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Electrical Muscle Stimulation Device

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Abstract: The mind is the one that issues orders (nervous signals) to the main muscles to carry out the movement and at the same time gives instructions to other muscles to do the work of assistance and stabilization. Conversely, some muscles work in opposition to the main muscles to protect the individual from the force of contraction of the main muscles and thus the occurrence of injury. Which has spread recently in a striking manner, especially back injuries due to lack of movement and inactivity.

As a result of technological progress and scientific development, many means and devices have been introduced in order to speed up the rehabilitation and treatment of injuries. Electrical stimulation has had a major role in the rehabilitation of some injuries. Its idea is to introduce electrical current to the muscles so that they work apart from the nerve signals issued by the brain through the spinal cord to the motor nerves to produce movement, and this What we clearly notice when an individual is exposed to electrical contact is that the muscles work involuntarily, and that the use of stimulation maintains the functional efficiency of the muscle and nerve, in addition to working to disrupt the pain signals emanating from the brain by creating an alternative sensory mechanism.

1.1 Introduction

Electrical stimulation is one of the types of electrical therapy, which is a method of physical therapy, which is done by using electric current, which helps to strengthen muscles, reduce pain and improve blood circulation. (Laura & Mohamad, 2022) When performing any movement, the mind is the one who issues commands (nervous signals) to the main muscles to do the movement and at the same time it gives instructions to other muscles to do the work of assistance and stabilization and on the contrary, some muscles work against the main muscles to protect the individual from the force of contraction of the main muscles and thus the occurrence of injury Which has spread recently in a striking way, especially back injuries due to lack of movement and lethargy. (Johnson, 2017) .As a result of technological progress and scientific development, many means and devices have been introduced in order to speed up the rehabilitation and treatment of injuries, and electrical stimulation had a great role in the rehabilitation of some injuries. What we notice clearly when an individual is exposed to an electrical short, the muscles work involuntarily and the use of stimulation maintains the functional efficiency of the muscle and nerve. (Nussbaum & et. al., 2017)

1.2 Objectives of the study

The research aims to study the internal and external voltages used in the electrical muscle stimulation device and the method of connecting it.

1.3 Statement of the Problem

The theoretical aspect is that studies the electricity entering the device, while the practical aspect is how to use the device for physical therapy in many medical conditions.

1.4 Significance and Motivations

Electrotherapy: is the use of electrical energy as a medical treatment. In medicine, the term electrotherapy can apply to a variety of treatments, including the use of electrical devices such as deep brain stimulators for neurological disease. The term has also been applied specifically to the use of electric current to speed wound healing. Additionally, the term "electrotherapy" or "electromagnetic therapy" has also been applied to a range of alternative medical devices and treatments.

Electrical Muscle Stimulation (EMS): offers rich opportunities for interaction. By varying stimulation parameters (amplitudes, pulse widths and frequencies), EMS can be used to either trigger muscle contractions, and so convey object avoidances or guide user movements, or provide rich haptic feedback. However, the way users' experience changes with these parameters, and EMS in general, is poorly understood.

Muscular Size: Muscle hypertrophy includes an increment in size of skeletal muscle through a development in size of its segment cells. A scope of boosts can expand the volume of muscle cells. These progressions happen as a versatile reaction that serves to expand the capacity to produce drive weariness in anaerobic conditions. In this study, the muscular size of the subjects was measured in their skeletal muscle mass, upper body muscle mass, lower body muscle mass, dominant hand muscle mass, dominant leg muscle mass, non- dominant hand muscle mass and non-dominant leg muscle mass.

2.1 Introduction

Muscle Stimulation Electronic muscle stimulation (EMS), also known as neuromuscular electrical stimulation (NMES) or electromyostimulation is the elicitation of muscle contraction using electric impulses. EMS has received increasing attention in the last few years, because it has the potential to serve as: a strength training tool for healthy subjects and athletes; a rehabilitation and preventive tool for partially or totally immobilized patients a testing tool for evaluating the neural and/or muscular function in vivo; a post-exercise recovery tool for athletes. The impulses are generated by a device and delivered through electrodes on the skin in direct proximity to the muscles

to be stimulated (Ahlborn ,2007).

Figure (1) Electronic muscle stimulation

The impulses mimic the action potential coming from the central nervous system, causing the muscles to contract. The electrodes are generally pads that adhere to the skin. Electrical muscle stimulation, or EMS, is the use of electrical impulses to cause muscles to contract. EMS has long been used in physical therapy, and research has shown that it can help strengthen and tone muscles, though only to a certain extent. However, manufacturers' claims that EMS devices promote weight loss or fat loss have never been proven. Indications Neuromuscular stimulation should be used only under medical supervision for adjunctive therapy in the treatment of medical diseases and conditions. Neuromuscular Stimulation (N.M.E.S) is the application of an electrical stimulus for use in muscle rehabilitation. An electrical stimulus is passed from the device to an electrode that is placed on the skin over the motor point of a targeted muscle or muscle group. This stimulation results in a muscle contraction. By assisting patients to fully contract a muscle or muscle group, N.M.E.S can move a patient more quickly towards normal function and the resumption of their normal activities (Aldayel, 2010).

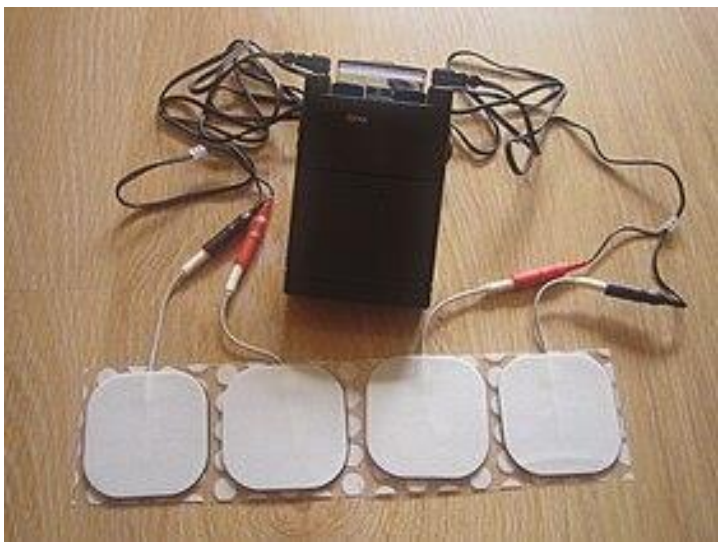


Figure (2) transcutaneous electrical nerve stimulation device.

2.2 Previous studies

- Medical electrotherapy was used in London in 1767 at Middlesex Hospital using a special apparatus. Several years later, another device appeared at St. Bartholomew's Hospital. Then Guy's Hospital published many cases that were treated with electricity. (Steavenson & William, 2017).

- In 1959, the journal Science published a research showing the use of direct current in the treatment of cancer, as it completely destroyed the tumor in 60% of patients (Humphrey & Seal, 1952).
- In a study presented by (Cancer Research magazine in 1985), it was mentioned that 98% of the animals shrunk the tumor by using continuous current for five days and an average of five hours per day.
- Recently, many studies have been presented that demonstrate the importance of electrostimulation therapy, (Lynne, Sheffler & John, in 2007) they presented a study on the use of neuromuscular electrical stimulation in neurological rehabilitation.
- (Bronfort & et. al., 2009), studied the use of non-surgical physical therapy in the treatment of types of chronic recurrent headaches. The study indicates that there are several methods used in the treatment of migraine headaches, including: Pulsating Electromagnetic Fields, Transcutaneous Electrical Nerve Stimulation (TENS), Therapeutic Touch, Cranial Electrotherapy, and a combination of selfmassage/TENS/stretching are used. The study also found that these methods have few side effects.
- (Aziz, Flemming, Cullum & Olyaee, 2010) Electromagnetic therapy for treating pressure ulcers was study by, Sores on the skin known as pressure ulcers are brought on by rubbing or pressure. They typically afflict people with limited mobility on their bony body parts, such as the elbows, heels, and hips, and they are slow to heal. Since the goal of Electromagnetic Therapy (ET) is to promote healing, it does not involve radiation or heating. Instead, it employs an electromagnetic field. The evaluation of studies found no conclusive evidence, nevertheless, to support either the benefit or harm of electromagnetic therapy for pressure ulcer healing.

2.3 The use of EMS in sports and fitness

Electrical stimulation in recent years has begun to be applied in sports, especially with athletes who need strength. It is implemented by using special appliances, and the length of stimulation lasts for 10- 15 seconds with breaks of 45-50 seconds, usually with 10 repetitions. It can be particularly useful when properlydosed; otherwise, its use can cause harmful effects, especially if used for longer than the scheduled time. By applying electrical stimulation blood circulation and metabolism of nutrients in muscle cells are improved, thereby contributing to the increase of muscle mass, and thus strength.Most often it is used for the purpose of recovery, but after three weeks of its effect lowers. The application of EMS in the sport and fitness helps strengthen specific muscles or muscle groups in order to achieve the desired proportions of the body, the development of muscular endurance, warming, strengthening and increasing strength, improves muscle recovery and rehabilitation of sports injuries (Vrcić, et al., 2015).

Figure (3) the use of EMS in sports

It is important to note that the effect of the EMS functioning can be expected only in regular use, it does not replace regular exercise but it is good as a complementary part. There are only a few studies in the scientific literature in the field of electrical stimulation of muscles. There are even fewer allegations that document the effects of applying this method to healthy people, and the physically active population, or recreational athletes (Banerjee, Caulfield, Crowe, & Clark, 2005; Davis, Hamzaid, & Fornusek, 2008).

Previous research in the field of the EMS identified the significant effects on strength and power, but in isolated muscle groups (m. quadriceps femoris or m.bicepsfemoris).There are top sportsmen (canoe or kayak) with a very positive attitude towards electrical stimulation, but even they apply it locally (on several muscles), before major competitions, including the Olympics. Some allegations indicate that if the EMS is applied regularly (twice a day) on the small muscles of the foot arch, improvements are probable, or on higher muscle groups the EMS treatment can vary from 15-60 minutes, twice a week to several times (Malacko & Rađo, 2004). In addition, the EMS has been successfully applied to the extensor muscles of the spine with the rowers and kayakers, who tend to the occurrence of pain in the lower back (Wheeler, Andrews, & Lederer, R., 2002 Zaciorski, & Kremer, 2009). Advantages of using the EMS to the whole body in order to achieve better physical form or shape have never been tested. However, it is evident that the EMS has an important place in the field of recreational exercise, and a growing number of fitness centers that follow the modern trends offer this type of training.

2.4 EMS and Skeletal Muscle Mass

According to (Porcari et al., 2002), EMS was more effective than exercise alone in strengthening skeletal muscle. This is because during the penetration of impulses to the muscle, the Central Nervous System (CNS) activates the smallest motor neurons and with increasing level of intensity, larger motor neurons were activated. During EMS training, 90% of the muscles was activated simultaneously giving contraction to muscle and the muscle contractions was stronger and more intense than a voluntary exertion can do alone. Compared to conventional weight training, deeper muscle groups was activated which lead to better intra and inter muscular coordination. Previous researcher by stated that, the intensity of each impulse current delivered to specific muscle groups in the body.

Figure (4) Demonstrates electrical stimulation of the muscle

Therefore, the electrically induced contraction must be in the range of 60- 80% of maximal voluntary contraction (MVC) or master intensity which was being used in this experiment using Xbody machine, making it possible to target the problem areas, body sculpt and increase strength in areas that people choose to focus on. The mechanism of action of EMS was the electrical stimulation does not specifically empower skeletal muscle. Electrical stimulation really energizes the nerve going to muscle and not muscle itself. According to (Petrofsky et al., 2001), high frequency stimulation which was more than 70 Hz was going to give neuromuscular intersection failure and muscles that easy to get fatigue. The motor nerve most powerful to stimulate at the point it branches to enter the muscle, called the motor point. In this way, the closer the electrodes were to the motor point, the less impulse it takes to fortify the muscle through its nerve. During training session, by moving impedance over the muscle, the point where the motor point enters the muscle can be effortlessly found.

2.5 The types of current for electrical stimulation are:

a) INTERFERENTIAL THERAPY

b) TRANSCUTANOUS ELECTRICAL NERVE STIMULATION

c) Faradic current

d) GALVENIC CURRENT

Osama Riyad and Imam Hassan divided the current used in motivation into: (Osama Riyad, Imam Hassan: 1999: 94-98)

a) ALTER NATING CURRENT:

It is a low-frequency current ranging from 1-2000 cycles per second and can be used to stimulate muscle, sensory and motor fibers.

b) FARADIC CURRENT:

An alternating current with a short duration of about one millisecond and a speed of 50 to 100 cycles per second, and it has the ability to stimulate the nerves and cause contraction in the muscles that it supplies.

c) SINUSOIDAL CURRENT:

It is a regular alternating current, meaning that the direction of the electrons passing through it changes regularly, at a speed of five cycles per second, and with a time of 10 milliseconds (the time of the pulsating electric wave).

d) Direct CURRENT:

It is a low current that, when discovered, was called the galvanic current after its discoverer.

2.6 How does electrical muscle stimulation work?

The brain is primarily responsible for the commands that come to the working muscle regarding voluntary or voluntary action, as it is known, and the brain sends commands to the nerve fibers via electrical signals. This signal is then transmitted to the muscle fibers, for the purpose of contraction. The brain is also truly responsible for electrical stimulation of the muscle, as well as monitoring the progress of electrical stimulus production during voluntary contractions. The stimulus is sent in the form of electrical waves to the nerve fibers, to stimulate them, and this excitement is transmitted to the muscular fibers, causing the basic response to movement (muscle tension), finally forming the basic requirements for muscle contraction. This muscular response is completely identical to what is drawn up in the brain regarding voluntary control of the muscle as a result of the instructions coming from it to control muscular action. From the above, we find that the muscle cannot work without the presence of electrical instructions or signals coming from the brain. In other words, the muscle cannot distinguish between commands, whether coming from the brain or through stimulation, as shown in the figure below. The devices used for stimulation, especially the modern ones, determine (the number of waves per second, contraction time, rest time, and total program time). The muscle is also subject to change according to the type of work and the number of muscle fibers involved in the work. In fact, it is necessary to have good knowledge of the physiology of the human body to fully master the process of stimulating the various programs of the devices used and according to the specificity of muscle contraction, as there are different types of muscle fibers, including slow, medium, and fast fibers. Fast fibers are known to control sprint events, while in marathon running, we need slow fibers greatly. Thus, the progress of muscle work is precise and according to the type of goal specified for it (strengthening muscles, increasing blood flow, for general strengthening, etc.) (Pierre, 2008).

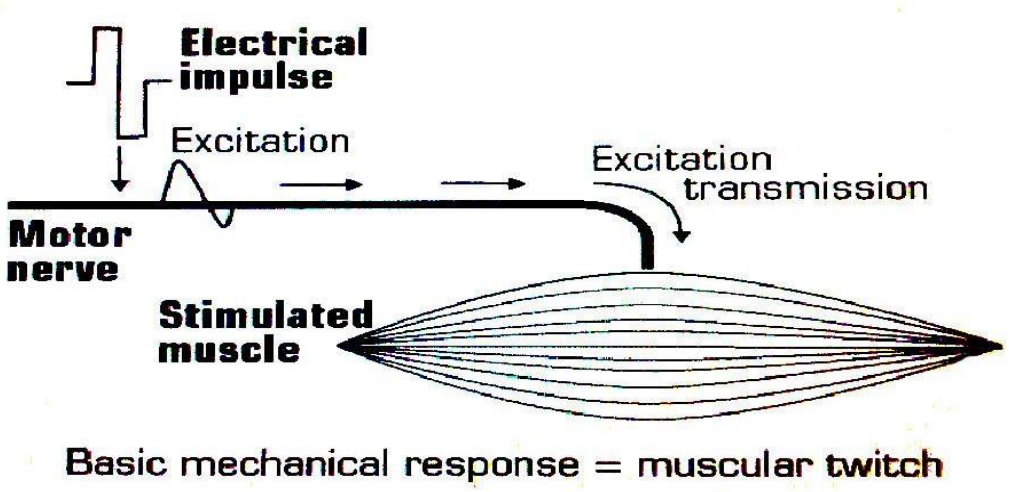


Figure (5) explains the rule of mechanical response to muscle tension

Electrical waves can also stimulate sensitive nerve fibers to provide pain relief or reduce the effectiveness of pain. Or through tactile stimulation of a group of nerve fibers that transmit pain to the nervous system. Stimulation is done through another type of sensitive fiber, which has a role in creating and increasing the production of endorphins, which have a role in reducing pain. Electrical stimulation combined with a pain reduction program can deal well with acute pain or chronic pain in affected muscles (Pierre, 2008).

2.7 Contraindications to Electrostimulation Therapy

Electrical stimulation therapy is not used in the following cases (Alberto, Jose & David, 2021)

- Patients with tuberculosis.
- If the patient is sensitive to the liquids used to wet the spongy pads which cover the electrodes.
- Avoid applying electrostimulation therapy near heart or eyes.
- Pacemakers.
- Cardiovascular Diseases.
- Implantation Cochlear.
- The presence of a metal implant or malignant tumors in the area to which the current is to be applied.
- Inflammation and skin flaws.
- Bleeding, Menses and Pregnancy
- Carcinoma.
- Allergy problems that appear in the places where the electrodes are placed.
- Organic psychoses and psychopathological syndrome.
- Multiple Sclerosis.
- Vein and Lymphatic path inflammation.

2.8 Disadvantages of Electrostimulation Therapy

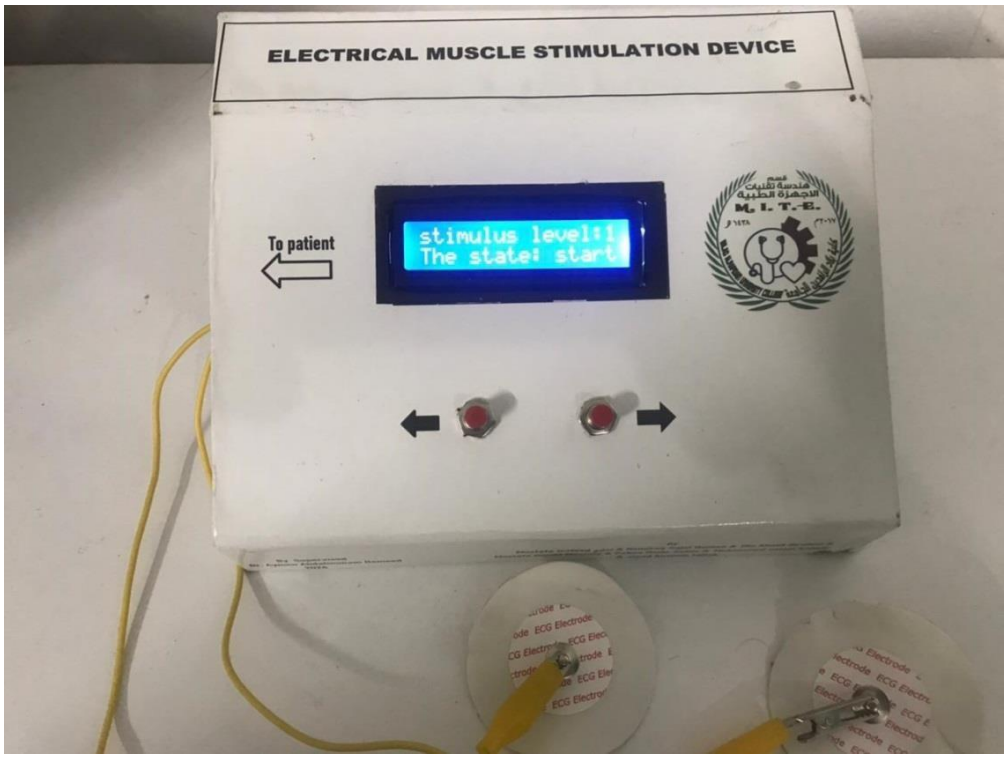
Therapeutic electrical stimulation does not currently have any documented long- term, harmful side effects. A few adverse effects are temporary. Spasticity may actually increase if electrodes are positioned improperly. Muscle pain can be caused by stimulation that is applied too vigorously. Immediately after the treatments are stopped, these side effects will go away. Occasionally,

instances of skin discomfort brought on by the electrodes have been made. If someone has a skin lesion or sunburn, skin irritation is more likely to happen (such as chicken pox). While such lesions heal, it is advised that treatment be discontinued. (Pelaez1 & Taniguchi, 2015)

3.1.1 Electrical muscle stimulation:

The electrical oscillation device for muscles is known as the electrical muscle stimulation device (in English: Electrical muscle stimulation) and its abbreviation (EMS), and it is also referred to as neuromuscular electrical stimulation (in English: Neuromuscular electrical stimulation), as this device works to stimulate the muscle fibers to contract by sending signals or High electrical vibrations, these contractions increase blood flow and enhance muscle mass.

The device was designed and operated using the Arduino board to allow the possibility of developing the use and control of the device



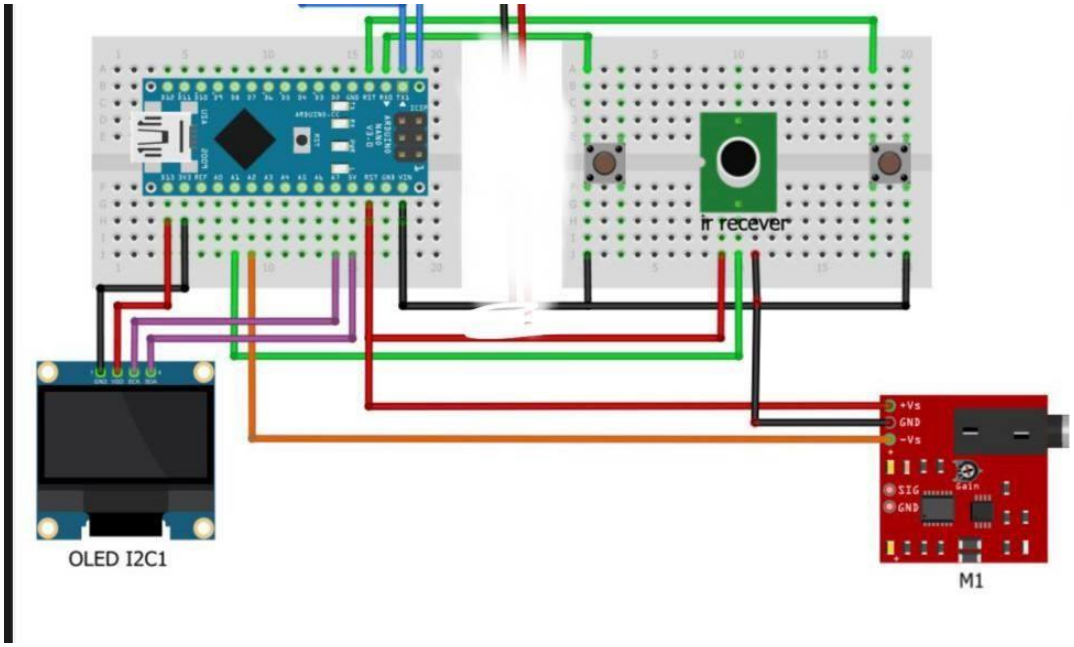
(Picture No. 3.1: Electrical muscle stimulation)

3.1.2 Device elements:

- Arduino nano v3.0: The Arduino board was used to control the muscle stimulation device and connect the device to a display screen using it.
- LED screen: A screen that displays stimulation levels and is connected to the Arduino board.
- Stimulation circuit: A circuit for creating and delivering the electrical impulses necessary to stimulate muscles.
- Voltage connection board: Connects voltage to all parts of the device.
- volt batteries: equip the device parts with the required voltage.
- Dual battery base: to connect the batteries and connect them inside the device.
- On and off switch: Turns the main device on and off.
- 2 control keys: to control stimulation levels and are displayed on the digital screen.
- Electrical connections: internal connections to the device parts.
- Patient conduction electrodes: Conduct electrical impulses to the patient.

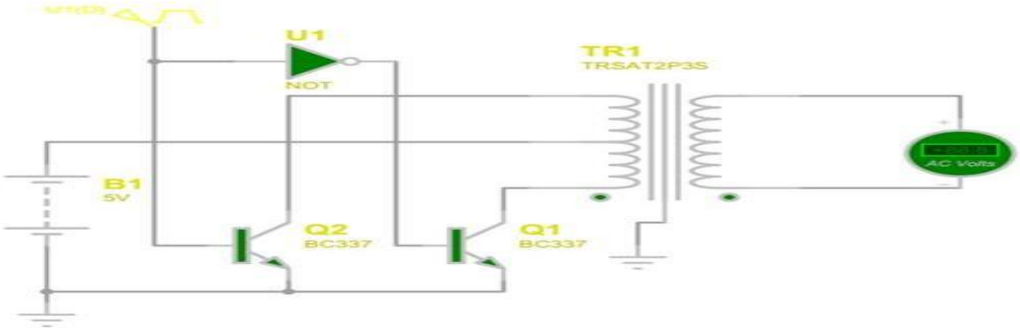
- Connecting disks: electrical impulses are given to the patient through them.
- External casing: the external appearance of the device.

3.2.1 The electrical circuit of the device:



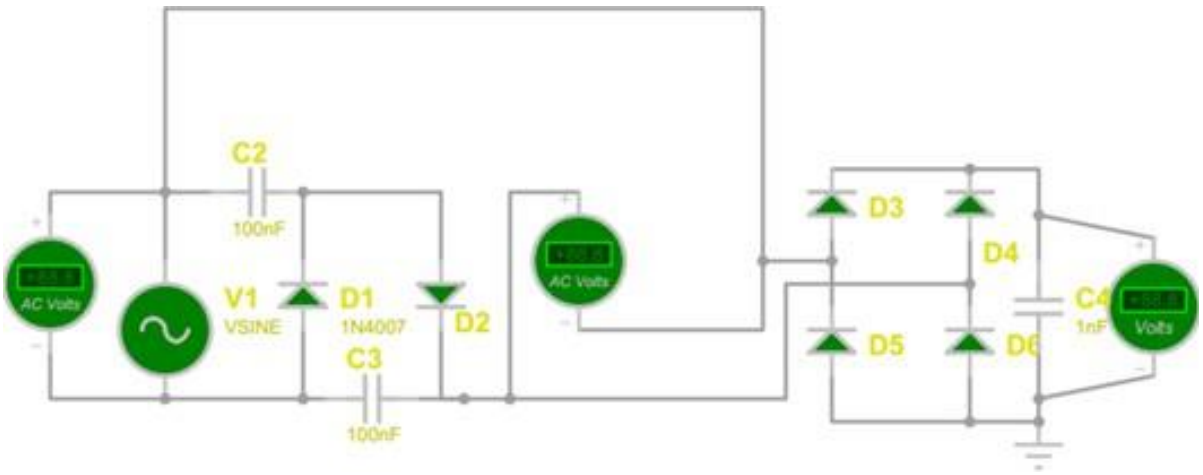
(Picture No. 3.2: The electrical circuit OF Electrical muscle stimulation)

3.2.2 Voltage raising and pulse generation circuit: This circuit first converts the fixed voltage from the battery into alternating voltage using the two transistors that receive the induction pulses from the controller, which is represented here by a square pulse generator U1. The transistor circuit Q1 and Q2 form a half-bridge circuit feeding the midpoint transformer TR1. Which in turn raises the voltage to a maximum value of 120 volts, which is controlled by pulse width modulation.



(Picture No. 3.3: Voltage raising and pulse generation circuit)

Voltage double circuit: Its function is to double the output voltage of the previous transformer to obtain a higher voltage field in order to increase the controllable field and obtain the current required for the pulse.



(Picture No. 3.4: Voltage double circuit)

3.3 **Steps to connect the device elements:**

- ✓ Install the device elements, each element according to the appropriate and previously specified place.
- ✓ Connect the elements using special connection cables according to the circuit shown below.

➢ Arduino nano v3.0

Connect two connection cables as follows:

- ✓ Connect the GND electrode on the Arduino to the GND electrode on the voltage connection board.
- ✓ Connect the VIN pole on the Arduino to the VCC on the voltage connection board.

➢ LED screen

Connect four connection cables as follows:

- ✓ Connect the GND pole to GND in the voltage connection board.
- ✓ Connect the VCC pole to the VCC pole in the voltage connection board
- ✓ Connect the SDA electrode to 4V on the Arduino nano v3.0
- ✓ Connect the SCL electrode to 5V on the Arduino nano v3.0

➢ Motivational circuit

Connect four connection cables as follows:

- ✓ Connect the GND pole to the GND in the voltage connection board.
- ✓ Connect the VCC pole to the VCC pole in the voltage connection board
- ✓ Connect pole IN1 to ~6 on Arduino nano v3.0
- ✓ Connect electrode IN2 to ~7 on Arduino nano v3.0

➢ Dual battery base

Connect two connection cables as follows:

- ✓ Connect the GND pole to GND in the voltage connection board.
- ✓ Connect the VCC electrode to the on and off switch.

➢ On/off switch

Connect two connection cables as follows:

- ✓ Connect the first cable to VCC in the dual battery base.
- ✓ Connect the second pole to VCC to the voltage connection board.

➢ Control keys

Connect four connection cables as follows:

- ✓ Connect the first pole in the first switch to GND in the voltage connection board.
- ✓ Connect the second pole in the first switch to ~8 on the Arduino nano v3.0 .
- ✓ Connect the first pole in the second switch to GND in the voltage connection board.
- ✓ Connect the second pole of the second switch to ~9 on the Arduino nano v3.0 .

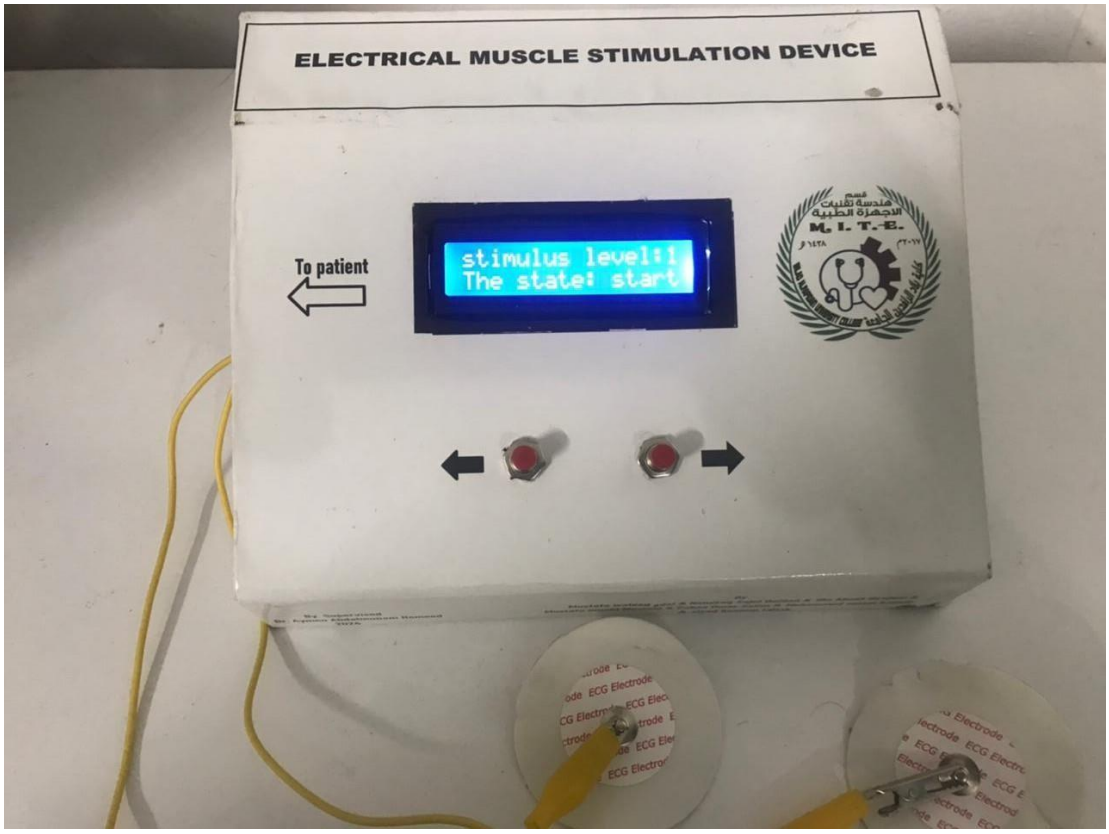
➢ Electrodes to connect the patient

- ✓ The patient's electrodes are connected to the exit port in the stimulation circuit.

➢ Arduino code

Arduino code is written using the Arduino IDE .

4.1 The introduction

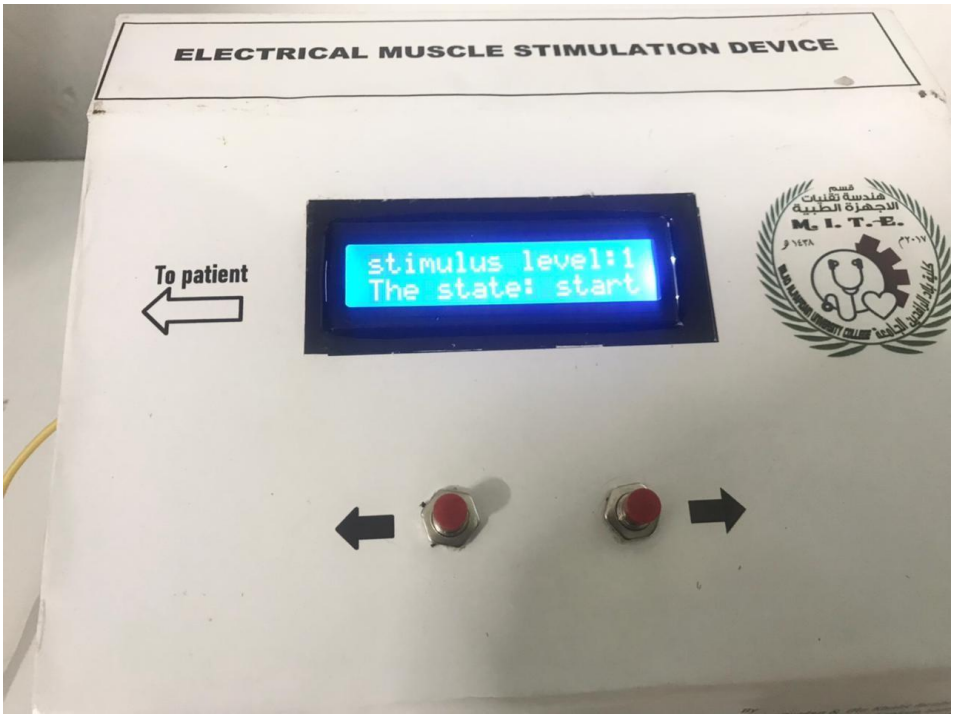


(Picture No. 4.1:The device)

After turning on the device from the operating key and attaching the patient's electrodes to the area of the patient's body to be stimulated, choose the desired stimulation level through the first key and the second key, and it is possible to change between the stimulation levels. The choice of stimulation has nine levels, each level defined by a specific voltage.

4.2 Levels Electrical muscle stimulation

O The first level, voltages range from 5 volts to 10 volts

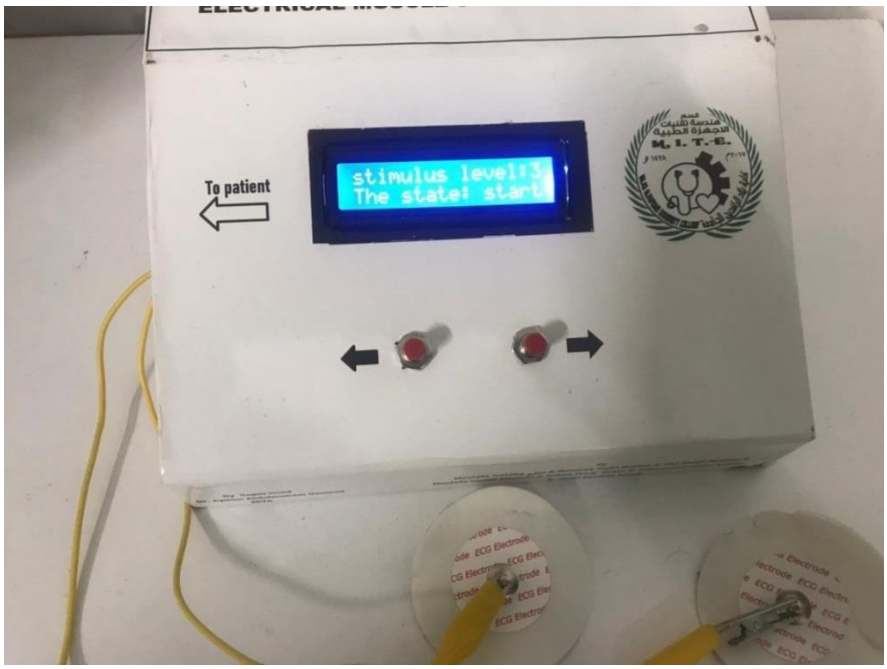


(Picture No. 4.2: Stimulus leval 1)

- The second level, voltages range from 10 volts to 15 volts

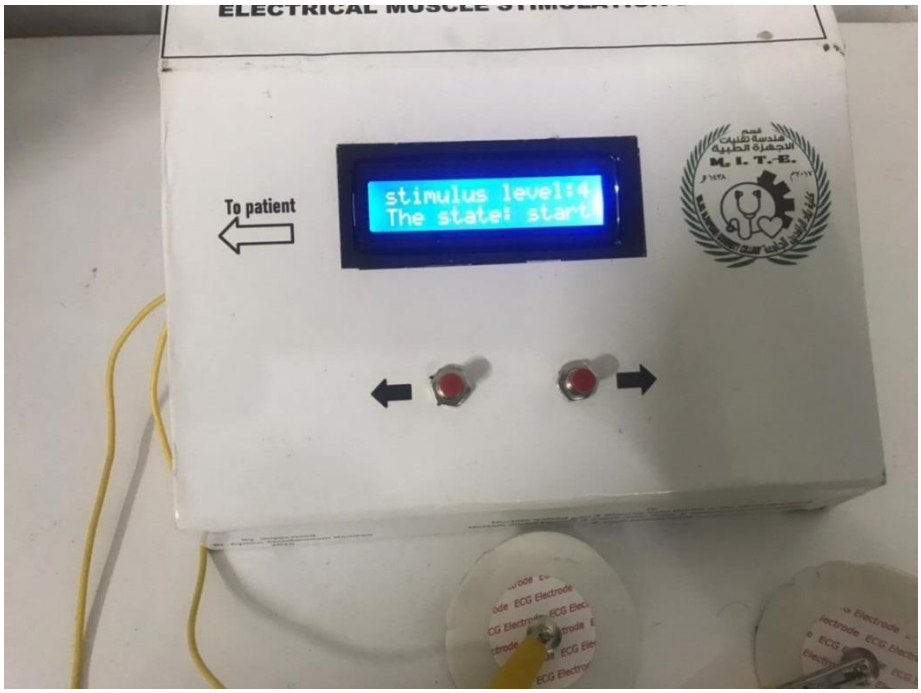
(Picture No. 4.3: Stimulus leval 3)

- The THREE level, voltages range from 15 volts to 20 volts



(Picture No. 4.4: Stimulus leval 3)

- The fourth level, the voltage ranges from 20 volts to 24 volts



(Picture No. 4.5: Stimulus leval 4)

- The fifth level, the voltage ranges from 25 volts to 29 volts

(Picture No. 4.6: Stimulus leval 5)

- The sixth level, the voltage ranges from 30 volts to 34 volts

(Picture No. 4.7: Stimulus leval 6)

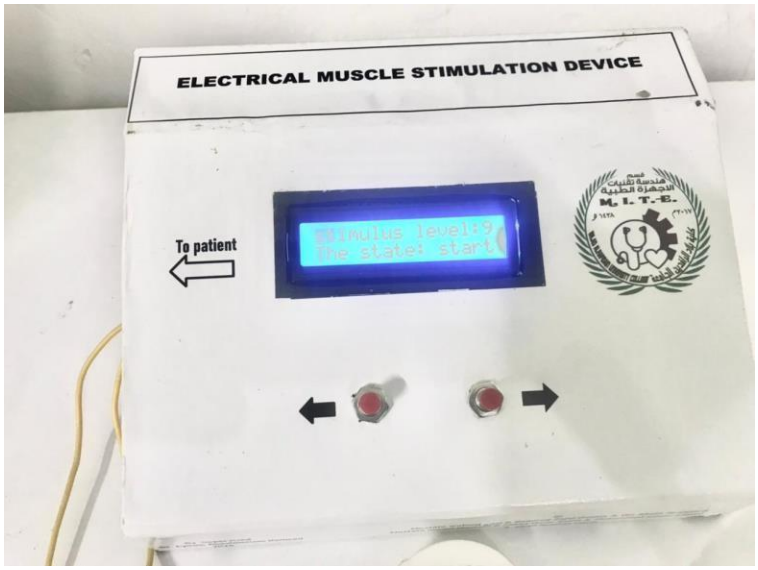
The seventh level, voltages range from 35 volts to 39 volts

(Picture No. 4.6: Stimulus leval 7)

- The eighth level, voltages range from 40 volts to 45 volts

(Picture No. 4.7: Stimulus leval 8)

- The nine level, the voltage ranges from 45 volts to 50 volts



(Picture No. 4.8: Stimulus leval 9)

CONCLUSION AND RECOMMENDATIONS

Electrical stimulation is a form of physical therapy used to help people who have suffered an injury. It is also used for people who suffer from pain, spasms, or muscle weakness. There are different forms of electrical stimulation your physical therapist may choose to use. There are some things to consider when dealing with electrical stimulation devices.

5.1 Conditions to be observed with the electrical stimulation device:

- Position of electrodes.
- Duration of time: As the pulse width increases, more muscle fibers are stimulated because the current is available for longer periods of time.
- Short pulses are less than 150 microseconds and longer durations are greater than 200 microseconds.
- Stimulation frequency: The greater the intensity and frequency of the pulses, the stronger the muscle contraction.

Duty Cycle: Duty cycle is the ratio of time between the stimulus period and the rest period. That is, it is the ratio of the time the current is on to the time the current is off.

Current Modulation and Ramp Time: Changes in the characteristics of the current or pulse are referred to as modulation. The current can also be modified by adjusting the frequency, amplitude (intensity), or duration. Whereas a gradient is a change in the intensity of the pulse or the duration of the current. Also, the ramp time is the time required for successive current stimuli to reach the desired amplitude and plateau.

5.2 Do not use the device.

There are some situations in which electrical stimulation should never be used. Your physical therapist should pay attention to these factors that make it necessary to avoid electrical stimulation.

You should avoid electrical stimulation if you have:

- Change in tissue sensation.
- Weak mental state.
- Having an implanted electrical device (electrical stimulation can interfere with pacemakers or implanted pain stimulators.(

- Malignant tissue.
- Very wet wounds.
- An affected area near the eyes, carotid sinuses, front of the neck, or above the genitals.
- Your physical therapist should have identified these issues during your initial evaluation. But it is important to remind him of any medical condition that could interact negatively with electrical stimulation.

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