DEGREE IN NURSING

Final degree project

TITLE: ULCER PREVENTION AND TREATMENT THROUGH ELECTRICAL STIMULATION: A SYSTEMATIC REVIEW AND A SINGLE CLINICAL CASE STUDY

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ABSTRACT

Nowadays, ulcers are still a big public health concern, even though there are prevention methods, they are not as effective as they should be. Some scientific articles claim that electrical stimulation is the ideal adjunct treatment and prevention method for ulcers. Is there some truth in these statements or is there not enough evidence? In this review we analyse the current scientific evidence available of the possible association between electrical stimulation and ulcers. The foundation of electrical stimulation therapy may be related to the increase of oxygen circulation and blood flow to the affected tissue. Furthermore, they affirm it reduces bacterial burden and pain. As a result, they suggest that electrical stimulation therapy would be the perfect additional therapy to the standard wound care treatment. Therefore, a systematic bibliographic review consulting databases was conducted. After analysing the information available from scientific articles, no conclusive results have been found due to the lack of larger study samples. Across the different studies it may seem beneficial, but more research is required to evaluate more thoroughly and objectively this type of treatment and its effects in relation to ulcers.

KEYWORDS

Electrical Stimulation, Ulcer, Pressure Ulcer, Pressure Sore, Vascular injury, Wounds, Treatment, Therapy.

RESUMEN

En la actualidad, las úlceras siguen siendo una gran preocupación para la salud pública, aunque existen métodos de prevención, no son tan efectivos como deberían ser. Algunos artículos científicos afirman que la estimulación eléctrica es el método ideal para el tratamiento y prevención de las úlceras. ¿Hay algo de verdad en estas afirmaciones o no hay suficiente evidencia? En esta revisión se analiza la evidencia científica actual disponible sobre la posible relación entre la estimulación eléctrica y las úlceras. El fundamento de la terapia de estimulación eléctrica puede estar relacionada con el aumento de la circulación de oxígeno y el flujo sanguíneo hacia el tejido afectado. Además, afirman que reduce la carga bacteriana y el dolor. Como resultado, sugieren que la estimulación eléctrica sería el tratamiento adicional perfecto para el tratamiento regular de curación de heridas. Por lo tanto, se realizó una revisión bibliográfica sistemática consultando bases de datos. Después de analizar la información disponible de artículos científicos, no se encontraron resultados concluyentes debido a la falta de muestras de estudio más grandes. A través de los diferentes estudios, puede parecer beneficioso, pero se requiere más investigación para evaluar más exhaustiva y objetivamente este tipo de tratamiento y sus efectos en relación a las úlceras.

PALABRAS CLAVES

Estimulación eléctrica, Úlcera, Úlcera por presión, llaga por presión, Lesión vascular, Heridas, Tratamiento, Terapia.

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ABBREVIATIONS

DTI = Deep issue injury
ES = Electrical stimulation
DC = Direct current
AC = Alternating current
HVPC = High-voltage pulsed current
LIDC = Low-intensity direct current
PEMF = Pulsed electromagnetic field
TENS = transcutaneous electrical nerve stimulation
PrU = Pressure ulcer
DFU = Diabetic foot ulcer
RCT = Randomized controlled trial
PAD = Peripheral Arterial Disease
SatO2 = Oxygen saturation
WMCS = Wireless micro current stimulation
PC = Pulsed current
NMES = Neuromuscular electrical stimulation
ICU = Intensive care unit
HVMPC = High-voltage monophasic pulsed current
SWC = Standard wound care
VLU = Venous leg ulcer
MPMC = Monophasic pulsed microcurrent
BST = Burst stochastic stimulation
VEGF = Vascular endothelial growth factor
IF = Interferential currents
VEGF = vascular endothelial growth factor

1. INTRODUCTION

Ulcers are characterized as “a break on the skin, in the lining of an organ, or on the surface of a tissue. An ulcer forms when the surface cells become inflamed, die, and are shed.” (NCI Dictionary of Cancer Terms, 2011, 2nd of February).

Inadequate wound healing results in chronic wounds, which are defined as those that remain open for longer than 30 days. Etiologically, chronic wounds can result from vascular insufficiency, diabetes, or pressure-related lesions (Ashrafi, M et al, 2017). First, a pressure ulcer is a necrotized area over an under-pressurized part of the body caused by poor blood circulation; therefore, the primary causes are body weight and bad circulation. When blood supply is restricted, cellular nourishment suffers, excretions build up, and eventually cell necrosis takes place and causes ulceration. Reduced blood flow and tissue oxygenation exacerbate the resulting tissue necrosis, resulting in larger and faster-forming pressure ulcers (Shahroki, A et al, 2014). Deep tissue injury (DTI), a type of pressure ulcer that begins over the bone, often goes undetected until it reaches the skin's surface. Regular skin checks cannot identify these DTIs, thus neither the victim nor the caregiver are aware of the extent of the injuries as they develop (Kane, A et al, 2016). Once advanced, pressure ulcers can take months, if not years, to heal, and patients frequently require more invasive therapeutic procedures like surgical debridement. Secondly, foot ulcers are caused by diabetes are a prevalent complication for individuals with poorly managed diabetes mellitus. These ulcers typically occur in regions of the foot that experience frequent pressure or trauma, often resulting from underlying neuropathy, peripheral vascular disease, or inadequate foot care. The primary cause of diabetic foot ulcers is inadequate glycemic control (Oliver, T. I., 2022, 20th of August). Lastly, venous ulcers are wounds that occur on the legs due to inadequate blood circulation in the veins. The primary cause of venous ulcers is damage to the valves located within the leg veins, which disrupts the blood flow and pressure regulation in the area. As a result, blood can accumulate and cause tissue damage, leading to the formation of ulcers. Venous ulcers are typically found in the lower leg or ankle region (Johns Hopkins Medicine, 2020, 20 of July).

In addition, the underlying causes are frequently multifactorial and may include skin lesions, malnutrition, dehydration, cachexia, incontinence, immobility, and loss of sensation (Kawasaki, L et al, 2014)

These injuries are common in older people, critically ill patients, and people with limited physical mobility, such as paraplegic or quadriplegic patients. This results in a major public health concern because of the detrimental impact on the patient’s quality of life, independence, dignity, pain, and possible physical impairment (Shahrokhi, A et al, 2014). The treatment of pressure ulcers is expensive for both the health-care system and the patients. The majority of pressure ulcers are avoidable. The most important principle of health care in patients at risk of pressure ulcer is prevention. However, the prevalence suggests that there are still opportunities to improve this principle (Kane, A et al, 2016)

The traditional strategies to prevent pressure wounds includes offloading the pressure by turning the patient frequently, every 2 hours. More recent methods apply pressure-redistributing mattresses and wheelchair cushions. Other possible treatment plans involve dressings, debridement, biological therapies, electric and negative pressure wound therapies to increase wound closure rates, medications to treat infection and skin grafts. Even though, these alternative treatments exist, they are not always effective (Kane, A et al, 2016).

The physiological process of wound healing is complex but well-organized, including numerous cells and chemical mediators. There are three phases: inflammatory, proliferative, and remodeling. Hemostasis to control bleeding, migration of inflammatory cells to the wound site, granulation tissue formation, collagen repair, vascularization, and re-epithelialization are all events that occur during these phases. This is slowed down in chronic wounds, which do not go through this specific stages of healing. This may occur as a result of conditions that slows down the healing process, such as advanced age, obesity, smoking, nutritional inadequacies, or underlying illnesses that make patients more susceptible to developing chronic wounds. Due to inadequate microcirculation, growth factor release, and reduced cellular migration in diseases like diabetes, wounds stay in a chronic inflammatory phase (Rajendran, S.B, 2021)

The "skin battery" refers to the fact that human skin is electrically charged. Cutaneous wounds produce large and long-lasting endogenous electric currents and fields known as the "current of injury." These findings have given rise to the theory that applying electrical stimulation (ES) may promote chronic wound healing by mimicking the natural electrical current that occurs in cutaneous wounds. In healthy human skin, Na/K ATPase maintains an endogenous potential of 10 to 60 mV; this physiological current is lost in chronic wounds. These findings have prompted researchers and clinicians to investigate the use of various treatments, specifically different types of electrostimulation in chronic wound healing, to reestablish this endogenous potential (Ashrafi, M et al, 2017) (Fraccalvieri, M et al, 2014).

As a result, the use of ES as a further therapy and preventative measure for chronic wounds of diverse aetiologies, such as burns, diabetic foot ulcers, venous, mixed, and arterial leg ulcers, and pressure ulcers, has been investigated (Fraccalvieri, M et al, 2014). For example, lower limb wounds that persist over time can have a major impact on both patients' well-being and the healthcare system. Despite the availability of conventional treatments designed to address the underlying causes of such wounds, such as revascularization, compression therapy, and offloading for pressure relief, their efficacy is not always guaranteed (Ashrafi, M et al, 2017). And the use of electrical stimulation can be one of the promising methods for these wounds. There exist different types of electrical stimulation such as, direct current (DC), alternating current (AC), high-voltage pulsed current (HVPC), and low-intensity direct current (LIDC). Pulsed electromagnetic field (PEMF) and the most known transcutaneous electrical nerve stimulation (TENS) (Thakral, G et al, 2013).

That’s why it’s interesting to study if ES can be made easier to use medical care. Therefore, the objective of this paper is to critically review evidence of the use of ES as healing therapy and form of prevention of ulcers.

2. RESEARCH QUESTION

Is there any scientific evidence on the use of electrical stimulation for the prevention and treatment of ulcers?

3. HYPOTHESIS

The use of electrical stimulation on ulcers is supposed to accelerate the healing process and can prevent the appearance of these.

4. OBJECTIVES

General objective

- To analyse the current scientific evidence available on electrical stimulation therapy as wound treatment.
- To investigate one patient's experience as a case study with this therapy.

Specific objectives

- To verify the use of electrical stimulation therapy as an alternative treatment for any type of ulcers.
- To evaluate the possible impact of this new technique on an economic front and patient healthcare level and its possible advantages.
- To determine the causes of why it hasn't been used yet as a standardized form of treatment.

5. METHODOLOGY

5.1. Systematic review

To carry out this work, a systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement February 2023. As databases, Pubmed and Web of Science were used.

Objective 1 mentioned above, which is "To analyse the current scientific evidence available on electrical stimulation therapy as wound treatment", corresponds to the systematic review section.

First, we carried out a systematic review around the topics of electrical stimulation and ulcers, to get to know the scientific evidence available defending or refuting this form of treatment and prevention. In the initial search, the keywords “electrical stimulation” and “ulcers” were used, as well as synonyms of these terms. The search query included both the Boolean operators AND and OR: (“Electrical Stimulation”) AND (“Ulcer” OR “Pressure Ulcer” OR “Pressure Sore” OR “Vascular injury”). The terms used in the search query are MeSH terms.

In order to filter the results of the search, we established inclusion and exclusion criteria. As inclusion criteria we chose 1. Studies in which the relation between electrical stimulation and ulcers is studied, 2. Articles with full text access, 3. English or Spanish articles, 4. Articles published in the last 10 years, 5. Clinical trial, 6. Systematic review, 7. Review, 8. Randomized controlled trial, 9. Evaluation study, 10. Controlled clinical trial, 11. Clinical study.

On the other hand, due to the fact that not all the evidence is of interest, the exclusion criteria are 1. Studies in which the effectiveness of electrical stimulation as treatment is not studied, 2. Studies in which electrical stimulation therapy is not used for ulcers, 3. Non full text access, 4. Articles that are not in English or Spanish, 5. Articles that have a publication date older than 10 years, 6. Meta-analysis, 7. Letters, 8. Editorials.

With the search query (“Electrical Stimulation”) AND (“Ulcer” OR “Pressure Ulcer” OR “Pressure Sore” OR “Vascular injury”) we obtained a total of 4082 results consulting 2 databases (Pubmed and Web of Science). First, we removed the duplicates and excluded the results using the filters provided by the databases, such as limiting the results to the last 10 years, English and Spanish as language, and articles with full text access.

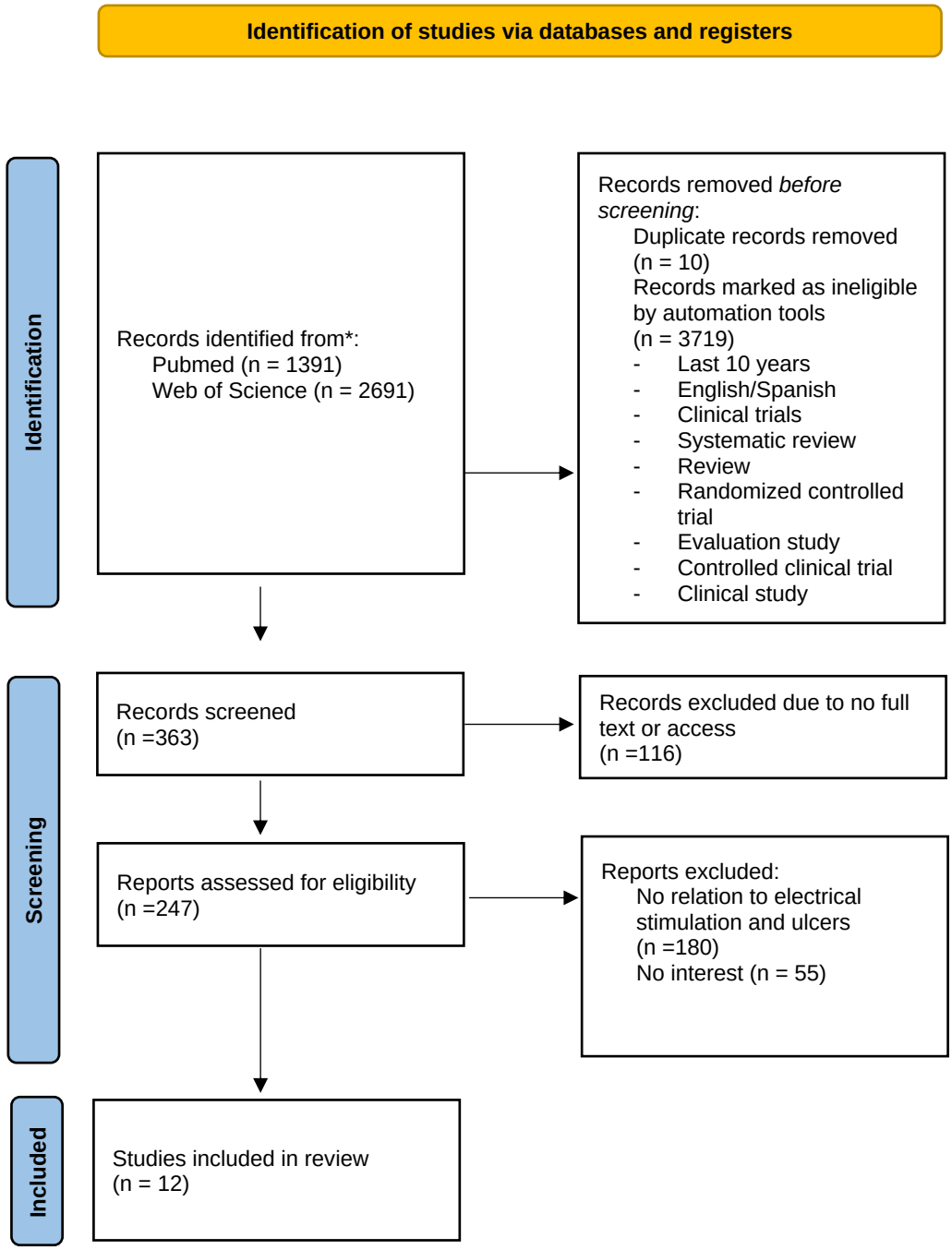
After applying these filters, 528 records were screened. From those records, the ones that didn’t have access to full text or didn’t meet the inclusion criteria by reading the title and abstract were eliminated. At the end, the final records included in this review were 12 articles.

FLOW DIAGRAM ELECTRICAL STIMULATION AND ULCERS

("Electrical Stimulation") AND ("Ulcer" OR "Pressure Ulcer" OR "Pressure Sore" OR "Vascular injury")

Figure 1.

Flow diagram of the systematic search.



Note. Flow diagram using the query ("Electrical Stimulation") AND ("Ulcer" OR "Pressure Ulcer" OR "Pressure Sore" OR "Vascular injury") (PRISMA, 2023).

5.2. Clinical case

In this paper a case study of a real patient and her experience is exposed. The patient has used electrical stimulation for the prevention of ulcers previously and not as part of this study. I will interview the patient about the difficulties of using this device, the type of electrical stimulation (ES) used, the comfort, the patient's sense of effectiveness and the pain and discomfort it has prevented. Objective 2 mentioned above, which is " To investigate a patient's experience with this therapy.", corresponds to the clinical case section.

The patient presented written consent for the collection and use of her health information in this clinical case study, and no information that could reveal her identity will be disclosed.

Patient information: a woman 62 years of age that suffered an accident that caused direct trauma to the spinal cord, to be exact complete cervical spinal cord injury (C4, 5 and 6), who has been using electrical stimulation since 2018 as form of prevention for pressure ulcers.

The patient's assessment has been based on Marjory Gordon's functional health patterns, obtaining the information directly from the patient. On the other hand, the NANDA Taxonomy (North American Nursing Diagnosis Association) was used to develop nursing diagnoses, Nursing Outcomes Classification (NOC) for the classification of the results and NIC (Nursing Interventions Classification) for planning the interventions.

In this clinical case study, I used the Norton and Braden Scale for predicting pressure ulcer risk in this patient to be able to determine if electrical stimulation is needed as prevention method.

6. RESULTS AND DISCUSSION

Table 1.

Summary of the articles included in the systematic review.

TITLE	AUTHOR AND YEAR	TYPE OF STUDY	OBJECTIVE	RESULTS
Home-Based Electrical Stimulation to Accelerate Wound Healing – A Double-Blinded Randomized Control Trial	A. Zulbaran-Rojas et al. 2021	A Double-Blinded Randomized Control Trial	The purpose is to investigate the efficacy of daily home-based E-stim to accelerate wound healing.	Daily home-based E-Stim presents preliminary findings on the feasibility, acceptability, and efficacy of E-Stim as a complementary treatment to accelerate wound healing in patients with chronic DFU and mild to severe PAD.
Wireless micro current stimulation – an innovative electrical stimulation method for the treatment of patients with leg and diabetic foot ulcers	P.G. Wirsing et al. 2013	Case study	The authors present their clinical experience with a new electrical stimulation (ES) approach, wireless micro current stimulation (WMCS), for the treatment of chronic wounds.	When using the WMCS approach, a noticeable improvement or clear advancement of healing of chronic wounds and a considerable reduction of pain (even within 1-2 weeks of the initial application) were seen.
Wireless Electrical Stimulation: An Innovative Powerful Tool for the Treatment of a Complicated Chronic Ulcer	O. Castana et al. 2013	Case report	We demonstrate the use of a new wireless electrical stimulation approach for the treatment of a difficult chronic lower leg ulcer.	The findings indicate that this simple technique is a viable treatment option for persistent ulcers.
The efficacy of electrical stimulation in lower extremity cutaneous wound healing: A systematic review	M. Ashrafi et al. 2016	A systematic review	To review the variety of electrical stimulation used in the management of lower extremity wound nowadays.	The majority of research show that pulsed current is superior to conservative therapy of lower extremity cutaneous wounds.
Electrical stimulation to enhance wound healing	S.B. Rajendran et al. 2021	A systematic review	This review focuses on how ES impacts the cellular mechanisms involved in normal cutaneous wound healing, as well as its antibacterial effects and therapeutic usefulness in accelerating chronic wound healing.	The current evidence supports the use of ES as an additional therapy for chronic wound management. However, due to differences in the experimental protocols of the research, the most effective ES cannot be determined from this review.
Efficacy and safety of neuromuscular electrical stimulation in the prevention of pressure injuries in critically ill patients: a randomized controlled trial	M.V. Baron et al. 2022	A randomized controlled trial	To evaluate NMES's efficacy and safety in preventing PI in critically ill patients.	The current study established the safety, feasibility, and efficacy of NMES in reducing the occurrence of sacral PIs in critically sick patients. However, NMES was unable to significantly reduce muscle mass loss.
A feasibility study of intermittent electrical stimulation to prevent deep tissue injury in the intensive care unit	A. Kane et al. 2017	A feasibility study	To examine the feasibility of using intermittent electrical stimulation (IES) as an option of preventing pressure ulcers in an intensive care setting.	The findings indicate that IES is both safe and viable for use in intensive care units.
The efficacy of pressure ulcer treatment with cathodal and cathodal-anodal high voltage monophasic pulsed current: a prospective, randomized, controlled clinical trial	A. Polak et al. 2017	Randomized controlled clinical trial	The purpose of this study was to assess the efficacy of cathodal versus cathodal+anodal ES in the treatment of Category II-IV pressure ulcers.	Cathodal and cathodal+anodal HVMPC reduced the area of Category II-IV PrUs in a similar way.

Efficacy of low-frequency monophasic pulsed microcurrent stimulation therapy in undermining pressure injury: a double-blind crossover-controlled study	Y. Yoshikawa 2022	Double-blind crossover-controlled study	The purpose of this double-blind, crossover-controlled study was to confirm the effect of electrical stimulation therapy on pressure injuries with undermining.	Electrical stimulation therapy for pressure injuries, using conditions based on the findings of an in vivo culture investigation, was helpful in reducing wound area.
Electrical Stimulation for difficult wounds: only an alternative procedure?	M. Fraccalvieri et al. 2014	Clinical trial	In this paper, we look at a specific ES with a distinct type of waveform that corresponds to the stochastic resonance principle.	When compared to other therapies such as surgery, dressings, and NWPT, ES with BST device has been shown to be superior to a good option in cases of minor size defects.
The mechanisms and evidence of efficacy of electrical stimulation for healing of pressure ulcer: A systematic review	L. Kawaski et al. 2013	A systematic review	The purpose of this article is to give a systematic review of the efficacy of electrical stimulation in the healing of pressure ulcers, as well as a discussion of its mechanism of action.	External electrical fields imitate the body's own bioelectricity and help to speed up pressure ulcer healing.
Impact of interferential current on recovery of pressure ulcers grade 1 and 2	A.Shahrokhi et al. 2014	Clinical trial	The purpose of this study was to see how interferential current (IF) affected the healing of pressure ulcers (grades 1 and 2).	The results of the first study in this sector revealed that using IF current can speed pressure ulcer healing and reduce its size.

Note. Results of the systematic search in databases for electrical stimulation and wounds in the last 10 years (own elaboration).

6.1. General information

After performing the systematic search and analysing the final selected articles, we can see that there is a wide variety of studies conducted with electrical stimulation in relation to ulcers.

If we look at the study populations, we find that these are heterogeneous between studies, including people from different ages, gender, and health status. This allows us to study possible differences in relation to ulcers and the effectiveness of electrical stimulation and the age of the individual.

The discussion section of this systematic review provides a comprehensive analysis and interpretation of the findings obtained through a rigorous and systematic approach. By synthesizing the results from various studies included in the review, this section aims to shed light on the broader implications of the research, identify patterns or discrepancies, and explore potential underlying mechanisms. Furthermore, it offers a critical appraisal of the overall strength of the evidence and highlights the limitations and implications for future research. Through this discussion, we aim to provide a deeper understanding of the relation between electrical stimulation and ulcers and contribute to the existing body of knowledge in the field.

6.2. Effectiveness

When looking more closely at the studies selected for this review, different kind of ulcers were used to conduct the research, in some cases the electrical stimulation (ES) was used on pressure ulcers (PrUs) or diabetic foot ulcer (DFU) or venous ulcers, meanwhile other studies did not specify the type of wound they were treating.

Zulbaran-Rojas et al (2021) conducted a study to assess the practicality, acceptability, and effectiveness of daily home-based electrical stimulation (ES) therapy for treating diabetic foot ulcers (DFUs). The study aimed to investigate the impact of ES on wound healing in individuals with DFUs (figure 8). It was already known that ES can enhance tissue perfusion, which is crucial for the wound healing process seeing as it increases the prevalence of epithelization. This randomized controlled trial (RCT) of DFU patients shows that only SatO2 was found to be associated with wound healing at the end of the study. Patients with peripheral arterial diseases (PAD) under ES therapy showed a faster healing period with higher gain of SatO2, even though the dosage may be adjusted to maintain those SatO2 levels and recover vascular deficiencies. Also, the study showed that this therapy may be more effective for patients who have poor tissue oxygen supply. On the other hand, different types of ES were used, however they have not been able to prove which type of modality is the ideal for DFUs. The results of the study show that patients in the ES group improved foot sensation and wound reduction compared to the control group.

Based on the study from Wirsing et al (2013), wireless micro current stimulation (WMCS) therapy is effective in accelerating lower extremity wound healing with no severe side effects or complications reports, observing a reduction of the wound area in the first two weeks of therapy. The treatment showed improved arterial blood flow and reduced bacterial burden and has potential in treating hard-to-heal chronic wounds and reduces wound pain substantially. Besides, WMCS can also be used on PrUs, venou-, arterial-, mixed-leg ulcers and DFUs. Although further testing is needed to confirm this. Another study, that focuses on WMCS on chronic ulcers of the lower limb (Castana et al., 2013) introduces this new device as an effective treatment for chronic ulcers, with low expenses and minimal risk infection. However, the article suggests the importance of the setting, whether to use it on outpatient ambulatory or inpatient environment, both having pros and cons. The choice of setting is also related to infrastructure and patient compliance.

On the other hand, other articles have studied the efficacy of ES in lower extremity cutaneous wound healing (Ashrafi et al, 2016) and have concluded that pulsed current (PC) is more beneficial than standard wound care, but it has no advantages over surgical intervention. Also, direct current appears to be inferior to pulsed current, meanwhile other types of ES lack research and large-scale trial data to determine their effectiveness. The goal is to find an ES device that is non-invasive, portable, and cost-effective, but most importantly that it doesn't interfere with the patient's daily life. Some researchers have designed wearable dressings, but further large-scale

trials are required to confirm their benefits. One example is WMCS, as I have mentioned above, which findings seem promising. Most studies showed accelerated wound healing with the use of ES comparing to stand wound care, several are used successfully on lower extremity wound healing. Nevertheless, there are difficulties to establish the best ES device due to heterogenous testing and different protocol used.

In addition, the review from Rajendran et al (2021) explains that the wound healing process is divided in three main phases: the inflammatory phase, the proliferative phase, and the remodelling phase. This process is influenced by the “skin battery”, these endogenous electric fields cause cellular migration which concomitantly help heal wounds. However, chronic wounds don’t progress correctly through these healing stages due to factors such as age, obesity, drinking, etc. This article focuses on how ES can influence the cellular function involved in wound healing. The evidence found shows how ES limits inflammation, increases wound blood perfusion, controls bacterial growth, increases fibroblast migration, induces angiogenesis, and encourages keratinocyte activity. Although, there is still more research needed to determine which type of ES is the most effective for the wound healing process.

Focusing more on pressure ulcers in the sacral area, neuromuscular electrical stimulation (NMES) seems to be effective in preventing sacral PrUs particularly in critically ill patients, which might reduce the patients stay in the Intensive Care Unit (ICU). First, the high prevalence of pressure injuries demonstrates that there is still no effective prevention strategy. The incidence of pressure ulcers (PrUs) can be reduced by utilizing neuromuscular electrical stimulation (NMES), which operates through three distinct mechanisms. These include relieving tissue pressure via contractions, promoting local microcirculation, and inducing muscle hypertrophy. Due to no results in muscle thickness of the gluteus maximus, they related the low prevalence using NMES devices to better oxygen circulation to the affected tissue and change of pressure areas (Baron et al., 2022). Another article (Kane et al., 2017), also discusses the issue of hospital acquired pressure ulcers in the ICU and identifies that even though there are different kind of interventions such as advanced mattress surfaces and nutritional supplementation, it is still a problem. The authors tested the feasibility of using an innovative technology called intermittent electrical stimulation (IES) to prevent PrUs in a wide range of subjects. This system was well-accepted by clinical staff and easy to manipulate, as well as safe and tolerated by all study participants. Preventing pressure sores early on during a patient’s hospital stay will help downstream morbidity and hospital expenses. Still more testing is needed to determine the efficacy of preventing ulcers.

Another article discusses the use of high-voltage monophasic pulsed current (HVMPC) combined with standard wound care (SWC) in the treatment of PrUs. The authors conducted a clinical trial on elderly individuals and found that the combination of HVMPC and SWC reduced the surface area of the wound more significantly than SWC alone. Additionally, ES was found to

decrease PrUs by half and increase the probability of PrUs closing within 3 to 17 weeks. Studies have shown that both cathodal and anodal stimulation can be effective in the healing of PrUs and venous leg ulcers (VLUs). The authors suggest that the polarity of the treatment electrode can be selected based on the stage of wound healing, rather than following a standard protocol. However, the study was too short to determine how long cathodal or cathodal+anodal HVMPC should be applied to complete the healing process (Polak et al., 2017).

Furthermore, Yoshikawa et al., (2022) investigated the effects of electrical stimulation therapy using monophasic pulsed microcurrent (MPMC) on pressure injuries with undermining. The crossover-controlled trial showed promising results in improving the healing rate of undermined pressure injuries, and overall wound area reduction. The study suggests that MPMC therapy may be a painless alternative to high-voltage pulsed current (HVPC) treatment with fewer side effects. However, the findings need to be verified with a larger sample size in future studies.

As mentioned above, it is still not clear what the exact mechanism of action of ES is, and that is why various types of current are used. Some types of currents work by activating galvanotaxis, which enhances migration of cells and allows for reepithelization, while other currents activate cutaneous sensory nerves, which may increase blood flow and sensitivity of injured tissue. This specific study focuses on a type of ES called burst stochastic stimulation (BST). The article also presents a case series that reviewed the efficacy of BST on various types of hard-to-heal wounds, with ES used only after conventional therapies had failed. The treatment lasted until complete wound healing, and the article notes that wound care should continue with conventional or advanced therapies once the wound changes from chronic to acute phase. BST aims to reestablish the bioelectrical stochastic noise that is compromised in chronic wounds reconnecting the wound to the peripheral nervous system. the article presents a promising potential use for BST in wound healing, although more research is needed to fully understand its mechanism of action and potential applications (Fraccalvieri et al., 2014).

After an exhausting review of different articles Kawaski et al. (2014) comes to the conclusion that electrotherapy is effective, with high-voltage pulsed current (HVPC) being a better choice than direct current (DC), due to its ability to trigger tissue healing and carry a lower risk of skin burn. Electrode and polarity configuration are more complex, with some studies using bipolar configuration and others placing the active electrode in the wound and the dispersive electrode at a distance. Different polarities can have different effects on healing processes, and some authors recommend using specific polarity depending on the phase of healing. The underlying mechanisms of electrical stimulation include enhancing angiogenesis and granulation, promoting collagen production and fibroblast proliferation, and increasing vascular endothelial growth factor (VEGF) production. Despite the evidence and recommendations from healthcare agencies, the implementation of electrical stimulation in hospitals and communities is limited.

Meanwhile, interferential currents (IF) have also shown improvement in the healing process of pressure ulcers. The results show prove that the use of IF current on the area of pressure injuries accelerates wound healing and reduces their sizes. Electrical currents were found to induce cellular functions in all phases of wound healing, stimulate fibroblast activities, and improve tissue perfusion, reducing swelling. IF current was also found to reduce pain intensity, edema, and improve muscle tonicity. While previous studies on adjuvant treatments such as electrical currents, ultrasound, and light therapy had no considerable effect on pressure ulcer healing, this study showed significant effects of IF currents on healing. The study even shows that IF has a greater analgesic effect than transcutaneous electrical nerve stimulation (TENS), the IF current stimulates nerves and underlying tissues by sending small electrical impulses through the skin and causes pain relief (Shahrokhi et al., 2014).

6.3. Limitations

As I have already mentioned above, more research is needed in a lot of studies included in this review to verify the findings and the efficacy of ES. So, the general limitations found in this review are:

- Sample size: many of the studies have a relatively small sample size, which limits the ability to generalize the results to a wider population.
- Lack of a control group: some studies do not include a control group to compare the results of electric stimulation with those of other therapies or treatments, which can make it difficult to understand the results.
- Variability in the way electric stimulation is applied: there is variability in the way electric stimulation is applied, which makes it difficult to compare the results between studies.
- Different types of ulcers: studies include different types of ulcers, which can affect the results and the ability to generalize findings to a specific type of ulcer.
- Small time frame: some studies needed more time to test the usefulness of this new therapy and there was no control of the patients after completion of the trial.

6.4. Clinical case

Case presentation: a woman 62 years of age that suffered an accident that caused direct trauma to the spinal cord, to be exact, complete cervical spinal cord injury (C4, 5 and 6), which caused paralysis in lower body and most of her upper body except her head, neck, arms, and elbows. She uses an electric wheelchair to move around. She lives with her husband, but a caregiver comes by twice a day to help her prepare for the day and put her in bed again at the end of the day. She works as a thesis tutor, assessing students.

Table 2.

Patient's assessment.

Functional health patterns	Patient information
1. Health perception and management	No drug use. Occasional alcohol consumption. Follows doctor's instructions and prescriptions.
2. Nutrition and metabolism	Balanced diet. Ineffective thermoregulation. Decay of skin integrity.
3. Elimination	Fecal elimination every 3 days. Suprapubic catheter. Dysfunctional gastrointestinal motility.
4. Activity and exercise	Self-care deficit. Impaired physical mobility. Mobility in wheelchair.
5. Cognition and perception	Chronic pain. No memory loss.
6. Sleep and rest	Normal sleep cycle
7. Self-perception and self-concept	Discomfort
8. Roles and relationships	Little social interaction.
9. Sexuality and reproduction	2 children and a husband.
10. Coping and stress tolerance	-
11. Values and belief	-

Note. Patient's health assessment based on Marjory Gordon's functional health patterns (own elaboration)

I applied the Norton Scale:

Figure 2.

The Norton Scale

The Norton Scale for Predicting Pressure Ulcer Risk*

Criterion	
Physical condition	4 = Good 3 = Fair 2 = Poor 1 = Very bad
Mental condition	4 = Alert 3 = Apathetic 2 = Confused 1 = Stupor
Activity	4 = Ambulant 3 = Walk with help 2 = Chair bound 1 = Bed bound
Mobility	4 = Full 3 = Slightly impaired 2 = Very limited 1 = Immobile
Incontinent	4 = Not 3 = Occasionally 2 = Usually/Urine 1 = Doubly

* Calculated as the sum of the scores in all 5 areas. A score < 14 indicates a high risk of pressure ulcer development.

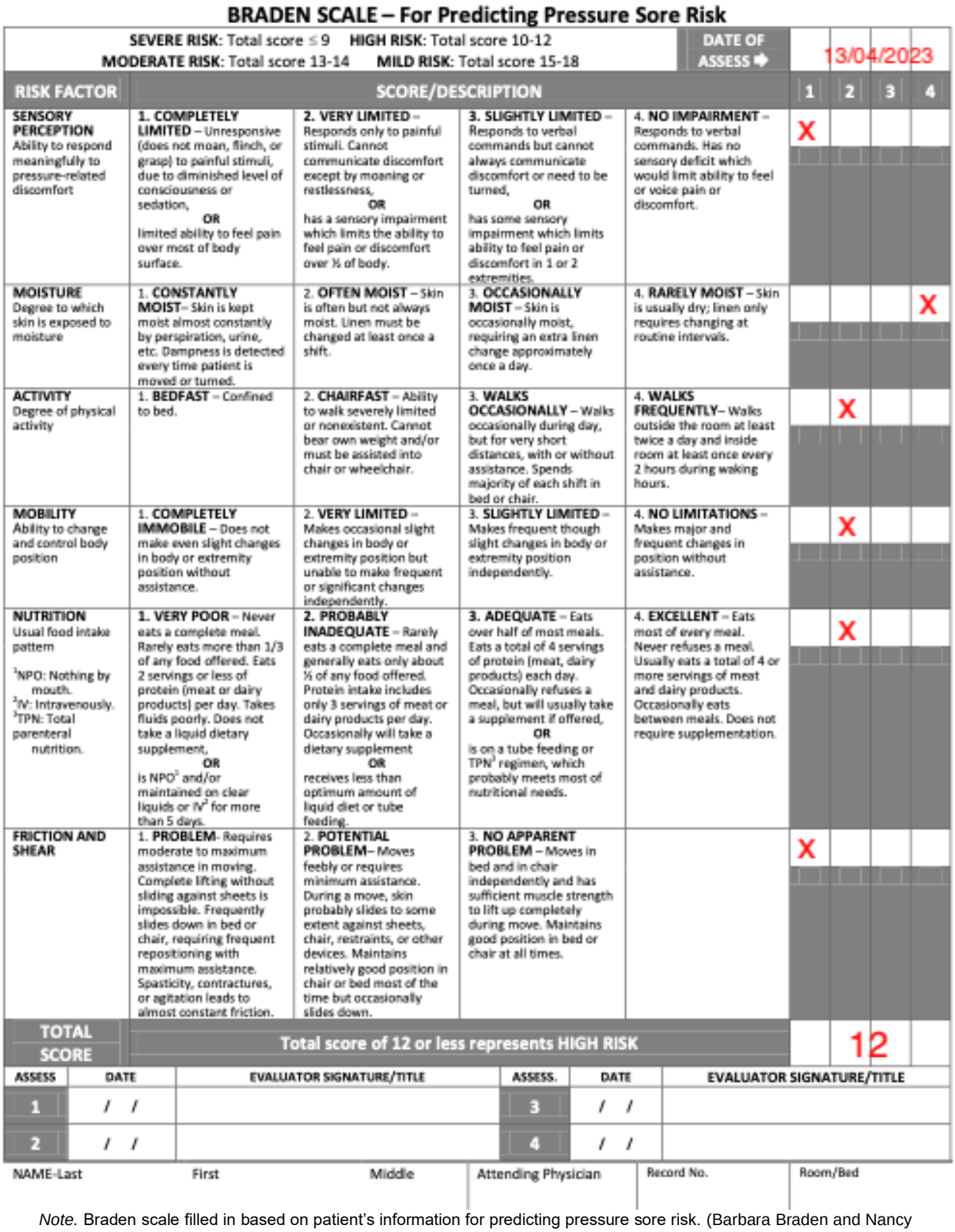
Note. The Norton Scale was applied on the subject for predicting pressure ulcer risk.

(Adapted from Norton, D: Calculating the risk: Reflections on the Norton scale. Decubitus 2(3):24–31, 1989.)

I obtained a score of 10 points, which indicates the patient is at high risk of pressure ulcer development.

Figure 3.

Braden scale



BRADEN SCALE – For Predicting Pressure Sore Risk

SEVERE RISK: Total score ≤ 9 **HIGH RISK:** Total score 10-12
MODERATE RISK: Total score 13-14 **MILD RISK:** Total score 15-18

DATE OF ASSESS ➡ 13/04/2023

RISK FACTOR	SCORE/DESCRIPTION				1	2	3	4
SENSORY PERCEPTION Ability to respond meaningfully to pressure-related discomfort	**1. COMPLETELY LIMITED** – Unresponsive (does not moan, flinch, or grasp) to painful stimuli, due to diminished level of consciousness or sedation, **OR** limited ability to feel pain over most of body surface.	**2. VERY LIMITED** – Responds only to painful stimuli. Cannot communicate discomfort except by moaning or restlessness, **OR** has a sensory impairment which limits the ability to feel pain or discomfort over ½ of body.	**3. SLIGHTLY LIMITED** – Responds to verbal commands but cannot always communicate discomfort or need to be turned, **OR** has some sensory impairment which limits ability to feel pain or discomfort in 1 or 2 extremities.	**4. NO IMPAIRMENT** – Responds to verbal commands. Has no sensory deficit which would limit ability to feel or voice pain or discomfort.	X			
MOISTURE Degree to which skin is exposed to moisture	1. **CONSTANTLY MOIST**– Skin is kept moist almost constantly by perspiration, urine, etc. Dampness is detected every time patient is moved or turned.	2. **OFTEN MOIST** – Skin is often but not always moist. Linen must be changed at least once a shift.	3. **OCCASIONALLY MOIST** – Skin is occasionally moist, requiring an extra linen change approximately once a day.	4. **RARELY MOIST** – Skin is usually dry; linen only requires changing at routine intervals.				X
ACTIVITY Degree of physical activity	1. **BEDFAST** – Confined to bed.	2. **CHAIRFAST** – Ability to walk severely limited or nonexistent. Cannot bear own weight and/or must be assisted into chair or wheelchair.	3. **WALKS OCCASIONALLY** – Walks occasionally during day, but for very short distances, with or without assistance. Spends majority of each shift in bed or chair.	4. **WALKS FREQUENTLY**– Walks outside the room at least twice a day and inside room at least once every 2 hours during waking hours.		X		
MOBILITY Ability to change and control body position	1. **COMPLETELY IMMOBILE** – Does not make even slight changes in body or extremity position without assistance.	2. **VERY LIMITED** – Makes occasional slight changes in body or extremity position but unable to make frequent or significant changes independently.	3. **SLIGHTLY LIMITED** – Makes frequent though slight changes in body or extremity position independently.	4. **NO LIMITATIONS** – Makes major and frequent changes in position without assistance.		X		
NUTRITION Usual food intake pattern [1]NPO: Nothing by mouth. [2]IV: Intravenously. [3]TPN: Total parenteral nutrition.	**1. VERY POOR** – Never eats a complete meal. Rarely eats more than 1/3 of any food offered. Eats 2 servings or less of protein (meat or dairy products) per day. Takes fluids poorly. Does not take a liquid dietary supplement, **OR** is NPO[1] and/or maintained on clear liquids or IV[2] for more than 5 days.	**2. PROBABLY INADEQUATE** – Rarely eats a complete meal and generally eats only about ½ of any food offered. Protein intake includes only 3 servings of meat or dairy products per day. Occasionally will take a dietary supplement **OR** receives less than optimum amount of liquid diet or tube feeding.	**3. ADEQUATE** – Eats over half of most meals. Eats a total of 4 servings of protein (meat, dairy products) each day. Occasionally refuses a meal, but will usually take a supplement if offered, **OR** is on a tube feeding or TPN[3] regimen, which probably meets most of nutritional needs.	**4. EXCELLENT** – Eats most of every meal. Never refuses a meal. Usually eats a total of 4 or more servings of meat and dairy products. Occasionally eats between meals. Does not require supplementation.		X		
FRICTION AND SHEAR	1. **PROBLEM**- Requires moderate to maximum assistance in moving. Complete lifting without sliding against sheets is impossible. Frequently slides down in bed or chair, requiring frequent repositioning with maximum assistance. Spasticity, contractures, or agitation leads to almost constant friction.	2. **POTENTIAL PROBLEM**– Moves feebly or requires minimum assistance. During a move, skin probably slides to some extent against sheets, chair, restraints, or other devices. Maintains relatively good position in chair or bed most of the time but occasionally slides down.	3. **NO APPARENT PROBLEM** – Moves in bed and in chair independently and has sufficient muscle strength to lift up completely during move. Maintains good position in bed or chair at all times.		X			
TOTAL SCORE	**Total score of 12 or less represents HIGH RISK**					12		

ASSESS	DATE	EVALUATOR SIGNATURE/TITLE	ASSESS.	DATE	EVALUATOR SIGNATURE/TITLE
1	/ /		3	/ /	
2	/ /		4	/ /	

NAME-Last First Middle | Attending Physician | Record No. | Room/Bed

Note. Braden scale filled in based on patient's information for predicting pressure sore risk. (Barbara Braden and Nancy Bergstrom. Copyright, 1988.)

On the Braden Scale, she acquired a score of 12 points, meaning she is at high risk of developing pressure sores.

Based on the patient's assessment I established nursing diagnosis following the NANDA Taxonomy (North American Nursing Diagnosis Association), Nursing Outcomes Classification (NOC) for the classification of the results and NIC (Nursing Interventions Classification) for planning the interventions.

- [0008] **Ineffective thermoregulation** related to immobility and neurological disorders as evidenced by slow capillary refill and chills.
    - NOC: [0909] asses neurological status:
        - NIC: [6680] monitor vital signs:
            - Monitor blood pressure, pulse, temperature, and respiratory status, as applicable.
            - Monitor and record for signs and symptoms of hypothermia and hyperthermia.
            - Regularly monitor the color, temperature and humidity of the skin.
            - Monitor for central and peripheral cyanosis.
            - Start up and maintain a continuous temperature monitoring device, as needed.

- [00046] **Impaired skin integrity** related to immobility as evidenced by pressure ulcers.
    - NOC: [0204] consequences of immobility: physiological.
        - NIC: [3540] prevention of pressure ulcers:
            - Use an established risk measuring tool to assess the individual's risk factors (Braden scale).
            - Keep record of any previous episodes of pressure ulcers.
            - Monitor closely any red areas.
            - Inspect the skin over osseous prominences and other pressure points when changing positions at least once a day.
            - Use special beds and mattresses, as needed.

- [00196] **Dysfunctional gastrointestinal motility** related to immobility as evidenced by difficulty defecating.
    - NOC: [0501] bowel elimination.
        - NIC: [2315] medication administration: rectal:
            - Determine if they present signs or symptoms of gastrointestinal alterations.
            - Determine the patient's ability to retain the suppository.

- Help the patient to get into the Sim positions lying on the left side with the upper leg bent up.
- Lubricate the gloved index finger of the dominant hand and the rounded end of the suppository.
- Gently insert the suppository through the anus, past the internal anal sphincter and against the rectal wall.
- Check if the effects of the medication take place.

- [00125] **Powerlessness** related physical disability evidenced by depression and loss of independence.
    - NOC: [1308] Adaptation to physical disability.
        - NIC: [5230] improve coping:
            - Assess the impact of the patient's life situation on roles and relationships.
            - Provide objective information regarding diagnosis, treatment and prognosis.
            - Provide the patient with realistic options about certain aspects of care.
            - Confront the patient's ambivalent feelings (anger or depression).
            - Encourage the verbalization of feelings, perceptions and fears.

Based on the nursing diagnosis made and taking into account the scales applied to the patient, she would be a perfect candidate to try electrical stimulation therapy because she is at high risk of developing pressure ulcers and her conditions are permanent.

Since the accident, which caused the paralysis, pressure sores where a recurring problem. They had been fighting this problem for a few years already when she was asked to participate in a new study about electrical stimulation as therapy for curing and preventing pressure ulcers. She started using electrical stimulation in 2018 and she bought the device for 350 euros, and since then she hasn´t had any type of pressure related injuries (figure 4). Because she participated in a clinical trial, they tested different frequencies and timeslots. The ES was applied via elasticated velcro shorts with embedded surface electrodes (50Hz). The stimulation amplitude was individualized and progressively increased every 3 weeks to minimize muscular fatigue. She started by receiving every night 6 hours of therapy, divided in blocks of 30 minutes stimulation followed by 15-minutes rest for 12 weeks. The patient mentioned she gained a lot of muscle mass during these 12 weeks, as if she went to the gym every day for 12 weeks. Most importantly, she didn't get any new pressure ulcers during this 12-week clinical trial. They related that the hypertrophy of the gluteal and hamstring muscle helps in the pressure distribution when the patient is seated in the wheelchair or bed. After these 12 weeks, the patient continued using ES but as a "maintenance electrotherapy", applying loose electrodes (figure 7) once a day for 45

minutes (figure 5 and 6). She did lose muscle mass with this new time interval, but her legs are still more muscular than before the use of ES. The patient is very content with this new device because it has resolved the recurring problem of pressure ulcers and it doesn't require any great effort. They showed her husband where to place the electrodes and which stimulation program to choose, and nowadays he manages her ES therapy effortlessly. Seeing that it helps preventing PrUs and is easy to use even by non-health care professionals, it is a great solution for patients with reduced mobility.

7. CONCLUSIONS

- There is a wide span of research articles on electrical stimulation therapy as wound treatment, which provides us different kinds of studies on various types of wounds and its possible therapeutic applications as prevention or treatment of ulcers. Although more studies with a bigger sample and an established controlled design are required to make objective statements regarding the effectiveness of electrical stimulation.
- Through a single case study, the functionality and convenience of electrical stimulation for wound treatment and prevention was shown. The patient found it easy to use and it showed promising results and is still using it nowadays even though the clinical trial is already over.
- Currently, the studies available are not as conclusive and lack scientific evidence to establish electrical stimulation therapy as an alternative treatment or complement for any type of ulcer. It may seem beneficial, but there is not enough evidence to determine what kind of electrical stimulation is the most suitable for each type of ulcer, and how long it should be applied.
- This new kind of therapy has shown to be safe and well tolerated by all patients and cost effective. And as the case study has shown, it is easy to manipulate and apply by people who are not health care professionals.
- Electrical Stimulation therapy hasn't been used yet as standardized treatment due to limited clinical evidence. Until now, most studies have been applied to small groups of patients not providing enough proof to determine what kind of ES should be used for each wound and for how long. So far it has been used as last resource, when all the previous treatment options have failed. It can be a valuable treatment options when tested on a larger sample.

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9. APPENDIX

Figure 4.

Electrical Stimulation device.

Note. Electrical Stimulation device used by patient referred to in clinical case (author's property).

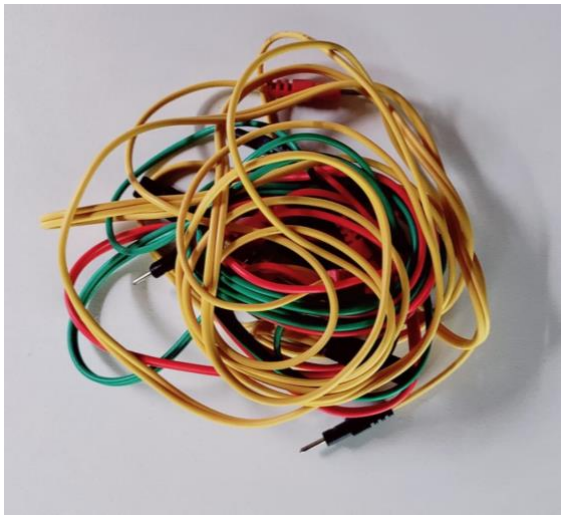
Figure 5.

Electrodes used for ES therapy.

Note. Loose electrodes applied on sacral and hamstring area to send electrical currents (author's property).

Figure 6.

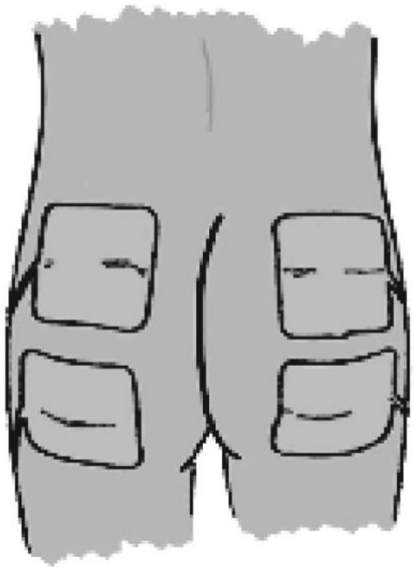
Cables



Note. Cables used to connect the electrodes to the ES device (author's property).

Figure 7.

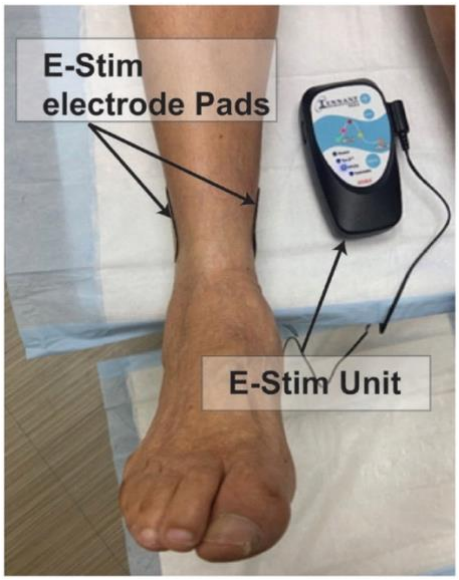
Electrode placement on buttocks.



Note. An example of electrode placement of sacral area to avoid pressure ulcers.
(Kane, A., Warwaruk-Rogers, R., Ho, C., Chan, M., Stein, R., Mushahwar, V. K., Dukelow, S. P. (2016). A Feasibility Study of Intermittent Electrical Stimulation to Prevent Deep Tissue Injury in the Intensive Care Unit. *Wound Healing society*, 6 (4).

Figure 8.

Placement of electrode adhesive pads



Note. Example of electrode adhesive pads above the ankle of the affected foot connected to the electrical stimulation device.

(Zulbaran-Rojas, A et al (2021). Home-Based Electrical Stimulation to Accelerate Wound Healing – A Double-Blinded Randomized Control Trial. *Journal of diabetes science and technology.)*