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Physiotherapy in Management of Diabetic Foot Ulcers

An Educational Packet for Physiotherapy Students

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Abstract

The aim for this thesis is to create an educational information packeage for physiotherapy students in Satakunta University of Applied Sciences about physiotherapy in wound care management of diabetic foot ulcers. This was accomplished by doing an in-depth literature review from trusted sources about the topic and to create an understanding of this information with its readers.

This topic was chosen to illuminate the role physiotherapist can and should play in wound care, specifically when it comes to the management of diabetic foot ulcers. Research supports the use of various modalities as well as therapeutic exercise when it comes to wound care. However more research is needed evaluating the effectiveness of modalities specifically on diabetic foot ulcers.

Diabetes, wound care, diabetic foot ulcers, physiotherapy, modalities, off loading

CONTENTS

1 INTRODUCTION

In this thesis diabetic foot ulcers (DFU's) and what a physiotherapist can do in order to treat and prevent them will be discussed thoroughly. Diabetic foot ulcers affect approximately 15% of all diabetics, with almost 25% of these ulcers requiring amputations (Turan et al, 2015). Research shows that after the first amputation in diabetic patients, 50% of the patients don't live past 5 years. Approximately 73,000 non traumatic diabetic amputations are performed every year in the USA. (Azura Vascular Care, 2017.) Diabetes is an ongoing and developing epidemic in the world, resulting in more deaths annually than breast cancer and AIDS combined yearly (Southwestern Academic Limb Salvage Alliance, 2017). The Finnish Diabetes Association reports that out of Finland's 5.5 million people, there is a combined total of more than 500 000 diabetics in the country. More specifically roughly 400 000 of those diabetics have diabetes mellitus type 2. (Finnish Diabetes Association, 2016.) The best way Physiotherapist can prevent diabetic foot ulcers in our patients is try and prevent them from getting diabetes in the first place (Turan et al, 2015). Which we can accomplish by promoting a healthy and active lifestyle that can be maintained for the remainder of their life. Further on in this thesis how wounds heal, what diabetes is, how diabetes affects wound healing and the complications it can create for the patient, what a diabetic foot ulcer is, how to manage them from the physiotherapy point of view will be discussed.

2 AIM AND OBJECTIVES

The aim of this thesis is to provide future physiotherapy students of Satakunta University of Applied Sciences with a educational package about what role physiotherapy plays in wound care management, specifically in diabetes by creating an education package. The aim will be accomplished by completing the following objectives: performing literature reviews of evidence based sources and information, compiling

educational webinar's/videos, and infographics/photographs. The information will then be compiled into a H5P platform for students to access via their Cardiopulomnary Physiotherapy course.

3 DIABETES

3.1 Diabetes Mellitus Type I

Diabetes mellitus type I (DM1) is a chronic condition in which the pancreas fails to produce enough insulin or any at all. Insulin is a vital hormone that enables us to produce energy by allowing glucose to enter our cells. The exact cause of DM1 is unknown, however there are various different reasons and risk factors believed to aid in developing this condition. Physically the body may turn on itself and destroy the insulin-producing cells found in the pancreas (islet cells), but why this happens experts aren't sure. (Mayo Clinic, 2020.) According to Physiopedia (2021) DM1 is a "autoimmune disease that leads to the destruction of insulin-producing pancreatic beta cells".

There are fewer signs and symptoms to Diabetes Mellitus Type 1 than there is in Diabetes Mellitus Type 2, and these ones are often objectively less severe. The common symptoms of Type 1 are as follows: extreme hunger, fatigue, increased thirst, mood changes, unintended weight loss, irritability, weakness, blurred vision, frequent urination, and bed-wetting in children who didn't do so previously. These symptoms often appear suddenly. (Mayo Clinic, 2020.) DM1 may be rapidly diagnosed which is believed to be because it presents similarly to the flu (JDRF, 2021).

Risk factors for developing DM1 are as follows: age, family history, genetics, and geography (Mayo Clinic, 2020). Physiopedia identifies that the following are associated co-morbidities: retinopathy, cardiomyopathy, hypoglycemia, diabetic foot disease, amputation, neuropathy, nephropathy, diabetic ketoacidosis (Physiopedia, 2021). Type one diabetes can occur/develop at any age, however there are two age groups where it seems to occur the most. Four years old to seven years old are the

first age group, followed by ten years old to fourteen years old in the second age group. Having anyone in your immediate family with DM1 increases your risk of developing it yourself. (Mayo Clinic, 2020.) According to the ADA if the father has DM1, the odds of the child getting it are 1 in 17. If the mother has DM1 and the child was born before her turning 25 the risk is 1 in 25, but if the child was born after her turning 25 the risks is 1 in 100. However there are always exceptions; 1 in 7 people with DM1 has Type 2 Polyglandular Autoimmune Syndrome. If a parent has this condition then the odds of the child having DM1 is 1 in 2. (American Diabetes Association, 2018.) Statistics tend to show that the prevalence of diabetes type one tends to increase the farther away you are from the equator (Mayo Clinic, 2020). The possession of specific genes increase your risk of developing DM1, and these genes can vary from ethnicity to ethnicity (American Diabetes Association, 2018).

Overtime DM1 can cause various different complications to occur within the body. However maintaining a healthy blood sugar level can reduce the risk or severity of those complications. (Mayo Clinic, 2020.) Diabetes mainly affects your cardiovascular system, nerves, kidneys and eyes, as is relevant from the associated comorbidities listed above from Physiopedia (2021). These complications occur because the sugar levels in the blood stream get too high and damage the interior walls of the big and small arteries. The body responds to this by creating a layer of plaque (to protect from further damage), which reduces the blood flow to the legs, feet, kidneys and eyes. This is known as atherosclerosis, when it is prevalent in the legs and feet and it is then known as Peripheral Arterial Disease (PAD). Diabetes makes PAD much more difficult to manage, and it can lead to amputation if not treated properly. (Society for Vascular Surgery, 2019.) Diabetes mellitus type 1 also damages the nerves because high blood sugar weakens the small blood vessels (as mentioned above) and they are responsible for supplying the nerves with blood (Mayo Clinic, 2020).

3.2 Diabetes Mellitus Type II

Diabetes mellitus type II (DM2) is different from DM1 in a few different ways. Where as type one occurs from the pancreas not producing enough insulin or any at

all, type two occurs from the pancreas not producing enough insulin or the cells not responding effectively to the insulin released. Type two usually occurs in adults, but can also occur in children. In recent years there have been more and more cases of type two diabetes in adolescents, and this can be attributed to the increased in childhood obesity throughout the world. The exact cause for why the body does not respond to insulin correctly or doesn't produce enough is also unknown for type 2 diabetes. There is no cure for DM2 either, but eating healthy, regular exercise, and weight loss have proven to help manage diabetes. (Mayo Clinic, 2020.) Physiopedia (2021) summarizes DM2 well by stating "your fat, liver, and muscle cells do not respond correctly to insulin, known as insulin resistance." This incorrect response to insulin unfortunately results in blood sugar reaching excessive levels in the blood stream, which is known as hyperglycemia (Physiopedia, 2021).

Diabetes Type 2 has more symptoms than DM1 and they are generally more severe. However, these symptoms are usually slow to develop, which often leads to people having this type of diabetes for years without knowing it. So early diagnosis is difficult, but very important to reduce irreparable damage that diabetes could to do the body. The most common symptoms of DM2 are as follows: increased thirst and hunger, frequent urination, areas of darkened skin (typically in the neck and armpits), frequent infections, fatigue, unintended weight loss, blurred vision, numbness or tingling in the hands and feet, and slow healing sores. (Mayo Clinic, 2020.)

There are many more known risk factors for DM2 than DM1. These risk factors are as follows: weight, inactivity, blood lipid levels, fat distribution, family history, age, race and ethnicity, polycystic ovary syndrome, pregnancy related health issues, and prediabetes. Being obese or even just overweight increases your chance of developing DM2. Physical inactivity also increases your risk because physical activity increases your body's response to insulin, uses stored glucose, and helps control your weight. Low levels of the good cholesterol HDL (high-density lipoprotein) and high levels of triglycerides are associated with a higher risk for developing DM2 (affects insulin production and sensitivity). If your fat storage occurs mainly in your abdomen instead of your thighs and hips you are more likely to develop DM2 (affects liver function). You can measure waist circumference, and for a male with more than 101.6cm or a female with more than 88.9cm circumference you fall into this in-

creased risk category. Having a parent or sibling with DM2 increases your risk. Your age is a risk factor because studies show that you are at an increased risk of developing DM2 the older you get, especially after aging past 45 years old. Experts are still unsure why, but some specific ethnicities (Native American, Asian, Pacific Islanders, and African Americans) are at an increased risk of developing DM2. (Mayo Clinic, 2020.) Physiopedia also notes the following associated co-morbidities: obesity, cardiovascular disease, neuropathies, retinopathy, skin wounds or infections, stroke, hyperglycemia, reduced pulmonary functions, hypertension, nonalcoholic fatty liver disease (NAFLD), and dyslipidemia. They also go on to break down DM2 affects on the body based on organs. It is briefly discussed but DM2 can result in damaged ocular blood vessels that could lead to glaucoma, cataracts, retinopathy and even blindness. The nervous system can become damaged by high blood sugar (hyperglycemia) weaking the walls of small blood vessels. Resulting in not enough nutrients being delivered to the nerves. Hyperglycemia forces the kidneys to work harder when filtering your blood, eventually resulting in your kidneys being overworked, potentially resulting in kidney failure. Extended periods of time with badly managed blood sugar can result in various cardiac illnesses/conditions. Some of which are: atherosclerosis, stroke and heart attacks. (Physiopedia, 2021.) Polycystic ovary syndrome is a risk factor because most of the women with this condition are insulin resistant, which we know is part of diabetes (CDC, 2020). If you develop gestational diabetes while pregnant or birth a baby heavier than 4kg's you are at an increased risk of developing DM2 (Mayo Clinic, 2020). Gestational diabetes results in insulin resistance during pregnancy, and increases your likelihood of developing DM2 after giving birth due to the insulin resistance. Birthing a baby heavier than 4kg can point to DM2 because the mother has insulin resistance (which is case with gestational diabetes) the babies pancreas will produce more insulin. This extra insulin in the baby results in excess fat to form on it, making it larger that it should be. (Freeborn, et al.)

Diabetes Mellitus Type 2 has some similar complications as Diabetes Mellitus Type 1, but in general has more complications that are typically more severe. Similarly to DM1, DM2 also damages your major organs such as your nerves, kidneys, cardiovascular system, and eyes. However, it also can lead to slow healing, skin conditions, sleep apnea, hearing impairment, and dementia. Like DM1, DM2 causes nerve damage (neuropathy) in the limbs, especially the lower limbs. This occurs because over-

time high blood sugar can destroy or damage nerves, producing numbness, pain, burning, tingling, or loss of feeling at the distal ends of the extremities and slowly works up the extremities. However, DM2 can also affect the nerves in the heart, digestive system and male reproductive organs. If it affects the heart, it can cause irregular heart rhythms. In the digestive system in can cause diarrhea, nausea, constipation, or vomiting. In the male reproductive organs it may cause erectile dysfunction. DM2 also damages your kidneys, and may lead to chronic kidney disease or even a kidney transplant. If it affects your heart it could lead to a stroke, atherosclerosis, high blood pressure and various heart diseases. DM2 can also lead to blindness, glaucoma, cataracts, and retina blood vessel damage. Diabetes can lead to slow wound healing, resulting in small cuts or injuries turning into infections that cause severe damage and may require amputation (which will be discussed more later). DM2 has been proved to increase your risk of bacterial or fungal infections of the skin. Sleep apnea is still a bit of a mystery when it comes to diabetes. Obesity has been proven to be a key factor in sleep apnea, but it is unclear as to whether or not controlled blood sugar helps in the management and treatment of this condition. (Mayo Clinic, 2020.) Diabetes can also lead to hearing problems or loss, and this is believed to be because of damage to the nerves and blood vessels in the inner ear due to high blood sugar (diabetes.co.uk, 2019). According to the Mayo Clinic (2020) "Type 2 diabetes seems to increase the risk of Alzheimer's disease and other disorders that cause dementia. Poor control of blood sugar levels is linked to more-rapid decline in memory and other thinking skills"

3.3 How Diabetes Affects Wound Healing

The hyperglycemic conditions that result due to diabetes complicates wound healing for a variety of reasons. This phenomenon is increasing around the world due to inadequate control or prevention measures. (Patel et al, 2019.) Vijayakumar et al states "Approximately 50-70% of all the limb amputations are because of diabetic wounds and it was reported that in every 30s, once leg is amputated due to diabetic wounds in worldwide." Diabetes inhibits all phases of wound healing which results in a negative long-term effect of reduced life quality with increased morbidity and morality. Diabetic wounds are associated with delayed acute wound and chronic wounds re-

sulting in inhibited healing due to a incomplete, uncoordinated, or postponed healing process. Diabetic wounds are associated with a consistent inflammatory phase that reduces the formulation of mature granulation tissue and reduced wound tensile strength. This is believed to occur due to the vascular damage that occurs in diabetes, which results in ischemia. It is widely known that diabetes is associated with poor wound healing, however the direct link between diabetic pathophysiology and poor wound healing is unknown. For proper healing it is known that there is a need for inflammatory cells to collaborate with biochemical mediators, however the alteration of those mediators has been shown to cause failure in wound healing in diabetics. Diabetes can be one cause for biochemical mediator alteration. (Patel et al, 2019.)

There are various factors that can lead to delayed or poor wound healing in diabetics. However, when it comes to diabetic specific conditions the most common reasons for poor or delayed wound healing is due to hypoxia, ischemia, metabolic deficiencies (such as hypoxia due to glycation of hemoglobin), alteration of red blood cell membranes, and blood vessel narrowing **(**Brem & Tomic-Canic, 2007) Hypoxia is the term used for decreased oxygen delivery to wounds due to the narrow blood vessels. Glycation of hemoglobin results in hypoxia because it creates a inadequate supply of oxygen and nutrients to tissues. Glucose deficiency, hypoxia, and deformed proteins create a stress response to cell by gradual growth of unfolded proteins that are housed within the ER (endoplasmic reticulum). (Schürmann et al, 2014.)

Ischemia is another common reason for poor wound healing in diabetics. As discussed earlier, the blood vessel coat their inner layers with plaque to protect the blood vessels. This plaque build up results in decreased blood flow, which is exactly what ischemia is. (Schürmann et al, 2014.) Hypoxic conditions can be a result of ischemia, if this occurs then a specific micro RNA (MiR-210) is induced and reduces proliferation of keratinocytes (Biswas et al, 2010). There are also other micro RNA's that can have various effects in diabetic wound healing, specifically on inflammation delay, keratinocyte and fibroblast migration, epithelialization, angiogenesis and re-epithelialization (Patel et al, 2019).

4 DIABETIC FOOT ULCERS

Diabetic foot ulcers occur in approximately 15% of patients with diabetes, and approximately 14-24% of patients that develop these ulcers, require amputations. According to the Centers for Disease Control and Prevention (2012) diabetic foot ulcers are the leading cause of non-traumatic lower extremity amputations in the United States. The result of these amputations are associated with a major decrease in quality of life, morbidity, and a heavy financial burden; but perhaps most important of all, the post-amputation patient survival is only 50% for 5 years after surgery (Turan et al, 2015).

Often time's foot ulcers can become quite large or severe in diabetic patients before they even realize they have them. This can occur because of peripheral neuropathy that develops as diabetes progresses. These ulcers can occur from something as simple as walking a lot in a new pair of shoes. But since diabetics with the peripheral neuropathy cannot fully feel their hands and feet, they may accidentally wear improper fitting shoes, which can lead to these ulcers. In most healthy people, this scenario would only cause a small blister, but since diabetics typically have poor blood flow paired with dull sensations, it can progress quiet quickly to a muscle or bone infection that may inevitably lead to amputation in an attempt to save the patients life. (Boike et al, 2010.)

4.1 Causes of Diabetic Foot Ulcers

Diabetes Type 1 and Type 2 can develop these ulcers, although they are much more likely to occur in Diabetes Type 2. Studies have also shown that males are more likely to develop Diabetic Foot Ulcers (DFU's) than females. One Turkish study reports that of the 142 participants they studied, 65% of them were males. The occurrence of these ulcers are more closely linked to the length of time that diabetes has been present, rather than the patients age at diabetes onset. Meaning that the longer the patient has had diabetes, the more likely they are to develop a DFU. More often then

not, DFU's occur due to peripheral neuropathy (damage to the peripheral nervous system) or peripheral artery disease (PAD – narrowing of the peripheral arteries). (Turan et al, 2015.)

4.2 Consequences of Diabetic Foot Ulcers

Diabetic Foot Ulcers can be divided into primary and secondary pathologies, even though multiple factors are involved in the development of them. Primary pathologies are limited to vasculopathy (any condition that affects the blood vessels) and peripheral neuropathy (damage to the peripheral nerves). Meanwhile secondary pathologies are isolated to hyperglycemic complications. DFU's may be ischemic (15%), neuroischemic (50%), or neuropathic (35%). Poorly controlled blood sugar levels often cause damage to the neural cells. Damage to the neural cells can result in sensory, autonomic, and motor neuropathy. Which would result in decreased sensory perception, altered or adapted foot anatomy and skin cracks. The decreased blood flow to the feet can be a result of various vascular conditions, whether that is macrovascular or microvascular. Typically ulcers tend to develop in the feet following thermal, chemical, or physical trauma. Foot deformities often result in diabetic patients, and can easily lead to DFU's if the patient does not take proper care of their feet and inspect them regularly. With foot deformities comes partnered with a decreased ability for the foot to absorb forces while walking or during other weight bearing activities. This often results in increased pressure in the metatarsophalangeal and subtalar joints, which can lead to the development of diabetic foot ulcers if left untreated. (Turan et al, 2015.)

4.3 Diabetic Foot Clinical Examination

When assessing a diabetic foot wound, it is imperative to assess the neurologic, vascular, musculoskeletal and dermatologic findings. In order to do that you must assess for any swelling, pain, redness, warmth, numbness or neuropathy type sensations, peeling, callus, nail deformities, skin breaks, and blisters. The examiner should check

all surfaces of the foot in addition to the nails and compare them to the hands. In order to determine what type of DFU the ulcer is, there are a variety of different tests that can be preformed. (Turan et al, 2015.)

In order to determine what type of DFU that patient has, it is important to perform accepted diagnostic tests. In order to assess if the ulcer is neuropathic, you need to evaluation the patient's protective sensations that should be present in the foot. The most common ways to do this are: testing for a vibration sensation using a tuning fork, using a two point discrimination tool for superficial sensation, and using a monofilament to check for pressure sensations. (Turan et al, 2015.) To evaluate if the ulcer is ischemic you need to check for proper blood flow into and out of the foot. This can be done a few different ways, with the most common being Ankle Brachial Index (ABI) testing. In ABI testing a Doppler is used to assess the blood pressure in the ankle and upper arm. They should be approximately equal, if the ankle is lower it indicates PAD, which essentially means reduced blood flow thus categorizing the ulcer as ischemic. When checking to see if the ulcer is neuroischemic, you will need to test for neuropathic and ischemic type ulcers using the methods mentioned previously. If there are positive findings in both categories, then the ulcer is deemed neuroischemic. (Myers, 2012.)

4.4 Abnormal Wound Healing and Chronic Wounds

When a wound does not complete the inflammatory process or is not progressing as it should, it is suspected to be healing abnormally or that it has become a chronic wound. Abnormal wound healing is examined clinically if the healing process is slower than expected by noticing periwound (typically used to refer to the 4cm area surrounding the wound) or the wound itself for a significant decrease in the normal/expected markers of sufficient wound healing for each phase. Unfortunately, chronic wound pathophysiology is not completely understood. (Myers, 2012, p.20.)

In cases where there is no inflammation, we need to consider initiating the inflammatory response. This can be done by performing debridement or by using electrical

stimulation or other modalities. There can be many reasons there is a lack of inflammation, such as: malnourishment, steroids, immune system disorders or age. A lack of inflammation can be noticed by looking for the classic signs of inflammation. The classic signs of inflammation are heat, redness, pain, swelling, and a decrease in function. (Myers, 2012, p. 21.)

The opposite of no inflammation is too much inflammation, known as Chronic Inflammation. In chronic inflammation there is a prolonged inflammation phase that may be partnered with the formation of fibrous tissues; this can last for months or even years instead of the normal 2 weeks. The presence of chronic inflammation inhibits normal wound healing because the body cannot create healthy tissue in a chronically inflamed environment. Cellular chronic inflammation is characterized by an increased amount of macrophages, plasma cells, lymphocytes and fibroblast proliferation. Chronic inflammation is self-sustaining by nature. The macrophages and lymphocytes summon more inflammatory cells to the site of injury, which results in more lysosomal enzymes and inflammatory mediators being produced and etc (as the normal inflammation phase progresses just without moving into the proliferation phase). (Myers, 2012, Chapter 2.)

There are currently three known common causes for chronic inflammation. They are: the existence of a foreign body in the area, cytotoxic agents, and finally repetitive mechanical trauma. Foreign bodies increase the inflammation process in an attempt to cleanse the wound. Repeated mechanical trauma constantly restarts the inflammation phase, because you are constantly introducing another trauma to the injury. Cytotoxic agents prolong the inflammation process because the kill or incapacitate human cells. (Myers, 2012, Chapter 2.)

5 PHYSIOTHERAPY IN DIABETIC FOOT ULCER

5.1 What is a Physiotherapist's Role in Wound Care

Wound care management should always be looked at as a interdisciplinary approach, with physiotherapy fitting into that in a very unique way. It goes without saying some tasks a physiotherapist might do in this setting will overlap with nurses. Some of these tasks are debridement, wrapping wounds, and wound cleansing; but there is much more to wound care management than that, and physiotherapists have a unique and specialized way in caring for patients in this setting. Physiotherapists also have unique training and education in various modalities that are typically isolated to the physiotherapy field that helps with wound care; such as the whirlpool, electrical stimulation, and laser treatments. They also use their knowledge and skills to help with patient positioning, friction reduction, and various exercises to help with restoring range of motion, strength, and sensation/nerve signaling and blood flow. (Academy of Clinical Electrophysiology and Wound Management, 2017.)

Physiotherapists often receive a basic amount of education in this field, with most of the education, training, and practice occurring in post-graduate areas. These areas are often self-study, mentorships, continuing education courses, or on the job training in wound care facilities or teams and are more plentiful in the United States of America. Getting specialized in this field takes lots of time and dedication, but allows for physiotherapist to better treat their patients in a wound care setting. (Academy of Clinical Electrophysiology and Wound Management, 2017.)

Outcomes have steadily been better when DFU patients are cared for by a interdisciplinary team. There are several different professions that would be beneficial to this interdisciplinary team. However the most beneficial ones may be a physiotherapist, podiatric or vascular surgeon, diabetologist, and a wound care specialist or nurse. (Turan et al, 2015.)

5.2 Modalities

There are two main forms of modalities that will be discussed in this thesis, heating agents and electrotherapy methods. The heating agents discussed will be ultrasound, global heat treatment, local heat treatment, and infrared treatment. The electrotherapy methods discussed will be laser treatment, shock wave therapy (ESWT), electrical stimulation, galvanic current treatment, and magnetic field treatment.

5.2.1 Heating agents

Heating agents have been proven to have a positive effect on healing when there are no contraindications affecting it. Heating agents have this effect by promoting/increasing vasodilation. (Turan et al, 2015.) As discussed previously, it is imperative for wounds of any kind and size to have adequate blood flow for it to heal completely and timely. Heat helps to promote vasodilation by sending signals to thermoreceptors. These receptors initiate the blood vessels to relax - or dilate - allowing for greater blood flow to occur closer to the skin. This happens as an effort to dissipate the heat and causes heat loss across the skin. (Gillam, 2015.)

In a study conducted in 2007, it was proven that exposing the patient to global heat prior to electrical stimulation increased healing rates. Global heat was accomplished by keeping the patient in a room that was 32 degrees Celsius for 20 minutes. The study demonstrated a 20% higher healing rate for global heat treatment than with local heat or no heat treatments. Local heat also increased blood flow and resulted in a higher healing rate, but paled in comparison to the results of global heat. Laser Doppler ultrasound measured blood flow during these tests. However, it must be said that local heat is much more attainable for clinicians to provide for their clients that global heat. Local heat was provided by using a heat lamp at 37 degrees Celsius that was targeting the wound for 20 minutes. This study lasted for 4 weeks, and the electrical stimulation (e-stim) used was biphasic e-stim (20 mA) 3 times a week for the full 4 weeks. (Turan et al, 2015.)

Ultrasound is also a form of deep heat, but starts out as sound waves. In ultrasound, the sound waves turn into heat energy once the pass through a homogenous environment. Ultrasound's use in chronic wound healing has been studied very extensively when compared to the use of other modalities. So much so that there are multiple different forms and techniques to doing it. A systemic review published in 2011 took on the daunting challenge of sifting through several studies and have discovered/observed that low-intensity, low-frequency, noncontact ultrasound is the most beneficial when it comes to diabetic foot ulcer healing. This systemic review looked at studies with low frequency's being between 20-30 kHz. It is important to note that Ultrasound does have various contraindications. Those contraindications are typically considered to consist of pregnancy, plastic or metal implant, malignant lesion, cardiac pacemaker, hemorrhagic diathesis, cardiac failure, and acute infection when directing acoustic energy over the area. (Turan et al, 2015.)

Several studies have been conducted evaluating various types of ultrasound, and it appears that the most common and recommended is the MIST Therapy System (MIST) or a device similar in function. MIST is a device that is essentially a water gun that sprays a mist of saline solution. The MIST device (and other noncontact low-frequency ultrasound device) should be held 0.5 – 1.5cm from the wound, the saline mist being sprayed onto the wound bed stimulates cellular activity. This should typically be done three times a week, with each session being 2-13 minutes. Not only does this type of device promote cellular activity, but also is a form of maintenance debridement and cleans wounds. However, it is important to note that this modality is only a part/supplement to wound care. (Aetna, 2021.)

5.2.2 Electrotherapy methods

Several studies have shown the efficacy of electrical stimulation (e-stim) when being used to strengthen muscles; however it can also be used to aid in wound healing. E-stim accomplishes this by creating a short pulse of electrical stimulus that is intended to copy the body's natural electrical system and to stimulate wound healing. E-stim

accomplishes this by affecting the cellular calcium channels, which promotes greater nitric oxide production. This is desirable because nitric oxide is a strong vasodilator, it may also change forms and take on the role of a strong bactericidal. Nitric oxide is also known to increase epithelization rates and collagen storage by promoting glucose transfer into cells. (Thakral, 2013.) E-stim also has been proven to stimulate several wound healing cells, such as macrophages, keratinocytes, neutrophils, and fibroblasts by interacting with several signaling mechanisms. (Petrofsky et al, 2010). There have been various studies to evaluate the effectiveness of specific waveforms and intensities. There has not been a widely accepted/agreed best option, just that the studies have showed e-stim can make a significant statistical difference in wound healing rates. It is also important to note that a cardiac pacemaker is a contraindication to e-stim. (Thakral, 2013.)

Extracorporeal shock wave therapy (ESWT) is a way of addressing specific soft tissue injuries. ESWT is similar to ultrasound in the sense that it uses sound waves. However, ESWT delivers stronger amounts of energy compared to ultrasound. So strong, that even though it is non-invasive, the waves can pass through the soft tissues and reach the bones. ESWT is classified as low, middle, or high energy based off of the mJ/mm^2 delivered. For DFU's it is recommended to use $0.03mJ/mm^2$ (low energy is classified as 0.1 mJ/mm^2 or lower) two times a week. (Thakral, 2013.) The objective when administering one of these treatments is to achieve 100 $pulses/cm^2$, which may take up to 30 minutes per area (Moretti et al, 2009).There have only been 2 studies done that tests ESWT's effectiveness on DFU's, but the results are promising. However, the contraindications that go along with this type of treatment are: cardiac bypass operation, major cancer, coagulation disorder, and active pregnancy. (Thakral, 2013.)

In physiotherapy low-level lasers (also known as cold lasers) are mainly utilized. These lasers are believed to work by increasing blood flow to the area. (Thakral, 2013.) Physiopedia (2020) states it "is used for pain relief, accelerated tissue regeneration and reduction of inflammation". Cold lasers work by emitting 1 wavelength of light. That light is believed to work by providing the needed stimuli for the cells to

kick it up a notch (so to speak) in the healing process. However, there has not been much research with this modalities efficacy for DFU's specifically, and calls for further investigation. But the results we currently have available are promising. (Physiopedia, 2020.)

Magnetic field treatment (Magnetotherapy - MFT) has a history of being considered controversial. It has found a modicum of popularity in alternative medicine based off of clinical evidence, but has been lacking proper research to scientifically support its efficacy. There have been limited studies evaluating it (especially for DFU's), usually with small sample sizes; thus its use tends to remain limited. (Henry et al, 2008.) However, these limited studies point to its potential success in facilitating wound healing, but it is still surrounded with a negative stigma. It is believed to have a positive effect on wound healing by how the magnets interact with the autonomic nervous system (ANS). MFT causes vasodilation by causing changes in the ANS, resulting in pain causing toxins to be removed. MFT may also promote the release of endorphins by supporting more permeability of the neuronal membranes and other hormones that are analgesic in function. There currently lacks to be a standardized implementation of MFT, but it is generally accepted that for DFU's it should be administered daily for 10 days, a hour each, at a relatively low intensity of 30 Gauss. It is important to note, that when using this modality the foot being treated should be placed in a solenoid coil. The MFT should penetrate down to approximately 22 mm. This modality also has slightly different contraindications that the ones previously discussed for other modalities, it is important to not use this with patients that are pregnant, or have a metallic implant such as an inner ear hearing device. (Thakral, 2013.)

Galvanic current (or galvanic stimulation) operates by using a zero-frequency electrical current that flows only in one direction and is polarized. This modality affects wound healing by stimulating the myelin-free pain fibers. Which results in paresthesia of the deep and superficial skin layers. This type of electrical treatment requires electrodes made with a carbon silicon surface. The current should be set with an intensity of 1 Ma that lasts for 20 minutes for DFUs. One study investigating the efficacy of DFU treatment with this method only studied 11 patients that had diabetes and impaired peripheral perfusion pressure. Initial results showed a significant in-

crease in peripheral perfusion within only 5 minutes of treatment. However, this modality like all others comes with contraindications, which are cardiac pacemakers and pregnancy. (Turan, 2015.)

5.3 Exercise

It is also important to remember that all though modalities are highly recommended to use, so is therapeutic exercise. Within therapeutic exercise we have 4 goals: improve/promote circulation/healing, proper gait training, maintain/improve range of motion, maintain/improve sensation in the extremities. Studies prove that exercise is effective for patients with DFU's and in preventing them from occurring in the first place. Specifically exercises aimed at improving range of motion, Buerger-Allen exercises, stretching, balance, and proprioception. (Turan et al, 2015.)

Buerger-Allen exercises (BAE) have shown to be effective when used to enhance blood flow to the extremity. BAE exercises may also lead to the creation of new vascular structures. In order to perform BAE, the patient should be supine with their feet raised for 3 minutes, then the patient should move into a sitting position and position their feet in pronation, supination, extension, and flexion (3 minutes each). When doing the movements in sitting the feet should become pink, which indicates increased blood flow, opposite to that the legs should turn pale/blanched when patient is supine with feet raised. If the patient's feet become painful or blue during sitting then they should return to supine with feet raised. Rest between movements/positioned is allowed as needed. At the end of completing all 4 positions in sitting the patient should return to supine with legs flat, and wrapped in a blanket. (Turan et al, 2015.)

Other recommended exercises involve ROM and stretching to help increase blood flow to the area, which again, promotes healing. The specific exercises that have been studied and resulted in improved ulcer healing are as follows active dorsiflexion, inversion, plantar flexion, and eversion of the ankles on the effected leg. Exercises studied to prevent/reduce improper plantar pressure while walking and ROM are as follows: active and passive dorsiflexion of the metatarsophalangeal and ankle

joints, active ankle supination and pronation, plantar flexion, and stretching the soleus and gastrocnemius muscles. (Turan et al, 2015.)

5.4 Offloading

The International Working Group on the Diabetic Foot (IWGDF) has published offloading guidelines in an effort to make a more uniformed approach to this area of treatment (Bus et al, 2020). Several studies over the years have tried to accomplish a similar goal. In a literature review from 2010 they discuss how there is a lack of uniform intervention when it comes to offloading. There are different types of offloading available, and even more ways to implement them. For example, total contact casting (TCC) has been thought of as the "gold standard" for offloading. However, clinicians can apply a TCC in a variety of ways, shapes and sizes. (Cavangah & Bus, 2010.) The IWGDF guidelines state that the ideal TCC for plantar forefoot or midfoot ulcer (most common areas for ulcers) is to use a knee-high non-removable cast (Bus et al, 2020).

The Rosalind Franklin University of Medicine and Science released a video in 2012 aimed at creating a easily understandable video for patient education for DFU's. However, this video is also a incredible resource for professionals looking to increase their own knowledge for DFU's and offloading specifically. This explains how important offloading is and its necessity for a DFU to properly heal. In the video they site several studies that address various healing mechanisms and TCC's have the highest healing rate by more than 20%. The purpose of a offloading device is to help evenly distribute your weight among your foot to give the ulcer the rest/ability to heal properly. A big reason that TCC's are more effective than other offloading methods is it is more difficult for patients to be noncompliant. It has often been observed that if a patient is given a diabetic walking boot (DWB) to wear that they will not wear it as directed, versus in a TCC (or a DWB that has been modified for harder removal) the patient has extreme difficulty removing the device themselves making it that much harder for them to be non-compliant. A DFU heals at approximately 1mm a day. It is common that patients' will not wear their offloading devices in their own homes or if they are only taking a few steps. However this is one of the worst deci-

sions they can make. For each step they take without a offloading device, they are losing one day of healing. (Rosalind Franklin University of Medicine and Science, 2012.)

5.5 Shoe Modification

It is also worth mentioning that another form of off-loading is shoe modification. Diabetics may be recommended by their physicians to purchase some diabetic shoes. These shoes are often custom made, with the intent to prevent DFU's before they form. However, the TCC's and other forms of off-loading are to treat DFU's that have already formed. It is known that repetitive trauma is a factor in developing a DFU. The most common trauma that results in DFU's stem from improper fitting shoes, which is another reason why modified shoes are so important to prevent these from forming. These may also be recommended on the notice of a foot deformity beginning to develop and may need to be adjusted/modified further as time progresses. (Turan et al, 2015.)

5.6 Standard Course of Wound Care Physiotherapy for Diabetic Foot Ulcers

Typically treatments for DFUs consists of pressure off-loading, wound dressings, debridement and drainage, and if they are infected then antimicrobial therapy is also usually included. However, diabetic patients have a lower extremity amputation rate of 17-40 times higher than non-diabetic patients do with foot ulcers. (Turan et al, 2015.)

Total contact casting (TCC) has become the gold standard of treatment when it comes to DFU's. TCC is a form of pressure offloading done by molding and placing a cast around the injured extremity. These casts are very similar to the casts that we tend to think of when we think of a broken leg or ankle. The key differences with TCC are that the cast covers the toes and it is a tighter fit. There are five main reasons this is believed to work so well. The first reason is that with the cast being

molded correctly it allows for weight bearing forces to be evenly distributed all around the foot while being rerouted from the area of injury. The cast also provides protection and benefits without immobilizing the patient, which is thought to enhance patient adherence. With this cast being a snug fit, it prevents shearing forces from occurring by immobilizing the foot and ankle. This snug fit also helps with edema and improves local circulation; those being the third and fourth reason. The last reason being it also covers the toes, assisting to protect them from damage and bacteria. (Myers, 2012, Chapter 13.)

6 THESIS PROCESS AND METHODS

The research conducted in this thesis was obtained via several literature reviews targeting wound care, modalities, exercises, and diabetes, and webinars from various wound care specialists. Various search engines were used to obtain this information, including PubMed, Pedro and Google Scholar. Information was found using various search terms such as: Diabetes, wound care, diabetic foot ulcers, physiotherapy, modalities, off loading, exercises, electrical stimulation, ultrasound, therapeutic heat, galvanic current, magnetotherapy. An educational package for the physiotherapy students in NPH19SP was created so they could pilot it within their Cardiopulmonary Physiotherapy course taught by Mari Törne in Spring 2021. Based off of the participants feedback no changes to the educational package was recommended and thus none were made. The educational package was aimed to condense the material in this thesis into a more user-friendly platform, allowing videos, pictures, quizzes, and information regarding the material showing the highlights and most important information from this thesis. After completing the educational package the participants completed a feedback form and an informed consent form, which can be found at the end of this thesis.

7 DISCUSSION

The initial topic for this thesis was chosen due the authors previous work experience in an acute care and critical care settings in the United States of America. In these settings Physical Therapists performed wound care regularly for a variety of conditions, most prominently infected ulcers or amputations. With the previous work experience and knowledge gained during the physiotherapy studies I believed this topic would not only suit my interests, but also push my research and critical thinking skills due to the lack of research about this topic. There is some research evaluating physiotherapies effectiveness for treating diabetic foot ulcers that have been published within the last 10 years. However there were not many modality studies evaluating their effectiveness for diabetic foot ulcers. Those studies rather evaluated the modalities effectiveness on treating wounds in general. Those studies were still used and deemed credible for this thesis because they are used in wound care today, and the research has not been disproven or questioned. Much is known about DFU's however more research would be beneficial to the healthcare systems and could reduce the amount of diabetic amputations performed each year. This thesis allowed me to explore and learn about more modalities than prior to starting this. However I would have liked to include more information regarding the anatomical and physiological changes in regards to the wound healing process, but that itself could be an entirely different thesis.

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APPENDIX 1

Informed Consent Form

Physiotherapy in the Prevention and Management of Diabetic Foot Ulcers Educational Package Material Pilot

I, _____, willingly agree to participate in the study mentioned above, and to give feedback about the study material created in this study.

I have clearly understood all requirements, completed necessary prerequisites, and provided truthful information to the best of my ability. I understand the purpose of this study and I am willingly agreeing to the rules and requirements mentioned in the previously distributed informational packets and meetings.

I agree to participate in this study, and complete it to the best of my ability.

Signature:

Name (printed):

Date:

APPENDIX 2

Feedback Questionnaire

Physiotherapy in the Management of Diabetic Foot Ulcers Independent Learning Material Pilot – 2021

Please answer each question with a rating of 1-5 (excluding number 6).

1 = I completely disagree

2 = I partially disagree

3 = I don't know

4 = I partially agree

5 = I completely agree

1. I gained valuable and evidenced based information.
2. The material was easy to understand and was presented in a clear and logical manner.
3. The material provided enough information.
4. I recommend other students complete the learning material.
5. The information is useful for a physiotherapist's work.
6. How long did it take to complete the learning material?

Please describe your experience with the learning material more in depth below while answering the questions listed/ What did you like about the material and why? What did you not like about the material and why? Do you think more information should be included it in, if so what would you like to be included? Do you have any suggestions or recommend any changes to the structure of the learning material? Etc.