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ARTICLE

MOBILE & COZY FIGHTS CHRONIC PAIN

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ABSTRACT
20% of people in North America suffer from chronic muscle pain and have difficulty performing daily activities. To manage the pain, they often use bulky and uncomfortable heating packs that have to be heated in the microwave, which is particularly inconvenient in the workplace. In this work, we report an all-textile heating element using conductive threads. It is thin, soft, and comfortable to wear and could be discreetly integrated into a variety of wearable products. It has been tested to provide 30 minutes of controlled heating and on-the-go pain relief.

INTRODUCTION
Pain is the leading cause of disability among adults in North America (Council for Disability Awareness, n.d.). It is responsible for more disabilities than heart disease, diabetes, and cancer combined (Council for Disability Awareness, 2021). Additionally, it is estimated that approximately one in five adults in North America suffers from some form of chronic pain (Brigham and Women's Hospital, 2021), which results in approximately 100 million people. Using statistical cluster analysis and patient body pain patterns, researchers have found that patients suffering from chronic pain can be classified into nine groups: axial low back pain; abdominal pain; lower back pain radiating to the thigh; upper and lower back pain; neck and shoulder pain; lower back pain radiating below the knee; neck, shoulder and lower back pain; widespread pain – light and widespread pain – heavy (Alter et al., 2021). It is not just one specific part of the body that hurts, but rather a significant region of the body that is typically affected. For example, the shoulder and neck areas are present in seven of the nine types of chronic pain, which is the most common localization, according to (Alter et al., 2021). Thus, we aim to develop a heating technology in the form of a scarf that reduces chronic pain in the neck and shoulder regions. Particularly, we focus on a flexible textile heating technology.

There is a lot of information in the literature about the effects of heat on the body. Among the negative effects, we note dehydration, physical exhaustion, and burns (PatientsLikeMe, n.d.; National Institute of Environmental Health Sciences, n.d.; Earth Networks, 2017; WebMD, 2020).

In this work, we focus on the healing properties of heat that can reduce muscle and joint pain in patients (Inverarity, 2020; Battisti, 2021; Nordik, n.d.; Physiopedia, n.d.). Particularly, heat causes a phenomenon called the vasodilation of blood vessels (Battisti, 2021; WebMD, 2022; Ramanlal & Gupta, 2022; Quora, 2022). In other words, blood vessels expand due to the relaxation of muscle cells, which, in turn, increases blood flow. This leads to the relief of pain caused by conditions such as muscular tension and arthritis. Moreover, the use of heat to treat chronic pain offers an alternative to "pain medication"- which has led to opioid epidemics (HHS, 2021) and the overuse of powerful, addictive, and organ-damaging non-steroidal anti-inflammatory drugs (NHS, 2019) - which are to be used with extreme caution.

To manage chronic pain, people often use bulky, uncomfortable heat packs that need to be heated in the microwave (Healthline, n.d.). Athletes also use heated jackets with built-in weak heating elements powered by batteries of relatively small energy capacity (Anseris, n.d.; Gobiheat, 2020). Such jackets require strong thermal insulation (i.e., bulky padding) to prevent heat loss and are mostly used for maintaining body temperature at comfortable levels. However, heat therapy requires higher temperatures (between 38 and 66 °C depending on the heat therapy product type) and shorter exposure times of 20-40 minutes (Spine-Health, 2021a). These solutions, which are good for the environment, are, however, less effective for professionals such as teachers, office workers, or professionals on the go because the heating elements are large, obvious, and unesthetic, and such heating elements can be used discretely. While analgesic creams can be used to treat minor pain, it is usually not recommended to use these products for prolonged periods (ex., more than seven days) without consulting a doctor (GlaxoSmithKline Consumer Healthcare Inc., 2017). Given that chronic pain is persistent, one cannot rely on analgesic creams for daily pain relief, whereas heat therapy can be used long term multiple times per day without significant side effects (Spine-Health, 2021b). To gauge the extent of the problem, office workers alone constitute approximately 1 million of the United States' workforce (Zippia, 2021). Among those, a sedentary lifestyle leads to significant health problems, with affected individuals suffering mainly from neck and lower back pain, where the occurrence of these ailments has been shown to range from 42% to 69% and 31% to 51%, respectively, within one year (Akkarakittichoke, 2022).

To meet these challenges and help chronic pain patients cope on the go, we developed a technological platform called MOBILE & COZY using electrothermal textiles (see Fig. 1). The prototype is a flexible heating scarf of a comfortable size that covers the neck region. It is realized using conductive threads sewn along the synthetic felt substrate. The scarf is powered by a compact high-capacity Li-Ion battery, which, together with an electronic control block, can be placed into an enclosure the size of a large cell phone (13cm x 9.5cm x 2.5cm) for carrying inside a pocket or a handbag.

HYPOTHESIS

All-textile conductive yarns could be used as a basis of a heating element to develop a compact and discreet thermal insert in the form of a scarf. The insert could provide heating and pain relief to the neck and shoulder region for approximately 20-30 minutes.

MATERIALS AND METHODS

To develop the prototype, it was necessary to determine the temperature needed to trigger vasodilation without burning the user. It is also necessary to find the dimensions of the scarf relative to the size of the neck and choose a material that is comfortable, hypoallergenic, and easy to work with. From the technological perspective, we must resolve several challenges: design a flexible heating element based on textiles, design a circuit to control the amount of heat deposited on the scarf electronically and find an energy source that could accommodate the prototype's energy needs.

Generally, at an ambient temperature of 32 °C, one can start to perceive heat (Benjamin, 1954). For a clothed person, the upper limit of homeostasis in a slightly humid environment is 52°C and 35°C at high humidity (Benjamin, 1954). At the same time, we want to ensure that the temperature of a scarf can reach the temperatures of ~45-60°C for durations of 20-40 min, which are the parameters often used by infrared saunas to achieve a well-documented positive therapeutic effect (Cryospa, 2021). The human body also emits energy and produces ≈57 W/m² (LaBonta, 2014; MedicineNet, 2021), while the neck region alone emits ≈3 W (Disabled World, 2022; How it works, 2013). For a human to perceive heat, we assume it is necessary to warm the targeted body part with more energy than it emits. We, therefore, built a scarf prototype for the neck treatment with a heat emission capacity of up to 60W.

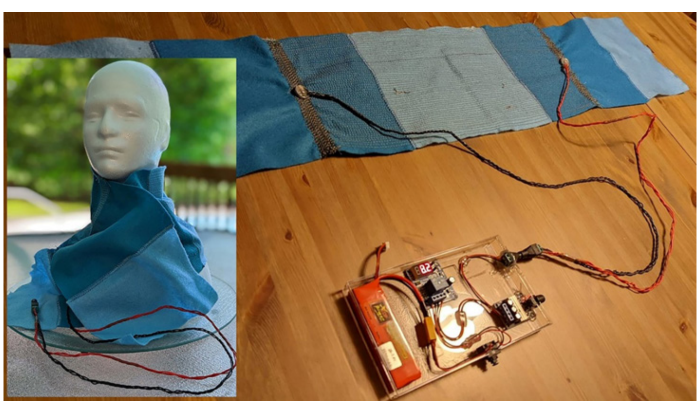


Figure 1. The prototype of a heating scarf (top) and a power control block (bottom).

A key material for the project relates to the realization of a heating element. Several materials can be used in flexible heating elements, such as conductive paints (The Pi Hut, n.d.), conductive tapes (Kraftex, n.d.), or conductive wires (Mayata, n.d.). For our project, we chose conductive threads over other materials as such threads can seamlessly integrate into textiles using standard sewing machines (Brother, n.d.). Importantly, such threads are mechanically and electrically reliable, while novel conductive threads are being developed and commercialized constantly due to their growing popularity in the smart textile community. When using a sewing machine, one has to choose a proper stitching pattern that results in the lowest resistivity per unit length while also being economical in terms of consumption of a relatively expensive conductive thread.

To choose the stitch type for sawing conductive fibers, it is possible to determine the rate of heat emitted by several resistive wires put in parallel under electric tension by employing the following formula (Course Hero, n.d.):

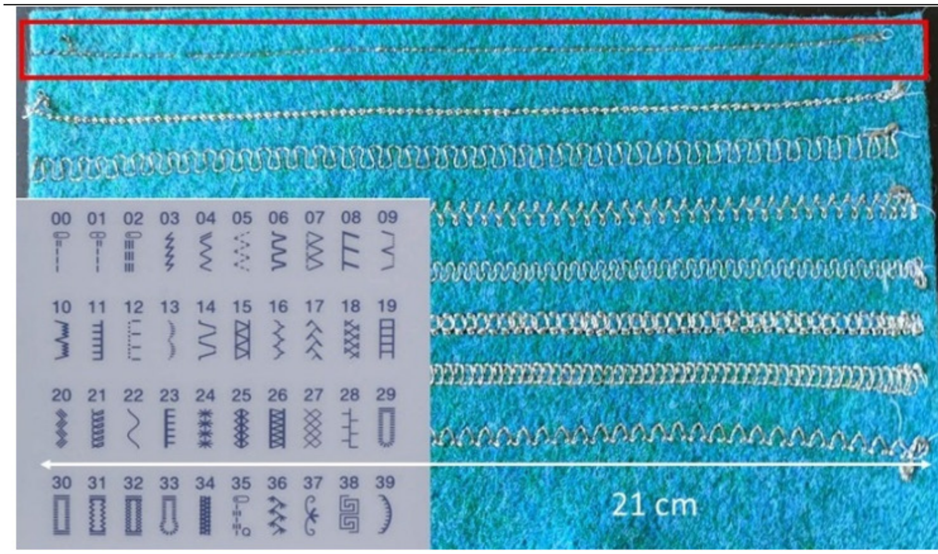
$$P=N\bullet V^2/R_1 \quad (1)$$

Where P is the emitted heat in watts, N is the number of wires, R_1 is the resistance of each wire in ohms, and V is the battery voltage in volts.

Therefore, a sewing stitch with the smallest resistance, R_1, is required to obtain the desired power with the smallest number of wires. By trying all the main stitch types offered by our sewing machine, we determined that the one best suited for our prototype is the basic "straight stitch." In Table 1, we present the photo of an approximately 21 cm-long sample of stitches that we tried and their respective resistances. Note that while stitch #13 appears to have the lowest resistance, it is effectively made of two interconnected simple stitches (stitch type #1).

Next, the scarf geometry was chosen to comfortably cover the neck region of the body to treat chronic pain in that area. Using the average data for the neck circumference (ranges between 36 – 48 cm), neck height (averaging between 10 – 12 cm) (Disabled World, 2022; How it works, 2013), and choosing the geometrical dimension to be somewhat larger than those indicated above, we find that the scarf's length of 58 cm and height of 22 cm covers most of the standard neck sizes.

Table 1. Resistances of different stitch types in order from top to bottom as they appear on the photo. The sample length is 21 cm. Insert: stitch types as indicated in the sawing machine panel.



Stitch type #	Stitch resistance
1	18.5
4	30.9
29	53.1
33	45.0
31	52.1
35	48.7
13	11.8
12	40.0

Moreover, from the detailed electrical analysis of the scarf, as described in the following section, currents as high as approximately 5-10 A can flow through the scarf, and most compact batteries cannot provide such high currents. To our knowledge, the only batteries capable of doing so are LiPo batteries that come in 3.7 V, 7.4 V, and 11.1 V variants, which are extensively used by hobbyists in electric models. 7.4 V LiPo batteries provide a good compromise between compactness (battery size 1.5 cm x 3 cm x 10 cm) and energy storage capacity, which are important factors in building a user-friendly device. Therefore, we will use a 7.4 V LiPo battery with a capacity of 3500 mAh (maximum current is 30A) which can deliver 7 A for up to 30 min.

Next, using a multimeter, we found that a single line sewn by the straight stitch of length 58cm (a little larger than the average neck size) has a resistance $R_1=54\Omega$ (see Fig. 2). By using a voltage source of V=7.4V from Equation 1, we determined 59 heating lines are needed to achieve a scarf heating power of 60W (Equation 2).

$$N=P\bullet R_1/V^2=59 \quad (2)$$

To ensure that the current crossing a single conductor wire, I_1, stays below the maximum current of 0.3A recommended by the manufacturer to burn the conductive thread (SparkFun Comment, n.d.). From Ohm's law (Course Hero, n.d.), this condition is indeed satisfied, with the current through a single conductor wire being 0.14 A, as seen in Equation 3.

$$I_1=V/R_1\approx 0.14A \quad (3)$$

Finally, the total current, I, flowing through the scarf made of N=59 heating lines connected in parallel is 8.4 A, as seen in Equation 4 (Course Hero, n.d.). This is below 35A recommended upper limit for our LiPo battery.

$$I=N\bullet I_1=8.4A$$

For the fabrication of the scarf, the base of the prototype was created by sewing together 3 sheets of felt (Trixes, n.d.). Next, the top part of the sewing machine was threaded with a regular thread (BlesSew, n.d.), while the bottom part was threaded with a conductive thread (SparkFun, n.d.). Then, 59 heating lines were sewn along with the scarf, as well as 30 conductive lines perpendicular to the scarf (on each extremity), thus, forming two conductive stripes that interconnect the main heating lines. Finally, the battery was connected using two heavy-gauge metal wires wrapped in silicone and connected to metal snap buttons (Rosenice, n.d.) sewn onto the conductive stripes.

For a two-cell LiPo battery, when the voltage drops below 70% of nominal voltage (5.2V), it short-circuits, rendering it unstable and not rechargeable. To prevent this from happening, we implemented a LiPo Protection Circuit, which contains a relay (Hoffart, 2008; Swe-Check, n.d.) (left of Fig.3). The relay acts as a switch that turns the power on and off. In our case, it measures the voltage of the LiPo (by presetting the battery to turn off at 5.2 V). When the voltage is lower than this, the relay receives a signal, it activates and turns off the LiPo battery.

To adjust the temperature emitted by the scarf, we must control the power delivered by the battery to the heating element using a control unit. The control unit has a pulse width modulator (PWM) (Loflin, n.d.) (middle of Fig. 3), which is essentially an electronically controlled switch, which is capable of reliable operation under high DC currents of up to 10A, and DC voltages of up to 16 V (HW-070). The PWM is used to control power using electronic power switching. By turning the current sent to the heating element on and off at very quick intervals, it is possible to control the current sent. Thus, the "Duty cycle" (fraction of the ON time

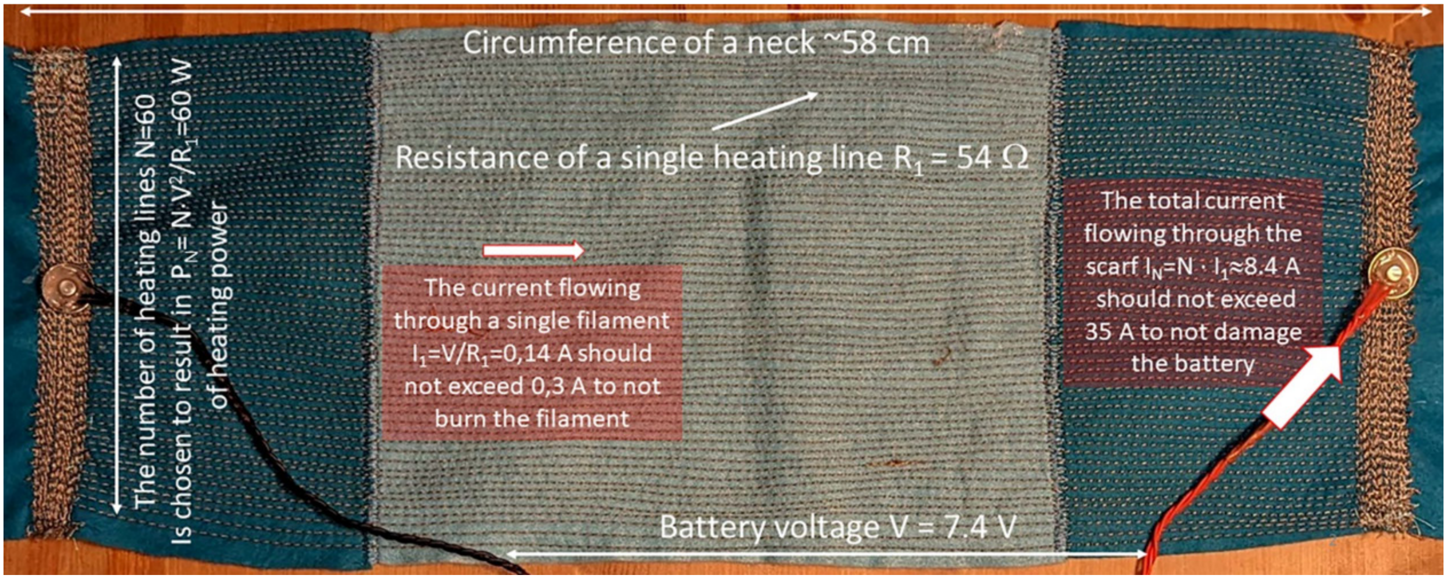


Figure 2. Closeup photo of a scarf heating element. Inserts indicate the main design parameters of an all-textile heating element.

compared to a period) makes it possible to regulate the current delivery. Therefore, allowing us to control the heat emitted by the scarf.

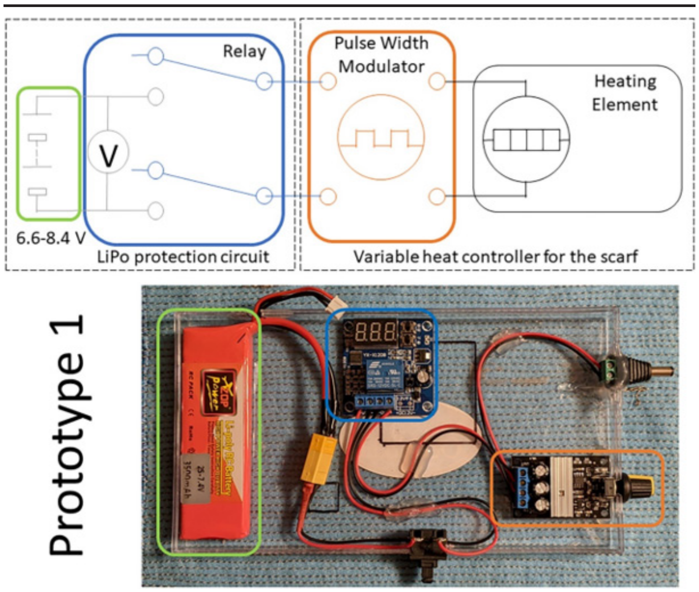


Figure 3. Electronic power controller for the scarf heating element and LiPo battery protection circuit. Top: schematic of the controller. Bottom: photo of the controller.

RESULTS

The final prototype of the heating scarf is shown in Fig. 4. To test the heating scarf, we conducted two experiments using a power control block set to maximum output in both cases. In the first experiment (left of Fig. 4), the Liquid Crystal thermometer was placed over the scarf. When power was turned on, the thermometer changed its colour from red (~25°C) to purple (~31°C) in approximately 1 minute, which allowed us to estimate a heating rate of a non-thermally isolated scarf as approximately 6 °C/min.

Next, the heating scarf was tested using a phantom of the

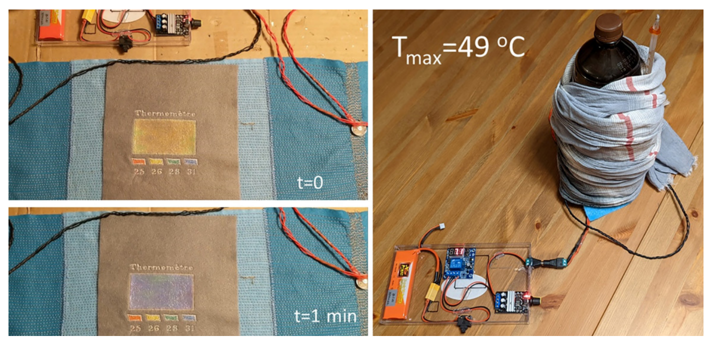


Figure 4. Test 1 (left): Heating of a Liquid Crystal Thermometer from 25°C to 31°C in ~1min at the maximal power output of a controller. Test 2 (right): Model of the neck in the form of a standard 2L plastic bottle filled with water at 37 °C.

neck in the form of a 2L bottle filled with water at 37°C (average body temperature), having a circumference like that of the neck. A long glass thermometer was attached directly to the bottle, and a heating scarf was rolled around the bottle with its conductive threads toward the bottle. In contrast, an ordinary scarf was rolled around the heating scarf as a thermal insulator (right of Fig. 4). Finally, the output power of the power supply was set to maximum. After approximately 5 minutes, the thermometer's temperature stabilized at approximately 48°C. Then, the temperature varied slightly between 47°C and 49°C during the next 23 minutes of the experiment before the battery was discharged.

DISCUSSION

The scarf is easy to make since it uses a standard sewing machine, simple stitching, easily traceable electronics, and batteries popular among hobbyists. Our prototype is fully flexible and portable, which is the primary goal of this project.

To make our prototype more user-friendly, we designed a compact shell (similar in size of a large cell phone) to hold all the electronics using free 3D modelling software Tinkercad and a basic 3D printer from MakerBot (Fig. 5). Additionally, we developed robust connectors designed to connect the control block to the scarf.

It has been approximately nine months since we started using the second prototype at home, school, and in our skating lessons. However, we noticed technical and aesthetic problems related to the functionality and longevity of the scarf. The biggest problem was the connectors, which got damaged frequently. Sweating also caused a colour shift, as well as thread issues. As a result of the high temperatures exerted on the scarf, the plastic melts, destroying the threads. Lastly, we observe that the resistance has grown by three times, thus decreasing the heating considerably.

CONCLUSIONS

The hypothesis put forward at the beginning of the project is confirmed. Indeed, a thermal scarf could be developed with a heating element based on all-textile conductive yarns.

The heating scarf is relatively straightforward to make since it uses a standard sewing machine, simple stitching, simple power electronics, and LiPo batteries popular among hobbyists. Our prototype is fully flexible and portable, which is the primary goal of this project. The scarf bulk temperature reaches approximately 49oC, a typical temperature used by infrared saunas to achieve a therapeutic effect. Finally, a compact 2-cell LiPo battery currently lasts approximately 25 minutes at the maximum output power. Longer heating times are possible by substituting the current battery with a higher-capacity one (although of a larger size).

To make our technology more user-friendly, we need to use more compact electronics and more reliable connectors. We also must continue searching for conductive threads that are more resistant to perspiration and mechanical damage. Our technology can be helpful to people suffering from chronic pain, by reducing the discomfort of their daily tasks. It would also allow for discrete wear as our flexible textile heating technology can be easily integrated into traditional clothing items. For example, the heating scarf can be inserted into a fashionable scarf and worn as a part of an everyday outfit.

For future studies, there are a couple of concerns that need to be addressed. First, we must make sure that all the materials of a scarf are safe to use under prolonged exposure to elevated temperatures. Second, we need to study whether the scarf materials can be used in direct contact with human skin, and if not, find alternative materials or bio-friendly packaging. Finally, we need to conduct clinical studies with real subjects suffering from chronic pain to see if our scarf is comfortable to wear and whether it is as effective at reducing pain as a standard heating pack.

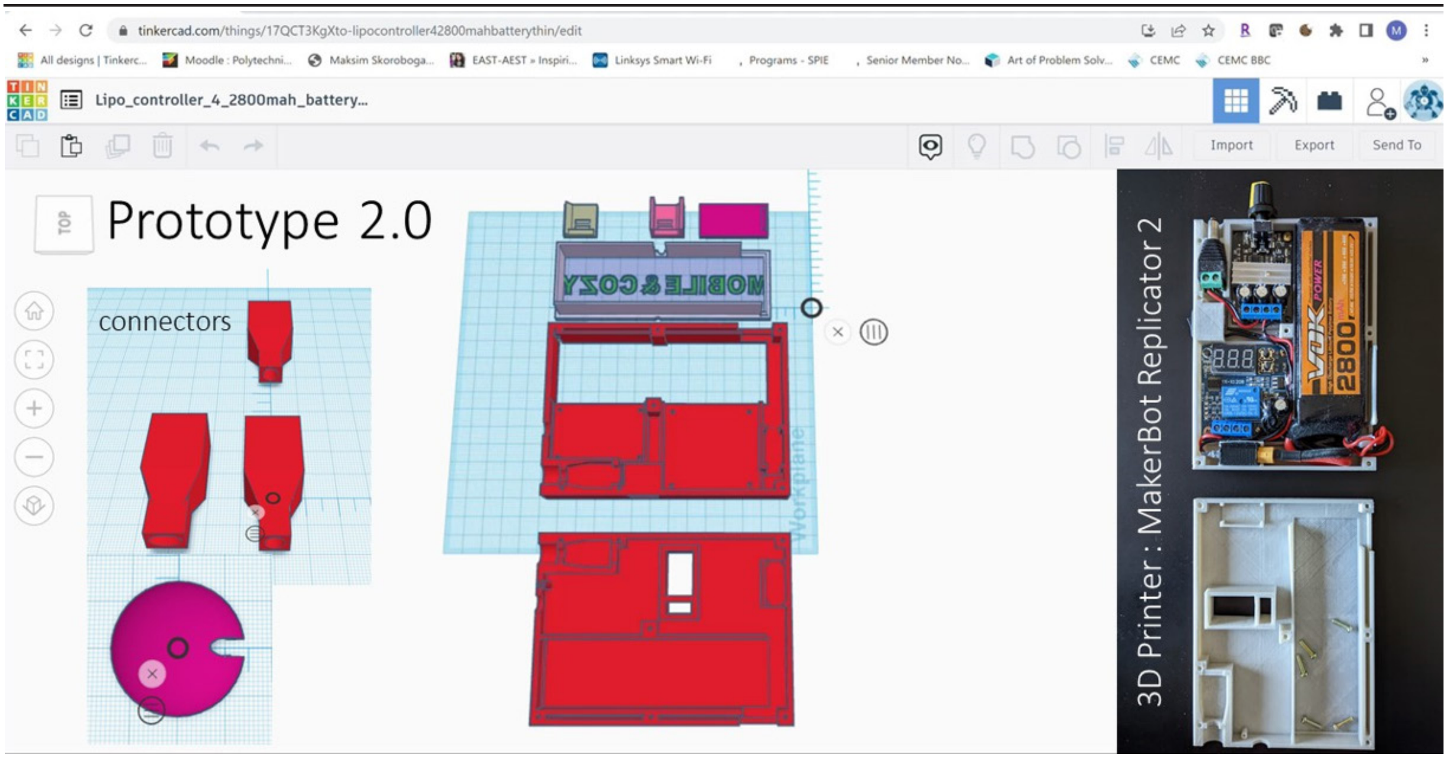


Figure 5. The second prototype of the power control module. (Left) 3D models of a compact shell to host power electronics, and various connectors. (Right) Photo of a 3D printed module with electronics.

REFERENCES

Alter, B.J., Anderson, N.P., Gillman, A.G., Yin, Q., Jeong, J.-H., & Wasan, A.D. (2021). Hierarchical clustering by patient-reported pain distribution alone identifies distinct chronic pain subgroups differing by pain intensity, quality, and clinical outcomes. *PLoS ONE*, 16(8), e0254862. https://doi.org/10.1371/journal.pone.0254862

Akkarakittichoke, N. Jensen, M.P., Newman, A.K., Waongenngarm, P., Janwantanakul, P. (2022). Characteristics of office workers who benefit most from interventions for preventing neck and low back pain: a moderation analysis. *PAIN Reports*, 7 (3), e1014. https://doi.org/10.1097/PR9.0000000000001014

Anseris. (n.d.) The health benefits of heated clothes for winter athletes. https://anseris.com/blogs/news/the-health-benefits-of-heated-clothing

Benjamin, F.B., (1954). The Effect of Local Heat Application on the Human Skin. *Loyola University Chicago* (Dissertations 437, 20-21). https://ecommons.luc.edu/luc_diss/437

BlesSew. (n.d.). Polyester Threads for Hand Stitching, Quilting & Sewing Machine. https://www.amazon.ca/Purpose-Polyester-Sewing-Machine-Assorted/dp/B06Y3RDWQ9/ref=rvi_sccl_1/138-9002182-6665730?pd_rd_w=pdeNP&content-id=amzn1.sym.8b4d8c20-8e51-4634-a76f-c00a1995a502&pf_rd_p=8b4d8c20-8e51-4634-a76f-c00a1995a502&pf_rd_r=66TFJB7DEQRZPNH77F9S&pd_rd_wg=gzE5R&pd_rd_r=04b9d383-8cf9-4ee0-b06d-917bee05b099&pd_rd_i=B06Y3RDWQ9&psc=1

Brigham and Women's Hospital. (2021, April 20). One in five American adults experience chronic pain. *ScienceDaily*. www.sciencedaily.com/releases/2021/04/210420092901.htm

Brother. (n.d.) LB6800 Sewing and embroidery machine. https://www.brother-usa.com/products/lb6800

Christina Battisti. (2021, September 08). When to use heat versus ice for pain.https://www.practicalpainmanagement.com/patient/resources/pain-self-management/when-use-heat-versus-ice-pain

Council for Disability Awareness. (n.d.). What are the most common causes of disability? https://disabilitycanhappen.org/common-causes/

Council for Disability Awareness. (2021, September 30). Disability statistics. https://disabilitycanhappen.org/disability-statistic/

Course Hero. (n.d.) Electric power and energy. https://www.coursehero.com/study-guides/physics/20-4-electric-power-and-energy/

Cryospa Clinics. (2021, May 9) Infrared Sauna Temperatures: How Hot Do They Really Get? https://cryospaclinics.com.au/infrared-saunas-how-hot-do-they-really-get/

Disabled World. (2022, April 05). Neck size: measurement chart and health information. https://www.disabled-world.com/calculators-charts/neck-chart.php

Earth Networks. (2017, July 1). The effects of extreme heat on your health. https://www.earthnetworks.com/blog/effects-extreme-heat-health/

GlaxoSmithKline Consumer Healthcare Inc. (2017, June 02). Product monograph: Voltaren Emulgel. https://pdf.hres.ca/dpd_pm/00039888.PDF

Healthline. (n.d.). Treating pain with heat and cold. https://www.healthline.com/health/chronic-pain/treating-pain-with-heat-and-cold

HHS (2021, October 27). What is the opioid epidemic? https://www.hhs.gov/opioids/about-the-epidemic/index.html

Hoffart, F. (2008, April 1). Proper care extends Li-ion battery life. https://www.electronicdesign.com/markets/mobile/article/21190344/proper-care-extends-liion-battery-life

How it works. (2013, May 30). Nead 2 head: long necks. https://www.howitworksdaily.com/head-2-head-long-necks/

HW-070. (n.n.). HW-070 voltage Regulator PWM DC Motor Speed Controller. https://www.aliexpress.com/item/1005002553731144.html?spm=a2g0o.order_list.0.0.1c001802AQJpV5

Inverarity, L. (2020, September 08). Hot packs used in physical therapy. https://www.verywellhealth.com/hot-packs-physical-therapy-modalities-2696130

Gobiheat. (2020). 5 Ways Winter Sports Athletes Benefit From Heated Apparel. https://gobiheat.com/blogs/news/5-ways-winter-sports-athletes-benefit-from-heated-apparel

Kraftex. (n.d.). Copper foil tape with conductive adhesive. https://www.amazon.ca/Copper-Conductive-Adhesive-1inch-12yards/dp/B018RDZ3HG

LaBonta, L. (2014, December 6). Human energy converted to electricity. http://large.stanford.edu/courses/2014/ph240/labonta1/

Loflin, L. (n.d.). Pulse width modulation power control for microcontrollers. https://www.bristolwatch.com/ele/pulse_width_modulation.htm

Mayata. (n.d.). Conductive Stainless Steel Thread. https://www.amazon.ca/Mayata-Conductive-Stainless-Supporting-Wearable/dp/B07Y6ZYLT9/ref=sr_1_15?keywords=Mayata&qid=1654531653&sr=8-15

MedicineNet. (2021, March 29). Medical definition of body surface area. https://www.medicinenet.com/body_surface_area/definition.htm

National Institute of Environmental Health Sciences. (n.d.). Effects of heat. https://www.niehs.nih.gov/research/programs/climatechange/health_impacts/heat/index.cfm

NHS. (2019, February 27). NSAIDs. https://www.nhs.uk/conditions/nsaids/

Nordik. (n.d.). The many benefits of thermotherapy. https://chelsea.lenordik.com/en/discover-the-thermal-cycle/the-benefits-of-thermotherapy/

PatientsLikeMe. (n.d.). Heating pad – hot packs treatment report. https://www.patientslikeme.com/treatment/heating-pad-hot-packs

Physiopedia. (n.d). Thermotherapy. https://www.physio-pedia.com/Thermotherapy

Quora. (2022, Jan 19). Why does the selective dopamine D1 agonist dyhidrexidine decreases blood pressure? https://www.quora.com/Why-does-the-selective-dopamine-D1-agonist-Dihydrexidine-decrease-blood-pressure

Ramanlal, R., & Gupta, V. (2022). Physiology, Vasodilation. Treasure Island (FL): StatPearls Publishing, *LLC*. https://www.ncbi.nlm.nih.gov/books/NBK557562/

Rosenice. (n.d.). Sew on snap buttons. https://www.amazon.ca/ROSENICE-Buttons-Fasteners-Accessory-15mm-Silver/dp/B07B2VD7QY/ref=rvi_sccl_1/138-9002182-6665730?pd_rd_w=T1REI&content-id=amzn1.sym.8b4d8c20-8e51-4634-a76f-c00a1995a502&pf_rd_p=8b4d8c20-8e51-4634-a76f-c00a1995a502&pf_rd_r=XE6EP35K8VV3551CA973&pd_rd_wg=gpifV&pd_rd_r=c6466bf5-ca86-449a-b68e-51ce08af9b1e&pd_rd_i=B07B2VD7QY&psc=1

Swe-Check. (n.d.). Understanding relays and wiring diagrams. https://www.swe-check.com.au/editorials/understanding_relays.php

SparkFun. (n.d.). Sewing with conductive thread. https://learn.sparkfun.com/tutorials/sewing-with-conductive-threadz

SparkFun Comment. (n.d.). Comment: Sewing with conductive thread. https://learn.sparkfun.com/tutorials/sewing-with-conductive-thread/discuss

Spine-Health. (2021a, June 12). How to apply heat therapy. https://www.spine-health.com/treatment/heat-therapy-cold-therapy/how-apply-heat-therapy

Spine-Health. (2021b, June 12). Potential risks and contraindications of heat therapy. https://www.spine-health.com/treatment/heat-therapy-cold-therapy/potential-risks-and-contraindications-heat-therapy

The Pi Hut. (n.d). Conductive paint tube. https://www.amazon.ca/The-Pi-Hut-100368-Conductive/dp/B00KBXT6JW

Trixes. (n.d). Multicoloured Felt Fabric Sheets. https://www.amazon.ca/TRIXES-Multicoloured-Glitter-Sticks-Crafts/dp/B07FXCJCTK/ref=rvi_sccl_1/138-9002182-6665730?pd_rd_w=Gu5LR&content-id=amzn1.sym.8b4d8c20-8e51-4634-a76f-c00a1995a502&pf_rd_p=8b4d8c20-8e51-4634-a76f-c00a1995a502&pf_rd_r=9A4SHPV1T4X1EY6ETG5S&pd_rd_wg=XP87s&pd_rd_r=f2a84fe0-b508-4693-bee2-c1e483513a50&pd_rd_i=B07FXCJCTK&th=1

WebMD. (2020, June 12). What heat can do to your body. https://www.webmd.com/first-aid/ss/slideshow-effects-of-heat

WebMD. (2022, January 19). Heat and cold therapy for arthritis pain. https://www.webmd.com/arthritis/heat-and-cold-therapy-for-arthritis-pain

Zippia. (2021). Office worker demographics and statistics in the US. https://www.zippia.com/office-worker-jobs/demographics/

ABOUT THE AUTHOR - ALEXANDER SKOROBOGATIY & ANASTASIA SKOROBOGATIY

My sister and I are fifteen-year-old students, starting 10th grade. We have always loved science, participating in numerous regional and provincial science and math competitions. More specifically, we are very passionate about life sciences. As a result, we have discovered many exciting topics, such as genetic modification, which was the subject of our previous project. We are also passionate about the medical side of science, hence our latest project, which focuses on the healing effects of heat. As for activities, we love to volunteer and practice sports such as figure skating.