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Development of Automatic Cryotherapy Device Using Arduino ATmega 328 Based Microcontroller for Facial Skin Care

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ABSTRACT

Cryotherapy is a series of therapies that put the body in a cold room below 0 degrees for a while. Cryotherapy is applied using various methods, including vapocoolant sprays, cold compresses or ice, and continuous control of cold devices. In 2023, cryotherapy using a compressor and refrigerant is needed for regular refrigerant refills. This affects temperature stability and cooling time. This prototype aims to develop a Cryotherapy with hardware and software designs for predetermined temperature and timer settings. The research design is a developmental research design with an experimental method. The prototype was evaluated by measuring the time required to reach low temperatures, temperature differences between the Cryosurgery gun and the probe tip, and the accuracy of the prototype. These test results indicate that the greater the temperature difference during cooling, the longer the cooling time. The time span that reaches the setting temperature at high temperature (17° C) is 0:04:05 – 0:07:53 minutes and it is linear. The timer test yielded an accuracy result of 93,02%. The final result of the Arduino ATmega 328-based Cryotherapy device prototype has an average accuracy of more than 96,31%.

KEYWORDS Alduino, Cyotherapy, Facial, Prototype.

I. INTRODUCTION

The skin is an organ that covers the entire outer surface of the body. The skin is the most visible and largest organ in humans. The skin is functioning as a barrier to protect the body from environmental influences and serves as a reflection of a person's health. The skin has a complex epithelial tissue structure, is elastic, sensitive, and comes in a variety of colours and types. Climate, race, gender and age all have an impact to the type of skin [1].

The total weight of the skin is about 16% of body weight and is the heaviest and largest organ of the body. The thickness of the skin varies from 0.5 mm to 6 mm depending on the location, age and gender. Hair, nails, sweat glands, oil glands, blood vessels, lymph vessels, nerves, and muscles are part of the skin. Skin is an indicator of a person's health; for example, the skin will become pale, yellowish, and reddish. Skin temperature increases when the skin is abnormal or when someone suffers from psychological disorders such as stress, fear, or anger that can cause changes in the skin [2].

The skin has several functions in maintaining overall human health, including protection, receiving stimuli (as sensory stimuli), excretion, regulating body temperature, storing fat, absorbing fat-soluble substances, and supporting appearance [2]. Maintaining healthy skin is very important because skin is sensitive, especially facial skin, because facial skin is the part of the skin that is often exposed to direct sunlight and air. Disorders of the facial skin include acne, blackheads, pigmentation disorders, fungal infections, premature ageing and disorders due to allergies [3], [4].

Facial skin treatments bring a variety of benefits that are not only focused on physical appearance, but also on overall skin health and well-being. One of the treatments for facial skin is cryotherapy or often called cryo-facial. Cryo-facial involves exposing the skin to extremely cold temperatures, typically liquid nitrogen or cryogenically cooled air, for a short period. This treatment is believed to stimulate collagen production, improve skin firmness, and reduce the appearance of fine lines and wrinkles [5].

Cryotherapy or cold therapy on the face has several benefits, including helping to shrink pores, reduce wrinkles, and reduce redness. Additionally, cryotherapy can also help relieve the itchy symptoms of eczema and psoriasis, as well as help manage acne, discontinuation of topical steroid use, and rosacea. In addition, Cryotherapy is indicated for skin diseases such as benign tumors, acne, pigmentary lesions, viral infections, inflammatory dermatoses, infectious diseases and malignant tumors. Some cryogens commonly used in cryotherapy include liquid nitrogen, nitrous oxide, and carbon dioxide. The techniques commonly used for the use of cryogens include the times spot freeze technique, the use of cryoprobes and are performed on appropriate patients by trained and experienced doctors with the right procedures. Complications can occur if the patient selection is not right or due to inappropriate procedures. Complications can be acute, subacute or chronic complications. Acute complications that can occur include local pain, edema, blister lesions, fainting and headaches. Subacute pain includes hemorrhagic necrosis, wound infection, delayed wound healing, scar hypertrophy and subcutaneous emphysema. Chronic complications that often occur include hypopigmentation, hypoaesthesia due to nerve damage, milia formation, and alopecia [6], [7]

The skin consists of 3 layers, namely the epidermis (outermost layer), dermis, and hypodermis. Blood vessels and nerves are found in the dermis layer [2], [8], [9]. Cryotherapy works by shrinking blood vessels and damaging blood vessel permeability, which then causes them to dilate rapidly when the skin returns to normal temperature. This rush of blood and oxygen can make the skin appear more vibrant and plump [5], [10].

Cryotherapy, also known as cold therapy, is a commonly used technique in medicine, physiotherapy, and cosmetology. Currently, the use of cryotherapy is increasingly widespread and is used for beauty treatments. Cryotherapy can be applied to the entire body or locally to certain parts of the body. Whole-body cryotherapy (WBC) is defined as the stimulus transmission of cryogenic temperature (below -100°C) for a short period (1-3 min) to the surface of the whole body to induce physiological responses to cold. Local cryotherapy occurs through the direct contact of cold with the skin, through evaporation or convection [11].

Cryotherapy is a therapy that freezes the surface of the skin or mucosa with cryogens. The cryogens used are nitrogen calf, carbon dioxide snow, and dimethyl ether and propane (DMEP). Cryotherapy is administered using various modalities, including vapocoolant sprays (non-contact), cold or ice packs (contact), and controlled continuous cold devices. Among these, controlled continuous cold device (peltier) are widely used in cryotherapy treatment due to their accurate temperature control [12].

Cryo facial treatments use the Peltier effect to cool the skin, which triggers a response that leads to improved blood circulation, collagen production, and overall skin rejuvenation. The process involves using a thermoelectric cooler (TEC) to chill a surface that then comes into contact with the skin. The cold temperature causes vasoconstriction (blood vessels constrict), followed by vasodilation (blood vessels dilate) as the skin returns to normal temperature. This rapid change in blood vessel diameter improves microcirculation, delivering more oxygen and nutrients to the skin, and flushing out toxins [13].

A study shows that the development of Cryotherapy using the cold compress method can utilize thermoelectric as a source of cold devices. The thermoelectric used is a peltier module that flows cold air into a closed system using an ice cap. Another study by Sahid (2020) found that a cryotherapy device with a Peltier as a cold-producing element for the therapy process can work well with an error percentage of 0.4% and a temperature accuracy level of 99.6% [14].

Thermoelectric Cooling (TEC), is a cooling system that places cold and hot temperatures face to face, as shown in Figure 1 [15], [16].

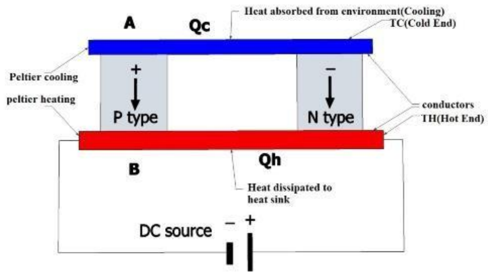

FIGURE 1. Thermoelectric Cooler Schematic

Thermoelectric (TE) cooling technology has many advantages over conventional vapor-compression cooling systems. These include being more compact devices with fewer maintenance necessities, having lower levels of vibration and noise, and having more precise control over the temperature [17].

Compared with other technologies, thermoelectric cooling has a number of advantages. For example, the cooling equipment does not involve moving parts, so it requires less maintenance and care, and has a longer service life of up to hundreds of thousands of hours of stable operation. Unlike cooling systems containing chlorofluorocarbons that need to be continuously charged, thermoelectric systems require relatively little routine attention. Temperature control of the component parts of such systems is generally recognized as good, and this approach can provide a cooling environment with the right size and sensitivity for medical applications [18].

ATmega328P Arduino Uno Microcontroller Module is a microcontroller board that combines various components such as resistors, capacitors, transistors, Crystals, ICs (Integrated Circuits), and is designed in such a way that it is easier to use. This module has a total of 20 input/output pins, namely 14 digital input/output pins where 6 input pins can be used as PWM outputs and 6 analog input pins, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP (In Circuit Serial Programming) header, and reset button [19].

ATMega328P is a microcontroller output from Atmel that has an RISC (Reduced Instruction Set Computer) architecture, where each data execution process is faster than the CISC (Completed Instruction Set Computer) architecture. This microcontroller has several features, including [20].

1. 130 types of instructions that are almost all executed in one clock cycle.
2. 32 x 8-bit general-purpose registers.
3. Speed reaches 16 MIPS with a 16 MHz clock.
4. 32 KB Flash memory and on Arduino has a bootloader that uses 2 KB of flash memory as a bootloader.
5. Has an EEPROM (Electrically Erasable Programmable Read Only Memory) of 1KB as a semi-permanent data storage because EEPROM can still store data even if the power supply is turned off.
6. Has 2KB SRAM (Static Random Access Memory)
7. It has 14 digital I/O pins, 6 of which are PWM (Pulse Width Modulation) output.
8. Master/Slave SPI Serial interface.

Based on the Table 1, it is known that the thermoelectric method can be used to replace refrigerants as a source of cold for devices. On that basis, the author is interested in making this tool in the form of a prototype Cryotherapy tool using thermoelectric and a vapocoolant spray system (Non-Contact) so that it can be used without touching the skin directly by utilizing the Arduino Atmega 328.

TABLE 1.
ATmega328P Arduino Uno Microcontroller Module Specifications

Microcontroller	**ATmega328P**
Working voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (6 of which are PWM outputs)
Analog Input Pins	6
DC Current for each I/O Pin	20 mA
DC Current for 3.3V pins	50 mA
Flash Memory	32 KB (ATmega328p) of which o.5 KB is used by the bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz

II. RESEARCH METHODS

A. RESEARCH DESIGN

This study uses a developmental design with an experimental method. The prototype results will be tested using a timer to measure the cooling time from the initial temperature to the desired temperature (Low/14°C or High/17°C). This test is carried out 5 times. Furthermore, the prototype will also be tested for temperature stability with a Thermometer TP101 measuring instrument at the tip of the spray and the tool sensor. This temperature test is carried out 3 times for each type of temperature setting. The test results will be analyzed using tabulation and graphs.

B. CONCEPTUAL FRAMEWORK

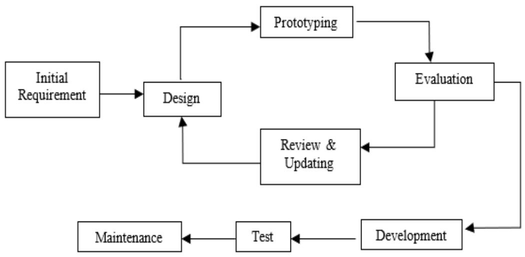

FIGURE 2. Proposed Conceptual Framework

Fig. 1 can be explained as follows:

1. Initial preparation includes module planning. This module is made to facilitate the writing and achieve the desired results. In addition to making the module, in the early stages also make block diagrams, wiring diagrams, design program flowcharts, determine measurement points for data collection, determine the components needed.
2. The design stage is the stage of creating or designing a design that will become a prototype according to the specified module.

3. Prototyping is the creation of a tool by creating a power supply circuit, microcontroller, input (1x4 keypad and temperature sensor), and output blocks (peltier, blower and fan).
4. Evaluation is done by testing and feasibility of the tool. If there is something wrong or needs to be corrected, it will proceed to the review and updating stage.
5. Finally, the prototype design is refined after which tests are carried out in accordance with the designer's wishes.

C. DATA COLLECTION TECHNIQUES AND RESEARCH INSTRUMENT

1. Data collection technique
   Data collection in this study uses primary data. The data collected is in the form of temperature and time calculations. The desired temperature is Low/14°C and High/17°C. While for time is taken using a timer. This time calculates the cryotherapy device from the initial temperature (room) to the desired temperature. The data is then presented in the form of tabulations and graphs.
2. Research Instruments
   Research instruments are all tools used to collect, examine, and investigate a problem, or systematically and objectively process, analyze, and present data to solve a problem or test a hypothesis. In this study, data collection was carried out quantitatively. Quantitative testing measures the correlation between temperature and time to reach the temperature.

   This research utilizes the following instruments:
   a. Sensor suhu DS18B20
   b. Thermometer TP101
   c. Stopwatch from a smartphone

III. RESULTS AND EXPLANATION

The creation of cryotherapy devices based on Arduino ATmega 328 is carried out in several stages, including software and hardware design. The design and appearance of the device can be seen in Fig 2 and Fig 3.

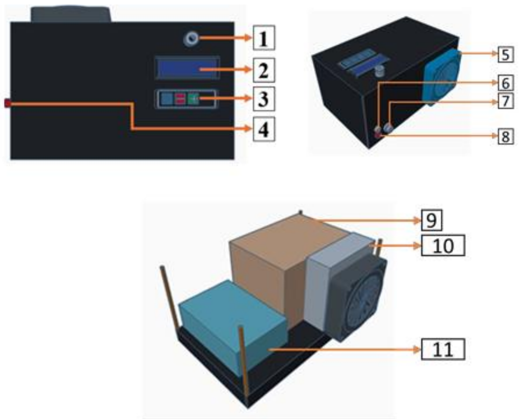

FIGURE 2. Prototype Design of proposed study

FIGURE 3. Final Look of the Arduino-based cryotherapy prototype

In Fig. 2 and Fig. 3, the components of this prototype can be seen. These components are as follows:
1. Point Test
2. LCD 16x2
3. Keypad 1x4 (OK, Plus, Minus)
4. Output Pipet
5. Cooling Fan
6. Jack GND
7. Fuse
8. Jack VCC
9. Cooling Box
10. Heatshink
11. Electronic Storage Place

The developed prototype operates using a 220V AC power source. To initiate the use of the device, several operational steps must be followed. First, the 12VDC/30A power supply module must be connected to a 220V AC power outlet. Next, the voltage source of the device is connected to the power supply module. Upon activation, the display will undergo an initialization process and present user identification information, such as name and student number (NIM). It is essential to ensure that the Peltier cooling fan is functioning properly before proceeding. Once initialization is complete, the system enters the main menu, which provides options to set the desired temperature and therapy duration. The user can select a target temperature using the control buttons: pressing the (+) button activates the High mode (17°C), while the (−) button sets the Low mode (14°C). After selecting the temperature, the OK button must be pressed to confirm the choice. Subsequently, the user can set the therapy duration, which ranges from 0 to 5 minutes, and confirm the selection by pressing the OK button again. The device will then enter a pre-cooling phase until the specified temperature is achieved. Once the target temperature is reached, the therapy process begins by directing the spray nozzle toward the designated treatment area. The timer starts counting down once the cooling phase reaches the desired temperature, during which the system maintains the set conditions. Upon completion of the therapy session, as indicated by the expiration of the preset time, the device will return to the main menu, signaling the end of the session.

How this tool works is explained in the block diagram in Fig. 4.. The power supply will receive 220V AC voltage, which is then divided by the power block into 12V DC and 5V DC to be distributed to each component. Furthermore, the Keypad is used to set the temperature and timer/time according to the settings specified by the user. The temperature sensor will detect the temperature continuously and the microcontroller will compare the temperature from the sensor output with the temperature setting from the user as a controller of the relay operation. When comparing this temperature, relays 1 and 3 will connect the Peltier and fan to a 12VDC voltage so that the temperature reaches the desired temperature setting. If the reading temperature does not match the temperature setting, the microcontroller will continue to order relays 1 and 3 to connect the voltage to the Peltier and fan to work to lower the temperature. If the temperature is under the temperature setting, the microcontroller will order relays 1 and 3 to disconnect the voltage to the Peltier and fan so that the temperature is obtained according to the temperature setting given by the user. Furthermore, the timer will be active and relay 2 will connect the blower to a 12 VDC voltage until the time counts to zero 0 seconds. The air cooled by the Peltier will be channeled to the air outlet hose by the blower.

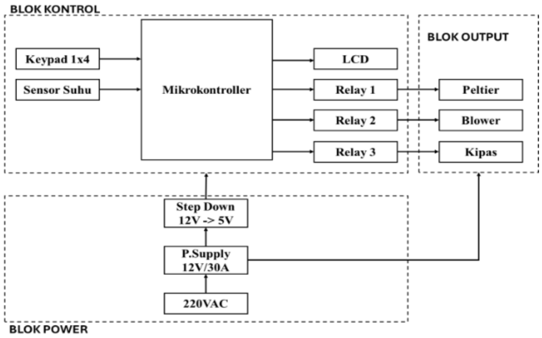

FIGURE 4. The Diagram Block of prototype

After designing the prototype tool, the designer tested the tool. This tool was tested one by one from its components whether it functioned properly or not. Furthermore, testing was carried out to assess the cooling time and temperature in the cryotherapy process. The results of this test are described in the points below.

A. COOLING TIME TESTING

Cooling time is the time required for the temperature indicator on the device from the initial temperature or room temperature to reach the set temperature (Low/14°C or High/17°C) before the Cryotherapy process is carried out. In this measurement, we measure 5 times at normal/room temperature against the set temperature at high/17°C. Table 2 showed the results of cooling time testing

TABLE 2. COOLING TIME MEASUREMENT DATA

No.	Ta	Tb	ΔT	t (minutes)
1	24,6	16	8,6	00:04:05
2	25,7	16,1	9,6	00:05:32
3	27,5	16,7	10,8	00:06:44
4	30,5	16,9	13,6	00:07:01
5	33,2	16,8	16,4	00:07:53

Description :
Ta : Initial Measurement Temperature (°C)
Tb : Final Measurement Temperature (°C)
ΔT : Difference between initial & final temperature (°C)
t : measurement time (minutes)

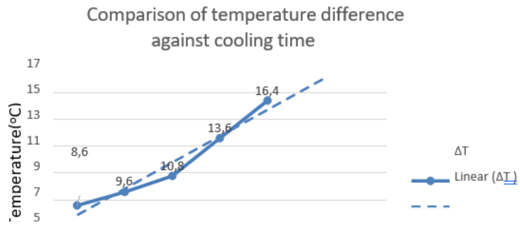

FIGURE 5. Comparison Chart of Temperature Difference Against Cooling Time

Fig. 5 shows a comparison of the temperature difference to the cooling time taken to reach the cooling point before the cryotherapy process. From the data it can be seen that the greater the value of the initial temperature difference to the cooling point, the longer the cooling time. The range of time required for the room temperature to reach the setting temperature at high temperature / 17℃ is 0:04:05 to 0:07:53 minutes. This increase is linear; therefore, the greater the difference in cooling temperature, the longer the cooling time.

B. CRYOTHERAPY PROCESS TEMPERATURE TESTING

Cryotherapy process temperature testing is needed to determine the stability of the temperature during the cryotherapy process. This measurement is carried out with a temperature sensor on the device (the result is referred to as TR) and the temperature of the measuring instrument with a thermometer (the result is referred to as Tp). The test time was carried out for 1 minute and data was taken every 10 seconds of time. And data collection was carried out 3 times at each type of temperature setting (Low/14℃ and High/17℃). The results of this test are presented in the graph below.

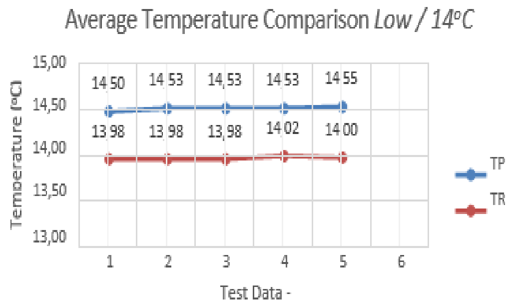

FIGURE 3. Avarage Temperature Procces of Cryotheraphy in Low Temp (14 C)

Fig. 8 shows that the average temperature change in each process test data has small fluctuations in both the real temperature reading on the device (TR) and the temperature of the measuring device (Tp). The error of these two temperatures is 3.69% and the average accuracy of the device temperature is 96.31%.

Fig. 8 shows small temperature fluctuations in both the real temperature reading on the device (TR) and the temperature of the measuring device (Tp). The error of both temperatures is 1.61% and the accuracy is 98.39%. So it can be concluded that the lower the temperature setting, the higher the error value. The stability level for both temperature settings is high, namely >96.31%.

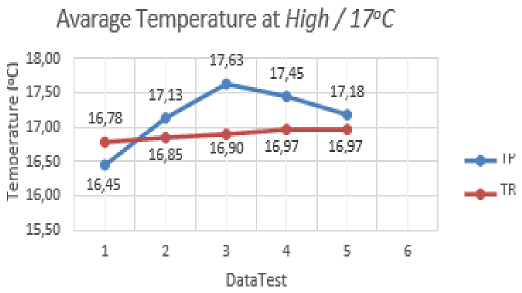

FIGURE 4. Avarage Temperature Procces Of Cryotheraphy In High (17℃)

C. TIMER TESTING

This time test is needed to find out whether the prototype that is made has a timer that matches the measuring instrument. The measuring instrument uses a stopwatch on a smartphone.

TABLE 3. TIMER MEASUREMENT DATA

No.	Tr	Tp	ΔT
1	01:00	01:04	00:04
2	01:00	01:05	00:05
3	01:00	01:04	00:04
4	01:00	01:05	00:05
5	01:00	01:04	00:04

Description :
T_r : Real Time on The Prototype (Minutes)
Tp : Measuring Instrument Time (Minutes)
ΔT : Difference between T_r and Tp (Minutes)

The results of the time measurement in Table 3. have an average value at the upper limit of 00:04 minutes and a lower limit of 00:05 minutes. This shows that the value of the comparison between the measuring instrument time and the real instrument time is stable on average at a value of 01:04.05 seconds with an error of 4.5% and an accuracy of 93.02%. This variation indicates a relatively small fluctuation in the measurement time in the time span of the 1 minute sample.

IV. CONCLUSION.

The process of making a cryotherapy prototype is carried out in 2 stages, namely software and hardware design. The Arduino ATmega 328-based Cryotherapy prototype device made by the author can function properly. The test results show that the greater the difference in cooling temperature, the longer the cooling time. The average time to reach a temperature of 17 ° C on the device is around 0:04:05 - 0:07:53 minutes. Timer testing on the device obtained an accuracy of 93.02% with small time fluctuations. The

Arduino ATmega 328-based Cryotherapy Device Prototype made by the author has an average accuracy of > 96.31%.

REFERENCES

[1] J. I. A. Puspita, 'Hubungan Tingkat Pengetahuan Dengan Perilaku Penggunaan Moisturizer Pada Mahasiswi Farmasi di Universitas Muhammadiyah Malang', Thesis, Universitas Muhammadiyah Malang, Malang, 2023.

[2] E. Rinata and H. Widowati, *Buku Ajar Genetika dan Biologi Reproduksi*. Umsida Press, 2020.

[3] Nurkhasanah and Murinto, 'Classification of Facial Skin Diseases Using the Method of the Convolutional Neural Network', *SAINTEKS*, vol. 18, no. 2, pp. 183–190, Oct. 2021.

[4] S. Adhisa, 'Kajian Penerapan Model Pembelajaran Kooperatif Tipe True or False Pada Kompetensi Dasar Kelainan dan Penyakit Kulit', *E-Jurnal*, vol. 9, no. 3, pp. 82–90, 2020.

[5] G. Gallagher, 'Is Cryotherapy on Your List of Facials to Try?', Healthline.

[6] E. Nurhasana, A. Inayati, Nury, and L. Fitri, 'Pengaruh Terapi Dingin Cryotherapy Terhadap Penurunan Nyeri Pada Fraktur Ekstremitas Tertutup di Ruang Bedah Ortopedi RSUD Jenderal Ahmad Yani Kota Metro', *Jurnal Cendikia Muda*, vol. 2, no. 4, Dec. 2022.

[7] Y. A. Sabila, 'Krioterapi Dermatologis', *Jurnal Ilmiah Kesehatan Sandi Husada*, vol. 10, no. 22, pp. 197–201, 2019.

[8] S. J. G. Kalangi, 'Histifisiologi Kulit', *Jurnal Biomedik (JBM)*, vol. 5, no. 3, pp. 12–20, 2013.

[9] Z. Harissya, A. Setiorini, M. Rahayu, B. S. Asbath, and L. E. Mahata, *Ilmu Biomedik Untuk Perawat*. Pekanbaru: Eureka Media Aksara, 2023.

[10] M. N. Jardak, E. A. Saad, R. Jalloul, N. Emmanuel, G. Nicolas, and J. P. Menendez, 'The efficacy of cryotherapy in reducing edema and ecchymosis in patients who underwent rhinoplasty: A narrative review', *Journal of Plastic, Reconstructive & Aesthetic Surgery*, vol. 84, pp. 279–286, Sep. 2023, doi: 10.1016/j.bjps.2023.04.053.

[11] A. Dzidek and A. Piotrowska, 'The Use of Cryotherapy in Cosmetology and the Influence of Cryogenic Temperatures on Selected Skin Parameters—A Review of the Literature', *Cosmetics*, vol. 9, no. 5, p. 100, Sep. 2022, doi: 10.3390/cosmetics9050100.

[12] N. A. Nguyen, S. S. Nguyen, K. B. Do, T. T. P. Tran, and T. T. Nguyen, 'Development of cryotherapy device using refrigerant compressor for decreased skin temperature', *Science & Technology Development Journal - Engineering and Technology*, 2023, doi: 10.32508/stdjet.v5iSI2.1092.

[13] E. O. Nwoye, O. P. Fidelis, O. Folorunso, O. E. Ajibola, and D. O. Odebiyi, 'The Design and Development of a Novel Cryotherapy Device for Physical Therapy : Preliminary Report', *Nig Q J Hosp Med*, vol. 26, no. 4, 2022.

[14] A. N. Sahid, 'Simulasi Cryo Therapy', Thesis, Universitas Widya Husada Semarang, Semarang, 2020.

[15] H. L. Ni, X. B. Zhao, T. J. Zhu, X. H. Ji, and J. P. Tu, 'Synthesis and thermoelectric properties of Bi2Te3 based nanocomposites', *J Alloys Compd*, vol. 397, no. 1–2, pp. 317–321, Jul. 2005, doi: 10.1016/j.jallcom.2005.01.046.

[16] Mi. J. Nagy, 'The Effectiveness of Water Vapor Sealing Agents When Used in Application With Thermoelectric Cooling Modules', in *International Conference on Thermoelectrics ICT97*, International Conference, 1997, pp. 687–689.

[17] Atta RM, 'Thermoelectric Cooling. Bringing Thermoelectricity in to Reality', *InTech*, 2018, doi: http://dx.doi.org/10.5772/intechopen.75791.

[18] M. G. Dolan, M. Thornton, D. R. Fish, and F. C. Mendel, 'Effects of Cold Water Immersion On Edema Formation After Blunt Injury to the Hind Limbs of Rats', *J Athl Train*, vol. 32, no. 3, 1997.

[19] A. Bahtiar, 'Sistem Pemantauan Kadar pH Air Menggunakan LCD Pada Tanaman Hidroponik', Diploma Thesis, Universitas Muhammadiyah Malang, Malang, 2024.

[20] Atmel, 'Atmel ATmega328P', 2016