatments to keep the person in a functional state, through the constant consumption of drugs; such diseases, today, are the cause of most deaths and disabilities worldwide.

It is essential to point out that diabetes is one of the chronic non-communicable diseases that affect men and women equally without any distinction.

It can also affect people of all ages, genders, ethnicities, and those from low socioeconomic backgrounds. It does not discriminate based on age or gender, although certain risk factors increase the likelihood of developing the disease. These factors include:

Family history: People with a family history of diabetes have an increased risk of developing the disease.

Sedentary lifestyle: Lack of physical activity and a sedentary lifestyle can increase the risk of developing type 2 diabetes.

Obesity or overweight: Excess weight, especially in the abdominal area, is a significant risk factor for type 2 diabetes.

Unhealthy diet: Eating a diet high in calories, saturated fats, refined sugars, and processed foods can increase the risk of developing type 2 diabetes.

Ethnicity: Some ethnic groups, such as African Americans, Hispanics, Asians, and Native Americans, have a higher risk of developing type 2 diabetes.

At this point, we clarify the definition of diabetes. The Pan American Health Organization (PAHO) defines it as "a metabolic disease characterized by elevated blood glucose levels".[4] Diabetes is a chronic disease that occurs when the body cannot produce enough insulin or cannot use it effectively. Insulin is a hormone produced by the pancreas that allows sugar (glucose) from food to enter the body's cells to be used as energy. When there is a lack of insulin or the body cannot utilize it properly, glucose accumulates in the blood instead of being absorbed by the cells, resulting in elevated blood sugar levels. It is now recognized that there are two general types of diabetes. The classification on which we will rely is taken from Medline Plus.[5]

Type 1 diabetes is less common. It can occur at any age, but is most often diagnosed in children, adolescents, or young adults. In this disease, the body produces little or no insulin. This is because the cells in the pancreas that produce insulin are damaged by an immune process and stop working. Daily insulin injections are needed. The exact cause of the immune process is unknown.

Type 2 diabetes is more common. It almost always occurs in adulthood, but because of high rates of obesity, children and adolescents are now being diagnosed with the disease. Some people with type 2 diabetes do not know they have the disease. With type 2 diabetes, the body is resistant to insulin and does not use it as effectively as it should. Not all people with type 2 diabetes are overweight or obese.

There are other causes of diabetes, and some people cannot be classified as either type 1 or type 2. Examples include LADA [latent autoimmune diabetes in adults, a variant of type 1 diabetes], MODY (maturity-onset diabetes of the young), and diabetes due to other diseases.

Gestational diabetes is high blood sugar that occurs at any time during pregnancy in a woman who does not already have diabetes.

There are relevant data and percentages according to the type of diabetes and its prevalence. Diabetes is one of the most common chronic diseases in the world. According to the World Health Organization (WHO), it is estimated that more than 400 million people worldwide have diabetes, and this number is increasing. Thus, we can see that the main types of diabetes are type 1 diabetes, type 2 diabetes, and gestational diabetes.

Type 1 diabetes accounts for approximately 5-10 % of all cases of diabetes. It develops when the immune system attacks and destroys the beta cells in the pancreas that produce insulin. Therefore, people with type 1 diabetes need daily insulin injections to control their blood sugar levels.

Type 2 diabetes: This is the most common type of diabetes, accounting for approximately 90-95 % of all cases. In type 2 diabetes, the body does not produce enough insulin or cannot use it effectively. It is often associated with overweight, obesity, lack of physical activity, and genetics.

Gestational diabetes: It develops during pregnancy and usually disappears after delivery. However, women who have had gestational diabetes have a higher risk of developing type 2 diabetes in the future.

About the above, research carried out by the Pan American Health Organization (PAHO) has shown the following data obtained.

It is estimated that 62 million people in the Americas live with Diabetes Mellitus (DM) type 2.

In the Americas, in 2019, diabetes was the sixth leading cause of death, with an estimated 244,084 deaths caused directly by diabetes.

Similarly, Arroyo et al.[3] states that:

Currently, there are more than 400 million people diagnosed with diabetes, and it is expected that by the year 2030, there will be more than 500 million, which makes it a priority intervention entity not only in the health system, but also for other sectors of society.

Relevant data indicate that in Argentina the government exposed in its page ("Diabetes Mellitus") the following data where we can observe that "1 in 10 people aged 18 years or older has diabetes and given that, for several years it remains without symptoms, approximately 4 out of 10 people who suffer from it are unaware of their condition."

Data from the "4th National Survey of Risk Factors", "show that in Argentina 12,7 % of the adult population presents diabetes or elevated blood glucose by self-report".

Its growing prevalence and the magnitude of the damage it causes make it a public health problem that requires the implementation of active policies aimed at preventing its development and reducing the associated disease burden.

On the other hand, it is necessary to emphasize the list made by Arroyo et al.[3], where they expose the complications resulting from uncontrolled diabetes:

Among the most frequent complications of diabetes are diabetic retinopathy, blindness, increased

cardiovascular risk, and, therefore, increased likelihood of stroke and renal failure. Additionally, alterations in the nervous system can compromise overall health and impact the quality of life for the individual. Diabetic foot is considered the main complication, mainly due to the neuropathies and vasculopathies present in diabetic patients, which generate ulceration. Its prevalence is between 8 % and 13 % of diabetic patients and affects mostly adults between 45 and 65 years of age, who are in a working and socially active stage. Diabetic foot is responsible for lower limb amputation and generates functional limitation in the individual with diabetes, which compromises their performance and social participation. Its prevalence and the cost of care have a significant impact on health systems, making it a problem that should be addressed through primary prevention, which should be led by a multidisciplinary team.

Based on the above, it is essential to emphasize that diabetic foot is a complication of diabetes. A research define it as "Diabetic foot is defined as one that presents infection, ulceration or destruction of the tissues of the foot associated with neuropathy and/or peripheral arterial disease of the lower limbs in people with diabetes".

In this regard, if a foot ulcer or other foot injury develops, it is crucial to seek medical attention immediately. Foot ulcers can become chronic and complex to treat, increasing the risk of serious complications, such as severe infections or even the need for amputation, making it a serious but preventable complication, where proper foot care, regular medical attention and disease management help many of the associated complications to be prevented or effectively treated.

As we have observed, in the first instance, we provided a brief description of diabetic foot, the types of diabetes, and considered this disease within the group of chronic diseases. In addition, having clarified the basic and necessary concepts, we will continue to explore our topic of interest in depth, specifically the diabetic foot.

The World Health Organization defines diabetic foot (DF) as "the presence of ulceration, infection, and/or gangrene of the foot associated with diabetic neuropathy (DN) and varying degrees of peripheral vascular disease, and resulting from the complex interaction of different factors."

In addition, a study sets out the following values to quantify the total number of people affected. Diabetic foot ulcers (DFU) are a serious and devastating complication of diabetes that affects 26 million people worldwide annually. People with diabetes have approximately a 25 % lifetime risk of developing a foot ulcer compared to those without diabetes, and a prevalence of 4 % to 10 % of the diabetic population has been reported.

Also, Sachaper NC et al.[6] states that "Diabetic foot disease consists of a series of foot alterations that can lead to ulceration, tissue infection, and even limb amputation".

Continuing with the development, we find the words of Carro GV. et al.[7] exposes the following values:

Diabetic foot (DF) is a complication that occurs in 19 to 34 % of patients with diabetes, with an annual incidence of 2 %. In Latin America, it is the reason for hospitalization in 3,7 % of cases and 20 % of those hospitalized with diabetes mellitus.[2] Ulcers in PD are associated with different degrees of neuropathy and peripheral arterial disease (PAD) as well as other characteristics (infection, presence of osteomyelitis, location, presence of Charcot neuroarthropathy (CN) that confer to this disease different degrees of severity that can threaten the preservation of the limb and the patient's life. The diabetic foot is addressed by different health professionals, seeking to improve the prevention and treatment of the pathology, among so many professionals who have researched on this particular topic we will highlight the work of Arroyo LD et al.[3] who wrote about the importance of the performance of the kinesiologist in the prevention and education of people who are suffering from the pathology of study in this manuscript diabetes, seeking to prevent diabetic foot and amputation. Similarly, they emphasize the education of health personnel to address the issue in as many areas as possible, highlighting the importance of interdisciplinary collaboration.

Similarly, the Argentine Ministry of Health and its team prepared a manual for the health team or any person detailing clearly and visually the tools to prevent or treat diabetic foot, stressing the importance of self-care and giving advice on how to avoid it, how to treat it and which level of care to go to depending on the severity of the injury.

The following authors, Carro G et al.[7] carried out a validation of the different diabetic foot classifications, which was published in Revista de la Sociedad Argentina de Diabetes. The validation aims to enhance interdisciplinary communication, facilitate lesion assessment, support prognosis, and contribute to statistical purposes.

Regarding the diabetic foot, its complications, and classification, it is necessary to consider the work done by Rivera Soto A et al.[8] who performed a multidisciplinary treatment with ozone therapy for chronic diabetic foot ulcers. The research and the results of the treatment were published in the Spanish journal of ozone therapy, where the treatment with ozone therapy performed in four people with different degrees of injury the application of the treatment for eight weeks was successful, in the research the importance of interdisciplinary work with nutritionists, doctors, nurses, kinesiologists is remarked.

On the other hand, Hernández Rodríguez J et al.[9] exposes in the Cuban journal of Endocrinology their

research work, where they

They emphasize the importance of physical exercise and describe the beneficial effects of exercise on people with type 2 diabetes.

For all the above mentioned, it is essential to emphasize that the diabetic foot begins with a minor laceration in the foot of the person with diabetes mellitus, which can be a product of the bad use of footwear, a traumatism, a bad cut of nails; without forgetting that in addition in the disease, we have neuropathies where the peripheral nervous system is affected causing alterations in the sensitivity and motor in the peripheral nerves. In this case, we are emphasizing those in the foot, as it is an essential feature, since neuropathy generates an abnormal distribution of weight load on the foot, which increases the risk of pressure injury.

The worrying thing about foot injuries is that the wound does not heal in the usual way. This healing process is usually slower, so if proper care is not taken, the wound may continue to grow in size and further complicate the situation. Hyperglycemia impacts the functioning of cells involved in the healing process, causing a decrease in their activity. Diabetes then causes non-healing wounds in many parts of the body, such as the legs or toes.[10]

It is of great importance to remark what Tortora, GJ et al.[1] exposed where he is going to explain about the stages of the wounds, which can be acute in which they heal in a time of approximately three weeks where all the phases of healing are fulfilled, if that process is not fulfilled the wound becomes chronic and can be presented in different forms such as bedsores, foot ulcers.

In the same way a study explains that:

Diabetic foot ulcer (DFU) is a disruption of the continuity of the skin of the foot, ranging from minimal involvement of the epidermis and part of the dermis to deep wounds that can reach the bone. Their chronicity characterizes them. They often have an impact on the quality of life, morbidity, and mortality of people with diabetes.

It should also be noted that peripheral arterial disease is produced as a consequence of arteriosclerosis. This factor hinders or prevents proper oxygenation of tissues, which in turn influences the appropriate healing of ulcers. Therefore, there is an increased likelihood of amputation of the lower limb.

As in many diseases, there are different factors that increase the probability of suffering from this condition, which are called predisposing, precipitating, and aggravating factors. Arroyo, LD et al.[3] details and discovers them in their scientific article, which we will mention below.

Predisposing factors are those that, in a diabetic patient, increase the risk of injury. These are related, on the one hand, with the ischemia generated by the vasculopathy responsible for the initial changes, such as skin dryness, which favors the appearance of ulcers in the event of any trauma; and, on the other hand, with neuropathy, since the main symptom that can be seen in patients is the decrease in deep, tactile, superficial and thermal sensitivity, which alters the musculoskeletal system (claw toes appear) and causes restriction of joint mobility.

Triggering or precipitating factors: factors that make the injury debut. These can be extrinsic or intrinsic. Extrinsic factors are divided according to the cause into traumatic (blows, falls); mechanical, such as ill-fitting footwear, considered one of the main aspects to be taken into account in the evaluation of the diabetic foot, since it is responsible for more than 40 % of the appearance of ulcers; thermal, by introducing the feet in hot water, use of electric blankets or hot bags; chemical, use of keratolytic agents, especially those containing salicylic acid; and intrinsic, which include deformities (hallux valgus or bunion, claw toes, Charcot arthropathy, among others) that can generate an increase in plantar pressure, which causes calluses, which can end in pre-ulcerous lesions.

Aggravating or perpetuating factors: factors that, in an established diabetic foot, facilitate the appearance of complications and delay healing. Here, we find microorganisms of various kinds, mostly of saprophytic nature, such as staphylococci and streptococci, among others. Aerobic and anaerobic organisms, such as Escherichia coli and Clostridium perfringens, can also be found in ulcers that are deep enough. Such microorganisms may invade deep tissues, causing conditions such as cellulitis and septic arthritis.

People who present one or more of these factors should be monitored every 6 months by a multidisciplinary team, who, through measures such as patient and family education and the family, reduce the risks of presenting diabetic foot and, therefore, the probability of lower limb amputation, which is not only “removing the compromised limb”, but also the psychological implications that it brings at a psychological level due to alteration of the body schema and gait pattern, which, although it can be solved in some cases, can be solved with the with prostheses prosthesis, the neurological alterations that the patient presents because of diabetes leave limitations in the performance of some of the activities of daily living that involve movement and greater weight loads, which ultimately affects the welfare and quality of life. At this point, we will stop to explain the prevention of diabetic foot, as described by Arroyo LD et al.[3] we find that:

Prevention of diabetic foot requires the control of all risk factors: body weight, glycemia, arterial hypertension and dyslipidemia, which from physiotherapy with a program of aerobic exercises, strength and flexibility mainly regularly and of moderate intensity, help to improve the well-being and prognosis of the patient, in addition

to optimizing the physical condition and functioning of the organism, which increases the quality of life and reduces mortality in people with DM or without it, which makes it an essential element of health promotion.

Continuing with the reading, it is essential to note that diabetic foot is a foot injury and the characteristic of this pathology is that the person will not have symptoms about what is happening in his foot, being a circulatory and neurological affectation, the vast majority of patients do not have pain until the condition is very advanced. Hence, the hospitalization for the treatment of PD is very high.

Prolonged hospitalization incurs significant costs for both the healthcare system and individuals. It affects the quality of care, as being hospitalized and unable to undergo outpatient treatment is not a favorable scenario for aging. Unfortunately, most of these hospitalizations end with amputation of the limb.[11]

In addition, noting that the conventional treatment performed in medical centers in Córdoba only focuses on the use of devices and drugs aimed at wound closure, using bandages or even orthoses for prolonged immobilization of the ankle joint and foot.

It is also important to note that prolonged immobilization can lead to ankylosis of the joint, significantly reducing mobility and impacting the person's gait and overall quality of life.

For all the above-mentioned points in this manuscript, we propose to carry out a complementary protocol that incorporates rehabilitation through movement to approach the complete care of the person suffering from diabetic foot. Additionally, we cover prevention through an interdisciplinary approach that utilizes all the tools provided by kinesiology and physiotherapy.

Finally, the overall objective of this manuscript is:

To develop a comprehensive approach to preserve the mobility and functionality of the foot in patients affected by diabetic foot attending the Centro de Flebología y Estética Dr. Gustavo Sanchez, to significantly improve their quality of life through the promotion of movement and prevention of complications associated with this health condition in the year 2023.

On the other hand, the specific objectives are:

To describe the physiotherapeutic treatments currently performed, using evidence-based kinesiology.

To perform an initial mapping on the incidence of patients arriving with the condition of diabetic foot and classification of lesions that come to the phlebology and aesthetics center.

Develop a proposal to complement the rehabilitation protocol used in the clinic by incorporating physical therapy.

Generate awareness about the importance of foot care. Specifying essential features of the chronic disease, diabetes, and its complications with the diabetic foot.

This scientific manuscript aims to emphasize the significance of movement in preventing ankle ankylosis in the diabetic foot, which is the primary focus of this work.

Through a systematic review, experimental studies were conducted and yielded promising, quantifiable results that demonstrate the benefits of physical movement and the improvement in quality of life for individuals with this condition.

This manuscript is part of a situation diagnosis in which a previous research is carried out, performing a bibliographic search and an analysis of the incidence of patients in the chosen center, which will allow to advance with an experimental research that will allow to quantify the benefit of the movement from the pre-established protocol in a near professional future.

METHODS

Methodological framework

Design

The research study is a retrospective, observational, exploratory, and descriptive study of a longitudinal type with a mixed approach.

This manuscript is observational in that it aims to describe an event or phenomenon in a specific population at a particular point in time.

It is also exploratory, as it is a preliminary investigation aimed at clarifying the situation regarding the problem.

The chosen design is descriptive because what is sought in this manuscript is to specify essential features of the chronic disease diabetes, specifically in diabetic foot complications and the loss of mobility of the foot in patients with the pathology.

A mixed approach will be employed, as the manuscript utilizes numerical collections and statistical analyses of treatment procedures. Additionally, we will conduct a more subjective exploration using the qualitative approach, where we interpret other articles.

The research design is non-experimental, where we will observe the treatments already proposed without modifying the nature of the context.

And it will be a longitudinal study, where we will observe the same patients throughout the remainder of

the semester.

Regarding the sample, it will be the medical records of patients with an age range of 18 to 85 years, regardless of sex, who are diagnosed with the chronic disease of diabetes mellitus and are affected by diabetic foot in the province of Cordoba, Argentina.

The choice of the sample will not be random, since we will use a non-probabilistic sampling where the inclusion criteria will be people regardless of sex, but who are diagnosed with diabetes mellitus and are suffering from the complication of diabetic foot, irrespective of whether it is chronic or acute in the period from 2020 to 2023.

The following criteria were considered for selecting medical records:

Inclusion criteria

- Individuals over 18 years of age.
- Diagnosed with Diabetes Mellitus.
- Patients completing treatment at the Centro de Flebología Dr. Gustavo Sanchez.

Exclusion criteria

- Patients with ulcers that are not a product of diabetes.
- Those who did not complete the treatment.
- People undergoing treatment at another medical center.

Data collection techniques

The tools we used in the data collection were pages such as PubMed, Google Scholar, data obtained by WHO and PAHO and medical journals. In addition, we conducted a census on the concurrence of diabetic patients attending at the medical center and the type of injury with which they transpire.

Inclusion criteria

- Articles from the year 2018 onwards.
- Short readings, which are considered useful for the review.
- English or Spanish languages.

Exclusion criteria

- Inability to access the original article.
- Healthy patients or patients with diseases other than Diabetes Mellitus (DM) or people with DM without ulcer risk.
- Studies that are not relevant to this review.

RESULTS

An initial search using Google Scholar retrieved a total of 11 500 articles related to diabetic rehabilitation, after applying the exclusion criteria, which mainly involved publications from 2018, the total number of articles related to diabetic foot rehabilitation was 4 300.

Finally, the articles included in this review are 9, which were selected as they met the necessary criteria. The articles that were not selected had the main reason for their exclusion as being unable to access the original article, and they were written in another language.

For a better understanding, we will divide them into four phases: first, education; then, ulcer classification; followed by conventional treatment; and ending with physical activity.

Education

As previously mentioned, the education of individuals suffering from this pathology, as well as that of all healthcare professionals, is of great importance for a comprehensive treatment focused on improving quality of life and reducing costs. With this objective in mind, the results found were as follows:

In the systematic review conducted by Quemba-Mesa MP et al.[12] 56 articles were analyzed, focusing on the importance of daily education in patients with diabetes for the prevention of diabetic foot. Different approaches to teaching are explored, highlighting the importance of education provided by health professionals during each intervention performed during treatment.

In a review by Sanchez-Uceda R et al.[13] seven articles were selected for experimental implementation of education and prevention. Five manners of the articles indicate a decrease in the incidence of ulcers as a result of prior education. The remaining two articles show no efficacy in education.

Finally, in the bibliographic search, a protocol proposed by the Argentine Ministry of Health was found, which includes a manual for health professionals that provides all the necessary tools for daily patient education.

Classification of ulcers

It is necessary to take into account that the whole work team has the same classifications and work guidelines. What was found and chosen for this work is presented below:

For the classification the experimental study carried out in Argentina in 15 different centers Carro et al.[11] expose that other results were obtained from which we will mark that, of the total of 312 patients, 76,6 % are male, 45 % have diabetes mellitus type 2, 26,6 % have a history of minor amputation and 5,4 % have a history of major amputation. Finally, 43 % required immediate hospitalization.

The causes of the injuries reported by these patients are: 30 % as a result of trauma, 22 % as a result of shoe rubbing, 18 % unknown, and 30 % as a result of nail cutting, foreign body in the shoe, or walking barefoot.

Given this data, it is essential to conduct a previous assessment of the patient, as all causes of injuries are avoidable through education.

Treatment

One of the most critical components of this work involves the treatment and care provided to the patient. In the literature search, we found the following:

The treatment performed in the clinic is conventional, utilizing physiotherapy to relieve symptoms and accelerate healing, as exemplified in the article prepared by Arroyo LD et al.[3]

On the other hand, the use of ozone therapy is performed, which has extraordinary evidence for the healing of chronic ulcers, in this manuscript we emphasize the article published in the Spanish journal where the authors Rivera Soto AM et al.[8] where the case of 4 patients with chronic ulcers is exposed where they are exposed to ozone therapy treatment where in 8 weeks there is an excellent progress in the healing of the wound allowing a prompt reincorporation in daily activities.

Physical activity

As mentioned in the previous paragraphs, the treatments performed favor ankle ankylosis; therefore, it is relevant to control movement based on scientific evidence for the prevention of such a condition.

A systematic review conducted by Tran MM et al.[14] states that foot movement and aerobic exercise have beneficial effects on ulcer closure. The movements performed are dorsal flexion of the foot, plantar flexion, inversion, eversion, and circumduction, which should be performed twice a day. Additionally, aerobic exercises of 50 minutes, three times a week, were recommended. Notably, 90 % of patients presented considerable improvements in ulcers and quality of life.

Likewise, in the review carried out by Sánchez-Uceda R etal.[13] 3 articles are analyzed where they show that physical activity and movement have beneficial effects on glycemia, strength, mobility, balance, reduction of the wound, reduction of the risk of diabetic neuropathies, improvements in the supply of oxygen and the quality of life of the person.

In the Cuban endocrinology journal Hernández Rodríguez J. et al.[9], conducted a systematic review where they analyze 83 articles, which expose the benefit of performing exercise at least 30 minutes for 5 days in people with Diabetes Mellitus type 2, where they demonstrate the benefit by reducing cardiovascular risk and reducing weight, obtaining greater metabolic control and valuable for the prevention of diabetic foot.

Finally, an exception is made and a quasi-experimental study by Aguila Y et al.[15] in which 40 people divided into two groups with 20 people each were evaluated, in which in the experimental group an exercise plan was carried out which had very beneficial effects where in an average of 6 to 12 weeks a decrease in blood glucose, cholesterol and triglycerides was observed, in addition to a reduction of blood pressure and improvement in the symptoms in patients with type 2 diabetes.

Clinical epidemiology results

As mentioned above, one of the specific objectives is to perform a mapping of patients attending the phlebology center. The results obtained are presented below.

The period used for this manuscript is from 2020 to mid-2023.

The total number of patients with diabetes who were seen at the medical center is 400 people, with an age range of 18 to 85 years. In the following graph, we show the percentage of male (220) and female (180) patients.

The next subclassification of patients is based on the location of the ulcer, as shown in figure 2, where we can quantify the area as supramalleolar, inframalleolar, or combined. In the graph, we will make a division between males and females.

It is essential to consider that the laceration may not be present in all patients in the same manner. In some, it is limited to the foot, while in others, it can be much broader, affecting the leg, and may even be combined with other injuries. The results obtained show that supramalleolar lesions are present in a total of 230 patients, which implies a greater impediment to foot mobility that can be limited by the use of gauze or bandages for

wound healing.

When we refer to inframalleolar lesions, we observe a total of 200 patients. We must evaluate the location of the ulcer, as it may be on the plantar side of the foot and hinder the patient's gait. And finally, the great majority of patients present with combined ulcers, which are located in both places.

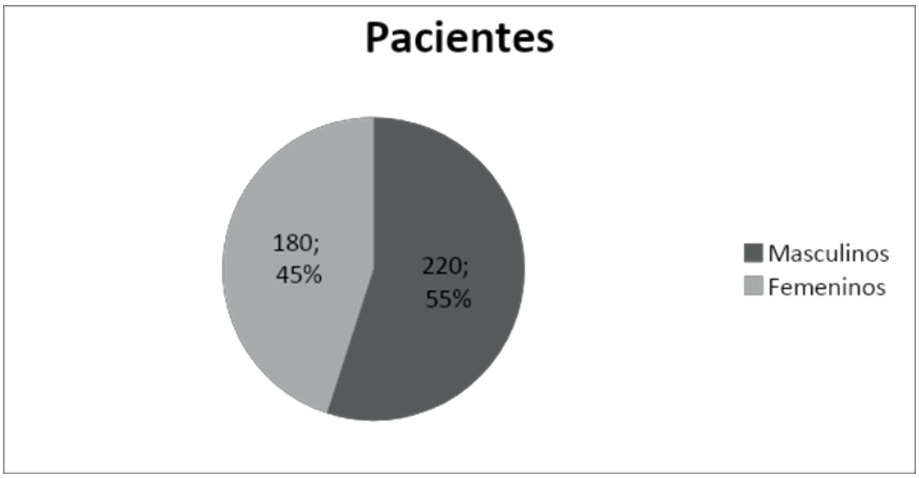

Figure 1. Number of patients

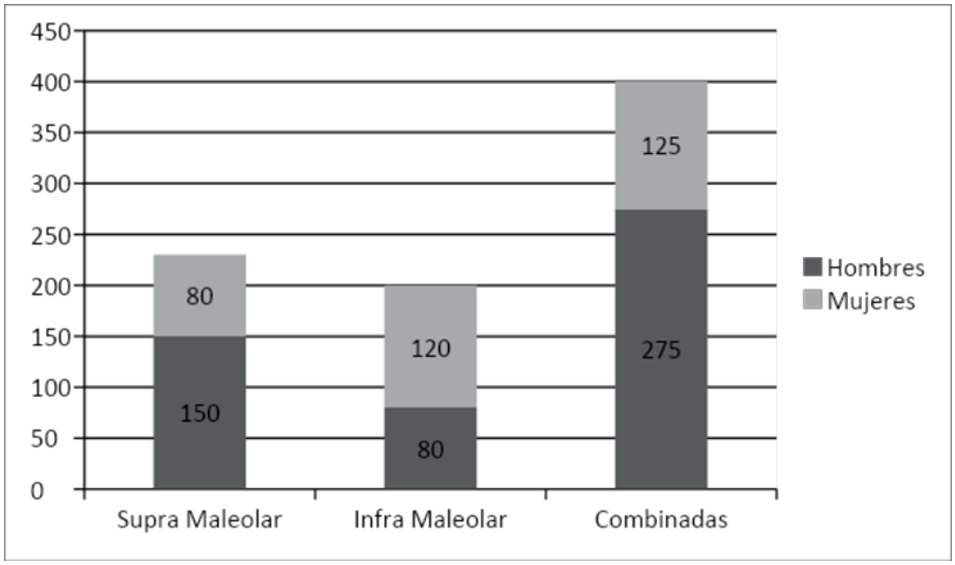

Figure 2. Location of the ulcers

The following illustration will show the number of patients who present ankylosis of the ankle, and as we have been demonstrating, we will make the difference between men and women.

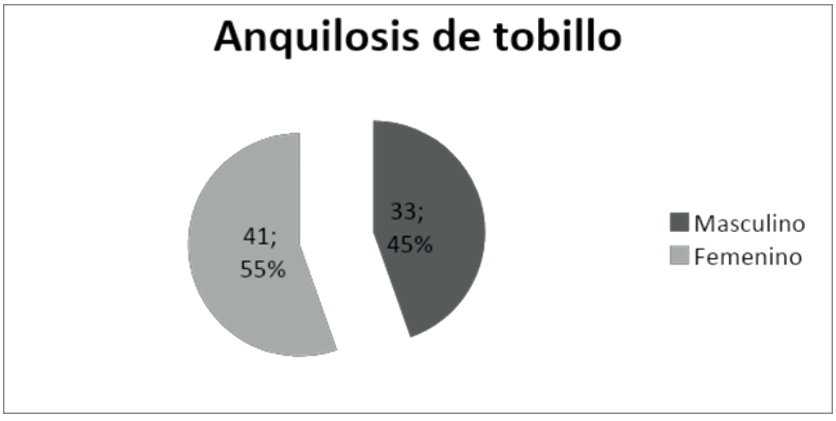

Figure 3. Ankle ankylosis

On the other hand, a significant number of patients have undergone amputations in their affected lower limb, so in the following figure 4, we will show how many patients are amputated and whether the amputation was partial or total. When we speak of partial amputation, we refer to the level of the toes and phalanges of the foot.

Here, we can see a total of 18 patients with partial amputations and 30 patients with supracondylar amputations.

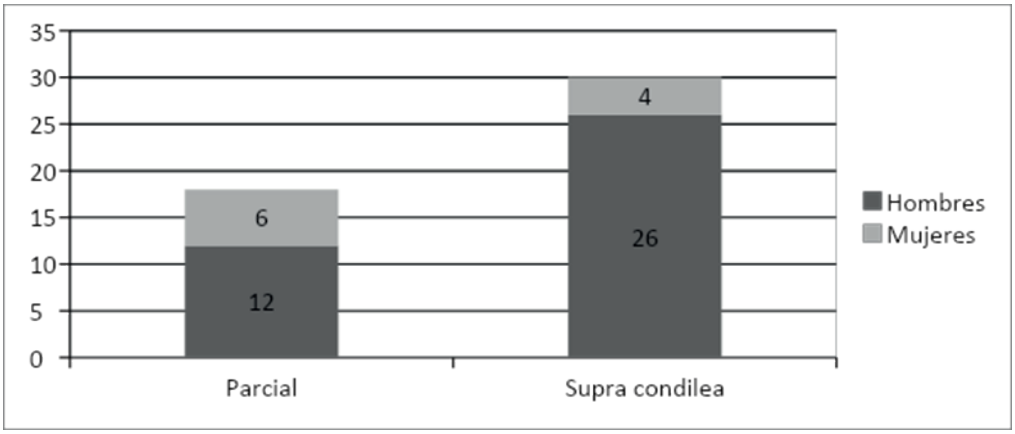

Figure 4. Amputations and their locations.

Lastly, a no less important fact collected in the anamnesis is that the vast majority of patients are active smokers. This is shown in the following graph.

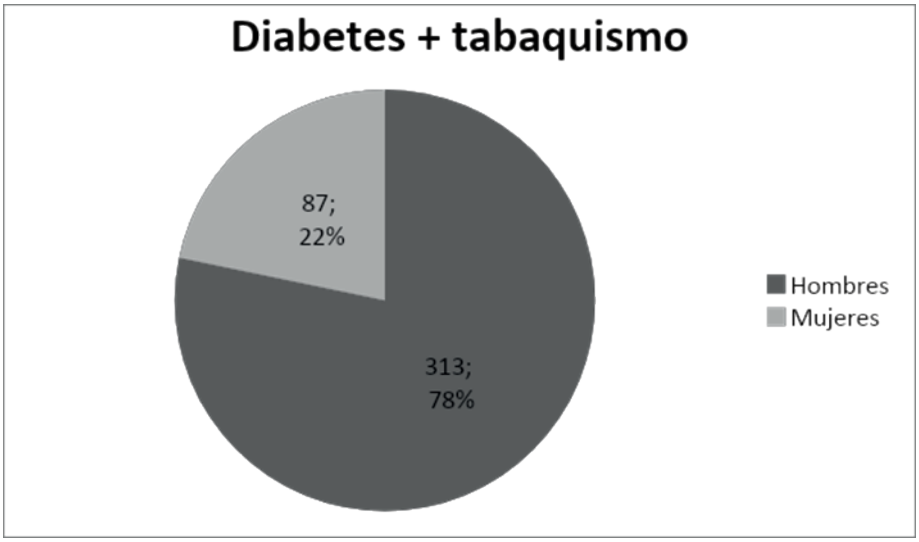

Figure 5. Patients who are active smokers.

The results obtained from the general mapping carried out in the clinic indicate that there is an abundant population in which diabetic foot ankylosis can be treated. The population is primarily male, but the condition is also found in the female population.

In mapping the patients, we found a lack of information on their joint mobility, which is a limitation in this manuscript.

The information we obtained indicates that there are 74 patients presenting with ankle ankylosis; however, we do not have goniometric quantification that evidences the magnitude of the joint mobility loss. This could be achieved through a goniometric assessment to provide a more accurate quantification of the severity.

DISCUSSION

As mentioned above, one of the objectives is to complement the rehabilitation protocol in which it is being carried out in the medical center, since at present they only focus on the healing of the ulcer, the application of devices such as the magnet and perform ozone therapy to optimize the healing times and accelerate the treatment.[16]

Based on the results obtained, patient education is crucial for preventing ulcers and minimizing wound

aggravation. Therefore, it is proposed to train the professionals of the medical center using the material obtained from the Ministry of Health of Argentina, so that patients acquire the skills necessary for self-management of foot care.[17]

With the prevention guidelines, we seek that the patient learns to perform:

- Daily inspection of the feet: observe the entire foot, looking for lesions, changes in skin color, inflammation, or any other signs that may require consultation with health professionals to make an early diagnosis.
- Maintain correct foot hygiene by using warm water and soap. Also, emphasize the importance of drying the foot correctly, without forgetting the interdigital spaces, to prevent moisture accumulation between them.
- Moisturizing and foot nail trimming: When moisturizing, avoid applying cream to the interdigital spaces, but instead, use it on the rest of the foot. Nail cutting is a critical issue, as a poorly cut nail can lead to infections. Therefore, it should be cut in a straight line, limiting the ends, without deepening the reduction on the free edges close to the skin. If the patient has difficulty doing so, they should consult a licensed podiatrist. In the presence of thick nails with cracks, lesions, calluses, or fissures, consult with the healthcare team.
- Socks: They should be worn every day and changed daily.

Preferably, they should be clear, cotton, and avoid seams due to repetitive rubbing; also, avoid tight fits to ensure good circulation.

- Footwear: Check the inside of the shoes before putting them on to avoid any foreign objects. Avoid tightness; do not excessively tighten the laces. The footwear should be adapted to the foot, not the other way around.
- Bandages: If the patient must use bandages, avoid tight bandages over the toes, as they could cause a tourniquet. Also, prevent folds and bulky bandages.

These guidelines should be taught to patients by health professionals, and it is also of great importance that they are reinforced in each session to establish the habit of self-care and prevention. Additionally, each patient must be reminded to exercise daily.[18]

The remaining guidelines to be taken into account can be communicated verbally during the session or conveyed through audiovisual means, such as videos and infographics, published on social networks and posted in the offices.[19]

Health professionals in each prevention session should complete a medical history to identify signs of potential injury and prevent it from occurring. The data to be found in the clinical history are the following:

- Inspection of the foot for lesions
- Palpation of peripheral pulses.
- Temperature of the foot
- Sensitivity of the foot

In addition, the kinesiologist should perform a goniometric assessment to control the ranges of mobility of the foot, performing this assessment in a preventive way of ankle ankylosis and the evaluations that will be recorded in the medical records are a valuable tool to quantify the motor evolution and patients get a numerical feedback of the progress to assess the functionality and adhere to treatment.[20]

Based on what has been investigated and exposed so far, an interdisciplinary treatment is proposed, composed of the medical part where wound healing is performed, where the wound is sanitized, non-viable tissue is debrided, infection is controlled by antibiotics either orally or intramuscularly, skin moisture is taken care of since it is vital for tissue regeneration. The edges of the wound are protected, preventing the wound from extending, and it is covered with dressings or bandages. In cases of very large or chronic ulcers, ozone therapy is employed, yielding excellent results for treating these wounds.[21]

This procedure is performed by the doctors and nurses of the Center of Phlebology and Aesthetics, under the direction of Dr. Gustavo Sanchez.

In physiokinesic treatment, physiotherapy is recommended, where the use of magnetotherapy and electrostimulation devices is employed.

Magnetic therapy is used for analgesic purposes and to increase tissue oxygen availability. The way it is used is:

- a pulsed modality,
- Intensity of 200 GAUSS
- Emission frequency up to 100 Hz
- Treatment time of 30 minutes

Envelope field emitters are placed on the affected limb.

While the patient is in the magnetic field/they can perform basic movements that have been proven to be beneficial for ulcer closure, which are:

- ankle flexion and extension
- inversion and eversion
- Circumduction

Ten repetitions of each exercise are performed. During the 30 minutes, the patient should complete at least two full series.

In the use of electrotherapy, the need of each patient was evaluated for the choice of current:

- Diadynamic: for analgesia and increased circulation.
- TENS: for electroanalgesia.

The frequency varies from 20 to 200 Hz, for a time of 30 minutes.

- Interferential: for pain reduction, anti-inflammatory action, improvement of metabolism and tissue regeneration, excitomotor effect.

The choice of device used in the session is based on the patient's needs and the kinesic objective, aiming to achieve symptom relief and muscle stimulation.

Therapeutic exercises were then performed, as there is evidence of benefits in all systems of the human body.

The patient is asked to perform the basic exercises explained while undergoing magnetotherapy. It is also recommended to perform at least 30 minutes of aerobic exercise, which has benefits in reducing insulin resistance, promoting weight loss, alleviating anxiety, stress, and depression, and lowering cardiovascular risk. The practice of physical exercise is the most effective way to maintain a person's functional capacity and prevent disability.

Additionally, flexibility, proprioception, resistance, and both loaded and unloaded exercises were performed in the clinic, including active and passive exercises aimed at preserving foot mobility and preventing ankle ankylosis.

It should be noted that the goniometer is used during the office session, a tool used to quantify the degree of mobility of the ankle and serve as a parameter for future sessions.

It is essential to exercise caution when dealing with ulcers on the plantar aspect of the foot, as it is not advisable to unload weight on them due to various factors, including the patient's pain and the risk of further damage to the wound. Faced with this situation, the patient can continue to move their body with adaptations that involve seated exercises, utilizing the effect of gravity to avoid unloading weight. In addition, in the market, there are therapeutic sandals that direct weight relief to another sector, insoles for selective relief, or interfaces such as felt, where the health professional makes the necessary cuts to adapt it to the wound, ensuring it does not produce localized weight relief in the wound. The lesion on the plantar aspect of the foot does not impede the performance of therapeutic exercises; it is necessary to adapt the exercises to each patient's individual needs.

List of exercises performed in the office:

- Lifting the internal arch and flexing the toes.
- With the feet in adduction, flex the toes.
- With the feet parallel, flex the knees and spread them apart.
- Do maximum dorsal and plantar flexion of the feet with maximum digital flexion (Lying down and with knees extended).
- Perform adduction and abduction movements of the toes.
- Stand on one foot, holding the posture for one minute.
- Standing on toes and heels.
- Abduction of the toes.
- Exercises with a tennis ball placed on the sole, causing the foot to slide.
- Knee extension and resistance band exercises for ankle mobility.
- Exercises to strengthen the lower limbs.
- Exercises for balance and gait.
- In case the patient requires assistance with walking, we will focus on strengthening the upper limbs. And exercises for balance and gait.
- Flexibility and stretching exercises for a calm return.

The proposal is that the duration of the therapeutic exercise should have a minimum of 30 minutes, but this

value will be adapted to each patient.

Based on the above, a complete approach to the patient is proposed, through tools accessible to all health personnel, ranging from education and injury prevention, healing treatment, period of use of devices for the relief of symptomatology and therapeutic exercise for the prevention of ankylosis of the ankle, all this is done in search of the overall welfare of the person and an interdisciplinary approach by health personnel.

REFERENCES

1. Tortora GJ, Derrickson B. Principios de anatomía y fisiología. 15ª ed. Madrid: Editorial Médica Panamericana; 2018.

2. Junqueira LC, Carneiro J. Histología básica. 12ª ed. Madrid: Editorial Médica Panamericana; 2015.

3. Arroyo LD, Burbano JI. Diabetes y pie diabético: una problemática mundial abordada desde la fisioterapia. Rev Colomb Endocrinol Diabetes Metab. 2019;6(3):199-208.

4. Organización Panamericana de la Salud (OPS). Diabetes. 2023. https://www.paho.org/es/temas/diabetes

5. MedlinePlus en español: Dr Tango. Diabetes. https://medlineplus.gov/spanish/ency/article/001214.htm

6. Schaper NC, van Netten JJ, Apelqvist J, Bus SA, Hinchliffe RJ, Lipsky BA, et al. Practical guidelines on the prevention and management of diabetic foot disease (IWGDF 2019 update). Diabetes Metab Res Rev. 2020;36(Suppl 1):e3266. https://doi.org/10.1002/dmrr.3266

7. Carro GV, Saurral RN, Issa CM, Witman ÉL, Braver JD, Casen MA, et al. Validación de clasificaciones de pie diabético en Argentina. Rev Soc Argent Diabetes. 2023;57(2):84-94.

8. Rivera Soto AM, Peredo Llaguno N, Weber Chuliá N. Pie diabético: tratamiento médico multidisciplinario y ozonoterapia. Rev Esp Ozonoter. 2018;8(1):181-196.

9. Hernández Rodríguez J, Domínguez YA, Mendoza Choqueticlla J. Efectos benéficos del ejercicio físico en las personas con diabetes mellitus tipo 2. Rev Cubana Endocrinol. 2018;29(2):1-18. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1561-29532018000200008

10. DBL Diabetes. Diabetes y cicatrización. 2022. https://www.dbl-diabetes.es/todo-sobre-la-diabetes/aspectos-basicos-de-la-diabetes/complicaciones/diabetes-y-cicatrizacion

11. Carro GV, Saurral RN, Witman EL, Alterin P, Braver JD, Carrió LM, et al. Características clínicas y evolución de pacientes con pie diabético en Argentina. Medicina (B Aires). 2023;83(2). ISSN: 1669-9106.

12. Quemba-Mesa MP, González-Jiménez NM, Camargo-Rosas MR. Intervenciones educativas para la prevención del pie diabético. Rev Cienc Cuid. 2021;18(1):66-80. https://doi.org/10.22463/17949831.2329

13. Sánchez-Uceda R, Tárraga-Marcos L, Madrona-Marcos F, Tárraga-López PJ. Educación y ejercicio en el pie diabético. J Negat No Posit Results. 2022;7(4):342-355. https://doi.org/10.19230/jonnpr.4451

14. Tran MM, Haley MN. Does exercise improve healing of diabetic foot ulcers? A systematic review. J Foot Ankle Res. 2021;14(1):19. https://doi.org/10.1186/s13047-021-00456-w

15. Águila Y, Vicente BM, Llaguno GA, Sánchez JF, Costa M. Efecto del ejercicio físico en el control metabólico y en factores de riesgo de pacientes con diabetes mellitus tipo 2: estudio cuasi experimental. Medwave. 2012;12(10).

16. Argentina.gob.ar. Diabetes mellitus. 2023. https://www.argentina.gob.ar/salud/glosario/diabetes

17. Asivamosensalud. ¿Qué son las enfermedades crónicas o ENT? https://www.asivamosensalud.org/actualidad/enfermedades-cronicas-una-epidemia-segun-la-oms

18. Ministerio de Salud de la Nación. Pautas de prevención para el abordaje de pie diabético. Buenos Aires: Ministerio de Salud; 2021. https://bancos.salud.gob.ar/sites/default/files/2022-07/pautas_prevencion_

abordaje_pie_diabetico_5-7-2022.pdf

19. Real Academia Española (RAE). Crónico. 2023. https://dle.rae.es/cr%C3%B3nico

20. Triana Ricci R. Pie diabético: fisiopatologías y consecuencias. Rev Colomb Ortop Traumatol. 2014;28(4):143-153. https://doi.org/10.1016/j.rccot.2015.04.006

21. Latarjet M, Ruiz Liard A. Anatomía humana. 5ª ed. Madrid: Editorial Médica Panamericana; 2019.

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