DEVELOPMENT OF WEARABLE HYPERTHERMIA DEVICE FOR SPORTS INJURY APPLICATION

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DEVELOPMENT OF WEARABLE HYPERTHERMIA DEVICE FOR SPORTS INJURY APPLICATION

Development Of Wearable Hyperthermia Device For Sports Injury Application

MUHAMMAD NAIM IMAN BIN AZHARY

A dissertation submitted in partial fulfilment
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ABSTRACT

A person experiences hyperthermia when their body temperature increases abnormally. Hyperthermia is a temperature above 38.3ºC, which is the upper limit of the average human body temperature. Other heat-related illnesses include heat exhaustion, heat stroke, heat rash, heat cramps, and heat syncope. By converting cancer cells into necrotic cells through denaturation, hyperthermia is a well-known alternative treatment for cancer. In recent years, this hyperthermia treatment has expanded beyond just cancer cases to include applications for lipolysis and sports injuries. Therefore, the importance of hyperthermia for sports injuries, particularly those caused by muscle cramps, is highlighted in this study. The heating pad cannot deliver the necessary uniform heat, and it is challenging to control the focal position's proximity to the treated muscle based on the current products that are on the market. Hence, in this project, a wearable heating device, Sports Injury Heating Applicator Therapy (SIHAT), is developed. SIHAT utilises Thermoelectric Peltier as the heating element. The Thermoelectric Peltier is integrated with Arduino Uno, IRF540N MOSFET and LM35 temperature sensor. This project is carried out and tested on 10 university-level athletes to test the effectiveness of the device. Findings found that the device is fairly comfortable and effective. The heat distribution of the device is tested and analysed by performing an experiment. The experiment tests the heating temperature if the device in different positions. The result shows that the heat is distributed homogeneously. The Arduino Uno's main function is to control the temperature of the device. The LM35 sensor will send a signal to the Arduino, and the Arduino will later send a signal to the MOSFET that will control the output. The suitable cut-off temperature is 40ºC since a temperature higher than 43 ºC applied to human skin may have permanent effects. Overall, this project provides a solution to the sports injury field by applying hyperthermia as a treatment. Further studies should be done in order to improve the performance of the device, or alternatives should be explored.

ABSTRAK

Seseorang mengalami hipertemperatur apabila suhu badannya meningkat secara tidak normal. Hipertermia merujuk kepada suhu di atas 38.3ºC, iaitu had atas suhu badan manusia purata. Penyakit berkaitan haba yang lain termasuklah keletihan haba, strok haba, ruam, kekejangan, dan sinkopi haba. Dengan mengubah sel kanser menjadi sel nekrotik melalui denaturasi, hipertermia merupakan satu kaedah rawatan alternatif yang terkenal bagi kanser. Pada tahun-tahun terkini, rawatan hipertermia ini telah berkembang melebihi kes kanser dan telah digunakan dalam aplikasi lipolisis dan kecederaan sukan. Oleh itu, kepentingan hipertermia bagi kecederaan sukan, terutamanya yang disebabkan oleh kekejangan otot, ditekankan dalam kajian ini. Alat pemanas tidak dapat menyampaikan haba secara seragam dan sukar mengawal kedudukan fokus berdekatan dengan otot yang dirawat berdasarkan produk-produk semasa yang ada di pasaran. Oleh itu, dalam projek ini, satu peranti pemanasan yang boleh dipakai, Terapi Aplikator Pemanas Kecederaan Sukan (SIHAT), telah dibangunkan. SIHAT menggunakan Peltier Termodinamik sebagai elemen pemanasan. Peltier Termodinamik telah diintegrasikan dengan Arduino Uno, IRF540N MOSFET, dan sensor suhu LM35. Projek ini dijalankan dan diuji ke atas 10 atlet peringkat universiti untuk menguji keberkesanan peranti ini. Dapatan kajian mendapati bahawa peranti ini agak selesa dan berkesan. Pengagihan haba peranti diuji dan dianalisis melalui satu eksperimen. Eksperimen ini menguji suhu pemanasan peranti pada kedudukan yang berbeza. Keputusannya menunjukkan bahawa haba diedarkan secara seragam. Fungsi utama Arduino Uno adalah mengawal suhu peranti. Pemalar suhu LM35 akan menghantar isyarat kepada Arduino, dan Arduino kemudiannya akan menghantar isyarat kepada MOSFET untuk mengawal keluaran. Suhu pemotongan yang sesuai adalah 40ºC kerana suhu melebihi 43ºC yang dikenakan pada kulit manusia mungkin membawa kesan kekal. Secara keseluruhannya, projek ini menyediakan satu penyelesaian bagi bidang kecederaan sukan melalui penggunaan hipertemperatur sebagai rawatan. Kajian lanjut perlu dijalankan bagi meningkatkan prestasi peranti ini atau mencari alternatif yang lain.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF ABBREVIATIONS

Notations

Table 0-1 Abbreviation List

HSP	Heat Shock Proteins
KT	Kinesio Tape
HIS	Hamstring Strain Injury
TEC	Thermoelectric Cooler
MOSFET	Metal Oxide Silicon Field Effect Transistors
SIHAT	Sports Injury Heating Applicator Therapy
PWM	Pulse Width Modulation

CHAPTER 1

INTRODUCTION

1.1 Introduction

This section presents the research background, problem statement, research objective, research significant, research scope and limitation, thesis outlines and summary of the chapter. Details on the discussion are provided in sections 1.2 to 1.9

1.2 Research Background

All ages and groups are encouraged to participate in sports and recreation as a part of a healthy lifestyle. However, sports injuries in recent years seem to have an upward trend. Sports-related injuries account for nearly one-third of all childhood injuries[1]. According to data, hamstring injuries are the most frequent injury subtype, accounting for more than one-third of all strains and 12% of all injuries[2]. Hence, this research emphasizes sports injury, specifically hamstring injury.

The existing treatment for muscle injury is by applying an ice-cold pack or moist heat pack. Blood vessels were vasodilated to send blood and oxygen to the muscles faster. The heat then increases local metabolism, which indicates the burning of more calories. However, the heat applied to the muscle by using the moist heat pack is not uniformly distributed. This research is a continuation of previous research done by Farah Aqila. Farah Aqila proposed using a hyperthermia heating pad for hamstring injury treatment.

Nevertheless, this research has a limitation, whereby various effect has been observed, especially when hot pressure at the cellular level was increased. Protein begins to ripen like an egg when the cell temperature approaches 40-42℃. There was a notice of gene disorders, increased plasma smoothness and membrane permeability, membrane receptor inhibition, and eventually cell death as cell temperatures began to rise. Actually, when the core temperature exceeds 40℃, all human training achieves

what is called 'voluntary failure'. This rule contains no exceptions. Any competitor who practices or competes in the heat can understand why it was incredibly important to be able to postpone this increase in core temperature. Heat Shock Proteins (HSP) are produced by the body in response to intense heat stress. It has highly protected proteins, which protect cells from stress, including heat. In addition, if an athlete is injured, HSP increases muscle protein production (increased hypertrophy) and protects muscles from atrophy. In the long term, heat stress increases other beneficial adaptations, such as more capillaries, more mitochondrial energy-producing cells, increased mitochondrial protein production, and increased endurance.

In addition, it also uses to improve athletic performance and prolong a professional sports career era. Therefore, in this research, further investigation on the capability of heating pads for sports applications, In this research, a heating pad with an antenna for sport application is designed and developed.

1.3 Problem Statement

On the market, there are various types of wearable devices for sports injury prevention. The existing heating pad, however, is unable to deliver the necessary homogenous heat and makes it difficult to regulate the distance from the focal point to the treated muscle. Thus, the purpose of this study is to suggest heating pads that use a thermoelectric Peltier to achieve uniform heat distribution toward the appropriate focal length of the targeted tissue. This heating pad is therefore intended to improve the heating pad's performance of sportsmen following the adoption of sports.

1.4 Research Objectives

This research primarily aims to improve the current heating pad for sports based on prior studies and the available products on the market. Similar to that, the main objectives of this study are to:

i. To develop a wearable device using a thermoelectric Peltier for sports injuries application.

ii. To analyse the heat distribution on the heated muscle

iii. To integrate the cut-off system when the heat reaches more than a threshold temperature

1.5 Research Significance

The main objective of this research is to introduce a wearable device which is used to lessen pain prior to regular exercise and sporting events. This heating pad is entirely different from the ones that are currently available on the market because it uses a thermoelectric Peltier to heat the targeted muscle.

1.6 Research Scope and Limitations

There are various types of hyperthermia applicators have been investigated. However, for this research, only the heating pad with an antenna applicator will be further examined. As in this research, the scope and limitations are as follows:

i. The targeted muscle to be heated is the hamstring muscle
ii. Peltier device is used in this research

1.7 Research Approach

This is a research study focused on a working prototype. The study starts with collecting data given by the supervisor and following up doing the research for suitable heating devices. After analysing the best heating devices from the research, the concept of the heating device is investigated further. Then, the arrangement of the heating device, which is either single or array, is identified. The best arrangement of heating device is selected for the constructed thigh phantom. Next, the development of coolant to apply the uniform heat distribution to the phantom. There are three processes involved in this research, as shown in Figure 1.1

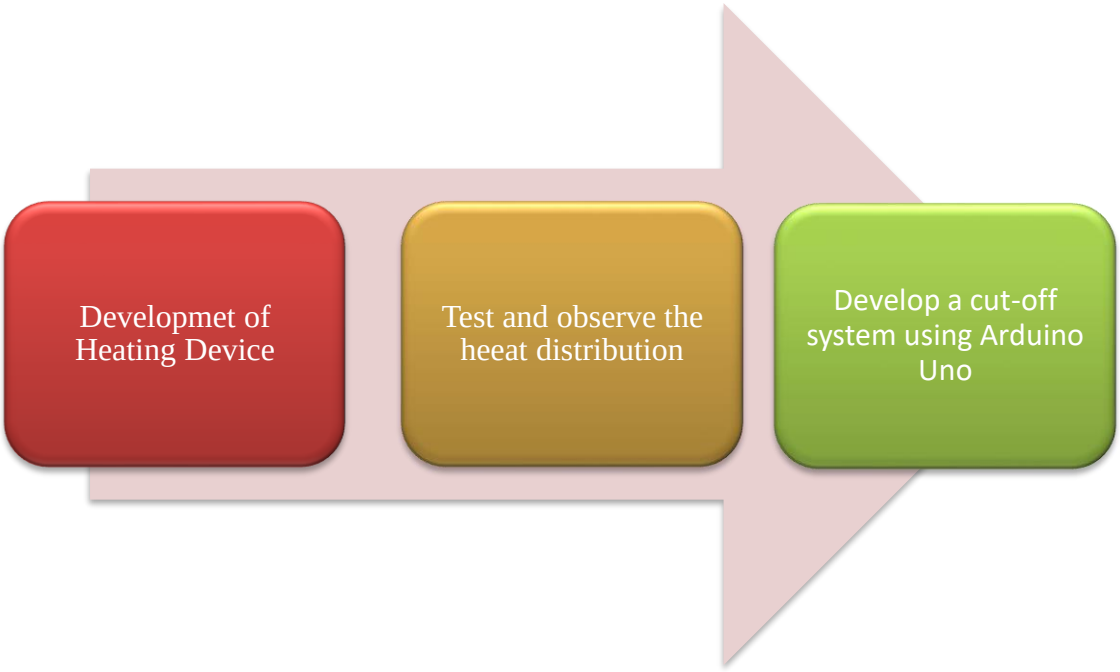

Figure 1.1 The process developed in this research

1.8 Thesis Outline

There are six (6) primary chapters in this thesis outline. The focus of Chapter 1 is on the Introduction of the research. The project's research background, problem statement, research objectives, and research significance are all included in this chapter. The scope and constraints of the research are presented in this chapter. A literature review is then presented in Chapter 2. It includes a review of the use of hyperthermia in sports, the application of a thermoelectric Peltier cooler during the operation, and the hamstring muscle as the targeted muscle.

The research methodology is presented in Chapter 3. In this chapter, research tools and the study process, which includes the creation of a thigh phantom, the development of a hyperthermia method, and analyzing the heat distribution, are discussed. The Experimental Methods employed in this study are presented in Chapter 4. This chapter contains information on three research experiments: the development of heating devices, the development of coolants, and the distribution of heat on heated muscles.

The Results and Discussion are the emphases of Chapter 5, and the Conclusion, which summarises the study and makes some suggestions for future improvements, is offered in Chapter 6.

Figure 1.2 provides the summary of the thesis contents, which commences with the Introduction and ends with the Conclusion chapter.

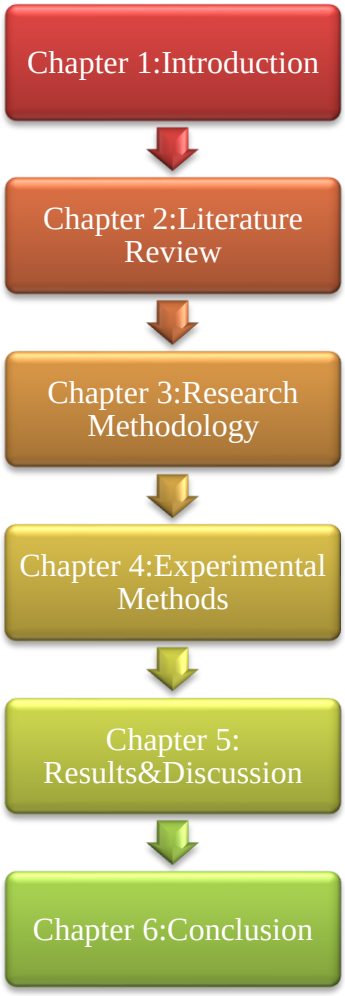

Figure 1.2 Thesis Outline

1.9 Summary of chapter

Research background, problem statement, research objective, research significance, research scope and limitation and thesis outline have been discussed.

This research is mainly to enhance the required area to be heated $352mm^2$.It is to ensure the heating distribution is applied sufficiently to the targeted area to be heated.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This section serves as an introduction to this chapter. This introduction of a literature review will explore sports injury statistics from different sources.

Chapter 2, Literature Review, discusses previous studies related to this hyperthermia application for sports injuries. Section 2.1 contains the Introduction. Section 2.2 describes previous research on Hyperthermia for Sports Applications, and Section 2.3 describes the research Sport Applicator, which includes the targeted muscle, the heating devices, and comparison between cold and hot therapy. Section 2.4 provides the summary of this chapter.

2.2 Sports Injury Overview

This section introduces the statistics on sports injuries. This section will give an overall overview of sports injuries from different studies and surveys. Table 2.1 presents an overview of sport injuries in general.

Table 2.1 Sports Injury Overview

No.	Year	Title	Author(s)	Observation
[3]	2011	Sports-and Recreation-related Injury Episodes in the United States, 2011-2014	Sheu et al.	Fractures, superficial wounds, contusions, strains and sprains made up the majority of the injury diagnoses.

[4]	2021	Epidemiology of sports-related injuries and associated risk factors in adolescent athletes: An injury surveillance	Prieto-González et al.	Injury prevention should focus on the following areas in particular: lower-body injuries, contact sports injuries, and injuries sustained during sporting events.
[5]	2021	Review of sports injuries presenting to an accident and emergency department	Boyce et al.	Lower limb injuries were the most common, with ankle sprains being the most common single injury.
[6]	2021	Adult sports injury hospitalisations in 16 sports: the football codes, other team ball sports, team bat and stick sports and racquet sports	Cassell et. al	Injury hospitalizations in Australian football increased significantly from 1,693 in 2002/3 to 2,098 in 2009/10, representing an estimated annual change of 3.6% (95% confidence intervals 1.8% to 5.3%) and an overall increase of 33% (15% to 51%).
[7]	1993	Sports causing most injuries in Hong Kong	K. M. Chan et al.	Sprains were the most common type of injury in Hong Kong. Sprains were found to be more common in sports that required a high degree of sudden turns and forceful jumping.
[8]	2007	Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives	Hootman et. al	Over the 16-year period, no significant changes in game or practise injury rates were observed. Lower extremity injuries accounted for more than half of all injuries.

According to [5], it was estimated about 3.7 million individuals in the USA and 1-1.5 million people in Britain visit accident and emergency (A&E) departments each year with injuries related to sports and exercise[5]. It was estimated that 3.5 million children under the age of 15 only in the United States sought medical attention each year for wounds sustained during sports practice. Furthermore, two-thirds of the injuries needed treatment in emergency rooms [4]. According to Cassell et al. [6], 12,460 adult hospitalizations for sports-related injuries occurred throughout the three-year study period 2007/08 to 2009/10 across 16 different sports. A sprain was found to be the most common type of acute injury. A sprain was when the ligament has been twisted or overextended and ripped or injured [2]. Due to capillary rupture in cases of severe ligament sprains, severe hematomas develop, the wounded area becomes painful and bloated, and the patient becomes immobile.

2.2.1 Lower Extremity Injury Overview

Table 2.2 shows different studies on lower extremity injuries.

Table 2.2 Lower Extremity Injury Overview

No.	Year	Title	Author(s)	Observation
[9]	2003	Risk factors for lower extremity injury: a review of the literature	D.F Murphy et. al	More than half of all injuries were to the knee, ankle, or lumbar spine, accounting for more than 79% of all injuries.
[10]	2002	Lower extremity injuries in youth sports	S.J. Anderson	In sports, the lower extremity was the most usually injured anatomic area among youth. Most injuries can be diagnosed with a thorough history and physical examination.
[11]	2007	Epidemiology of Lower Extremity Injuries among U.S. High School Athletes	Fernandez et. al	Sprains, strains, contusions, and fractures were the most common diagnosis among high school students in the U.S. The ankle,

				knee, and thigh were the most often injured joints.
[12]	2003	Occurrence of acute lower limb injuries in artistic gymnasts in relation to event and exercise phase	Kirialanis et al.	To record the incidence of lower limb injuries in Greek artistic gymnasts in relation to the event and exercise phase. The most common anatomical location was the ankle, followed by the knee.

Table 2.2 shows an overview of sports injuries specifically focusing on the lower extremity of the body. The lower extremity, known as the lower limb, is every part of our body from the hip to the toes. The hip, knee, and ankle joints, as well as the thigh, leg, and foot bones, are all part of the lower extremity. According to S.J. Anderson [10], the lower extremity is the most injured anatomical area in sports. Injuries can occur because of repetitive stresses associated with running and jumping or because of a single traumatic event. Over half of all injuries (54%) occurred in the lower extremity, with the knee being the most frequently injured anatomical region [9].

Sports and recreational injuries are estimated to affect 4.5 million children and young adults in the United States each year. Lower extremity injuries are the most common type of sports-related injury, affecting two-thirds of children and young adults (ages 5 to 24). These injuries account for 20% of all emergency room visits by children and adolescents [11]. In gymnastics, Kirialanis et al. [12], this study found that the injuries in gymnasts have a diverse anatomical distribution. However, the lower limb area is the most affected area and has the highest number of acute injuries accounting for 40% of acute injuries. According to the National Collegiate Athletic Association's injury surveillance system for 2000-2001, the ankle, knee, and lower leg were the most common injury areas among collegiate soccer, field hockey, basketball, and lacrosse athletes [8].

The most frequent sorts of injuries were muscle strains, ligament sprains, and contusions. Injury surveillance in the Union of European Football Associations Champions League revealed that muscle injuries account for more than 30% of all player injuries and account for roughly one-quarter of total time lost due to injury. Over