Automatic Leg Cramps Relief Device

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Abstract—**A sudden contraction of calf muscles that can leave pain and soreness for an hour. The purpose of this paper is to apply the TRIZ approach in designing an automatic leg cramps relief device. The method is based on the study of TRIZ Engineering Contradiction and Contradiction Matrix. The study showed two possible elements that can be used for this project, heat and vibration. The effect of heat and vibration on the contracting muscle was analyzed by reading the surface Electromyography (EMG) signal on the calf muscle. Before the analysis, participants were requested to perform a few leg exercises to make the calf muscle tense. The result indicated that heat treatment can reduce EMG muscle reading while the vibration is vice versa. In conclusion, the heat can give some relaxation to the contracting muscle.**

Keywords—Leg Cramps; TRIZ; Electromyography; Heat; Vibration

I. INTRODUCTION

THE estimation is that 33.33% adults and 50% of adults age more than 60 years have leg cramps, mostly at night [1]. Leg cramps, most frequently occur in the veal, are spontaneous muscular spasms anywhere in the body. The muscle strains induce irritation or mild to extreme pain and stress in the leg [2]. Nocturnal leg cramps can also refer to other problems. They will interrupt sleep and interrupt a person's sleep cycle, which may render them feeling exhausted or lethargic the next day. Leg cramps can make it very difficult to fall asleep, and that may contribute to problems such as insomnia over time [2]. The duration of leg cramps differs, with cramps lasting for only seconds to several minutes. After the cramp itself stops, muscle soreness can remain. Such cramps are more prevalent in older individuals (Mayo Clinic Staff, 2019). In adolescents and certain instances during the night, they happen very often. A nocturnal leg cramp will, in addition to being painful, cause a lot of discomfort and anxiety [3]. Potential causes contributing to the condition include fatigue and poor blood pressure to the muscles that are used during extended sitting or lying down, as well as the existence of other minerals (magnesium, potassium, calcium and sodium but the proof is mixed) [4].

When the cramp happens, it can be reduced by applying a massage, do light stretching or apply some heat on the targeted muscle [5]. For the elderly, sometimes they need help to do those treatments and to make the matter worse, there is no one around and they are left in pain alone.

Therefore, this paper proposes a device called Automatic Leg Cramp Relief Device (ALCRD) to help the elderly especially those who live alone to ease cramp pain automatically. It uses heat to relieve muscle cramp. The heat is applied automatically to the muscle when cramps occur. Heat can help muscle recovers and increase the rate of glycogen replenishment [6] [7]. Heat can also increase muscle flexibility and decrease the energy rate of muscles contraction (Jarosch, 2008). As the proposed device uses electricity to produce heat, it needs to be on standby mode for 24 hours (cramps can happen anytime), it could contribute to

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large power consumption. Cooling and heating appliances use 48% of energy [8].

To reduce power but produces a large heating space (in this case around the calf leg), The Soviet initiated Theory of Inventive Problem Solving (TRIZ) is used as a method to inventive ideas and as a problem-solving. TRIZ is able to suggest a few ideas that solve a contradicting problem [9].

A detailed explanation of the TRIZ methodology and the prototype design will be discussed in the second section. The third section will present the methodology of the feasibility of the prototype to ease muscle cramp and the fourth section will present the results together with the discussion. The purpose of this paper is to apply the TRIZ approach in designing the prototype. The next purpose is to study the effects of heat and vibration on muscle activity by using an EMG Myoware sensor. EMG sensor used to measure electrical currents produced in muscles during its contraction expressive muscles signal activity.4 In this project, an EMG sensor was used to read the activity of the calf muscle when the heat and vibration were applied during the muscle contraction. After examining the effects of heat and vibration on muscle activity, the final prototype is made.

II. ENGINEERING PROBLEM SOLVING BASED ON TRIZ

A. Project Functional Model

Project Functional Model shown in Fig. 1 is the detail of the structured system for this project. It consists of several components such as a heating element, vibration motor and power supply.

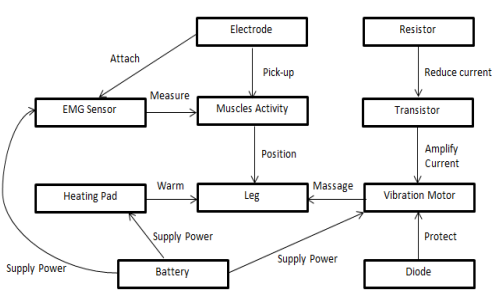

Fig. 1. Fucntion model for ALCRD

B. Cause and Effect Chain

All the causes that contributed to the power consumption of this prototype were reviewed by asking the 'why' question to find out the potential root that causes the problem. Fig.2 shows the cause and effect chain to determine the root for high power use. It is found that the root is the heating element that needs a large power to operate it for fast heat.

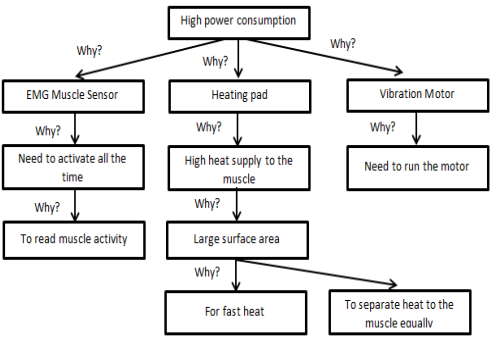

Fig. 2. Cause and Effect Chain Analysis

C. Engineering Contradiction

In this problem, the engineering contradiction is:

If the surface of the heating pad is large, (#6)
Then, the heat can dissipate faster, (#9, #16, #17)
But the power consumption is high. (#21)

The parameters:
#6 : Area of stationary object
#9 : Speed
#16: Duration
#17: Temperature
#21: Power

According to this engineering contradiction, the improving and worsening parameter is classified.

- To improve: Surface of a heating pad, heat dissipated faster.
- Worsening: Power consumption is high.

In TRIZ, all possible Inventive Principle (IP) based on identified engineering contradiction (improving and worsening parameters) can be

obtained from the contradiction matrix table [10]. IP are generic solutions that can be used to solve the contradictive problem [11]. Table 1 shows the obtained recommended IP from the contradiction matrix table.

TABLE 1. Parameters and Recommended Inventive Principles

Parameter to be Improved	Parameter That Worsen	Recommended Inventive Principles
6,9,16,17	21	#2 Taking part #14 Curvature #16 Partial of excessive action #17 another dimension #25 Self service #19 Periodic action #32 Color change #35 parameter change #38 Strong oxygen

From these nine inventive principles, IP number #14, #16 and #19 are chose to design the device.

D. Potential Solution and the Design

An automatic Leg Cramp Relief Device is proposed to relieve soreness in muscles contraction when cramps occur. The main intervention is by using a heating element or vibration. However, the heating element needs high power to make the heat dissipate faster. As a solution, some parameter can be changed for example by applied the heating pad only in a specific area. Not only that, but the periodic action can also be applied to the heating pad by making it turn on and off at the given time. The heating pad can also be design as a curve to make the heat transfer whole on the muscle.

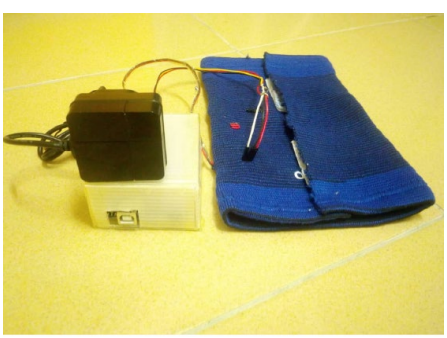

Fig. 3. The design of the ALCRD. The pad is fix heat plat and will be wrapped around the calf and the white box is the EMG reader.

III. METHODOLOGY

A. Parameter

To compare, two parameters were used to study the suitable elements that can ease the contraction muscle, which was heating pad and vibration. To analyze the output graph of the muscle signal, the EMG muscles sensor is used to read the signal when:

- No contraction on muscles
- Contract muscle
- Applied heating pad on muscles
- Applied vibration on muscles

B. Participants

All the 10 female participants that volunteer for this study are between the age group of 20 to 25 studying in Universiti Teknikal Malaysia Melaka (UTeM). Participants were separated into two groups which are athletes and non-athletes that have bodyweight less than 60 kg. Each group consists of 5 participants. Participants were requested to do some leg exercises to make the leg muscles became contract or tense.

C. Leg Muscles

Mostly, the leg muscle that is affected when cramps occur is the calf muscle [2] [5]. Therefore, three surface EMG electrodes; the middle muscle electrode, end muscle electrode and reference muscle electrode were placed on the gastrocnemius muscle of the participants. Before placing the electrodes, extra precaution was made to ensure there is no dirt or dust on the muscle as it can affect the reading of the EMG muscles sensor.

D. Procedures

1. The normal muscle reading for all the participants was taken using an EMG muscles sensor.
2. The participants were requested to do some stretching and warming up.
3. Participants were asked to rum 500m before climbed four-story stairs for two rounds.
4. After the exercises were done, the EMG recording was taken placed by prone the

participants to lying down with the leg 180 degrees.

5. The contracted muscle signals were taken before the heat around 20 degrees Celsius up to 30 degrees Celsius been applied to the muscle for 20 minutes.
6. The vibration with a frequency of around 50 Hz was applied around the calf for less than 5 minutes.
7. The readings of the surface EMG signal for the whole experiment were recorded.

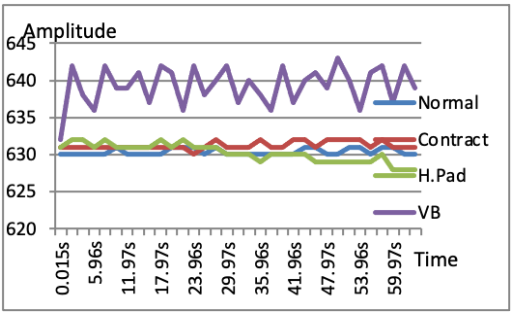

Fig. 5. Grand average results of 5 Athlete EMG participants muscle signal reading for 1 minute

IV. RESULTS

The relationship between the normal muscle activity was recorded by the EMG muscles sensor with the contracting muscle after some exercises and the effect of heat and vibration on the muscles is analyze. Fig. 4 and Fig. 5 show that the relationship of EMG muscle signal on calf muscle during no contraction on the muscle, contract muscle, applied heat pad, and applied vibration for non-athlete and athlete respectively.

Fig. 4 shows the grand averaging results of EMG muscle signal reading on the calf muscle of non-athlete participants before and after the experiment. The graph shows that non-athlete normal muscle signal activity is below the contracting muscle. While Fig. 5 shows that normal muscle signal activity for athlete participants are almost the same as the contracting muscle. This tells that the athlete participant muscles is tenser than the non-athlete participant.

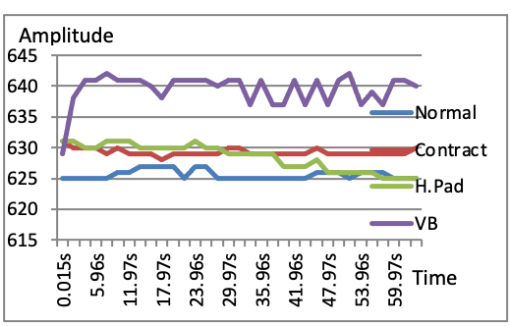

Fig. 4. Grand average results of 5 Non-athlete participants EMG muscle signal reading for 1 minute.

V. DISCUSSION

From the TRIZ analysis, the ALCRD is designed based on the suggested IPs i.e., curvature shape, partial heating point and (periodically) on/off the power supply. To investigate the feasibility of the ALCRD to treat muscle tense, two treatment were compared, which were ALCRD (heat) and vibration. Based on the EMG reading, the heating treatment on the calf was enough and successfully healed the tensed muscle. From the results, every participant has different muscles signal activity when there is no contraction on the leg muscle. However, all participants generate almost the same pattern of muscle activity when there is a contraction on the muscle which was an increase of amplitude when contraction occurred. ALCRD (heat) is proving to have some good effect on muscle contraction or muscle tense compared to vibration. Based on Fig. 4 and Fig. 5, both types of subjects showed that vibration increased the tense of the muscles, not heal them. Whereas, ALCRD (heat) brought the muscle tense to normal overtime as clearly shown in Fig. 4. Therefore, ALCRD (heat) can be used to relax the muscle tension during leg cramps.

VI. CONCLUSION

From the results. it can be concluded that between heat and vibration, the most suitable element that can be used in made an Automatic Leg Cramps Relief Device is heated. With proper parameter in designing the heating pad such as

the area of the heating pad, temperature, and duration, it may help the user to relief the tense on muscle when a cramp occurs. Therefore, the finalized design for the Automatic Leg Cramps Relief Device, the vibration motor will not include in this prototype anymore

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