Athletic Recovery Device

ECE-497 Final Report

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Abstract:

During sports competition, athletes frequently obtain both acute and chronic injuries that require various recovery methods. Athletic trainers and rehabilitation tools are utilized to treat these injuries at medical training facilities, which are regularly used at academic institutions with intercollegiate sports teams. At Union College, injured athletes visit the athletic training room where they are often advised to use the standard recovery protocol, R.I.C.E.: Rest, Ice, Compression, and Elevation. During the 'Ice' process, the training room typically uses recyclable single-use plastic ice bags, wrapped in plastic wrap to make them stay on the injury. Other implementations of cold therapy include machines which can apply cold more uniformly and controllably, which often come at a higher cost. In an effort to reduce the plastic waste of the college, our team aims to create a device which fulfils the function of the plastic ice packs more sustainably, while not sacrificing the convenience, effectiveness, and low-cost that make the ice bag method attractive. Through further research and the creation of design specifications and a test plan, while considering relevant engineering ethics and standards, we have developed a solid base from which to build our project.

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Introduction:

Topic Overview:

Risk of injury, associated with competing in a sport at a high level, is a setback that all athletes fear and many come to face. The recovery process can be intense, confusing, and complicated for many acute injuries. A standard method of treatment currently recommended for athletes suffering from a wide variety of injuries is the R.I.C.E. method, which stands for Rest, Ice, Compression, and Elevation. While taking a break and placing the injured area in an elevated position are simple tasks, the other two recovery methods can be more difficult to execute. For example, the “Ice” method involves cold therapy, which can be accomplished by placing a cold object like an ice pack on the injured area for ten to twenty minutes. For the best quality recovery tools, athletes flock to the training rooms to utilize cold baths, rehabilitory equipment, and many more specialized tools.

Problem Definition:

As any athlete at Union College would agree, our training room facilities are clean, organized, and well-run by the excellent training staff. If an athlete treating an ache or pain wants to use cold therapy on the affected area, they will most likely go into the training room, grab a recyclable plastic ice bag, fill it with ice from the machine, and have it wrapped around the area with plastic wrap. While this is a quick, easy, and portable application of cold therapy, there are some drawbacks to this process that could be improved upon. One of the biggest concerns of this method is its reliance on unsustainable single-use plastic material. Current products on the market that alleviate this issue can be messy, expensive, and cumbersome to operate; they also do not cater to a training facility that has to treat many athletes and must be used consecutive times without needing to be refrozen. Icing an injured body part is a simple way to recover, but there are a lack of options that are sustainable, inexpensive, and easy to use.

Project Goals:

For this project, we will be working with Union College's athletic training room to design a device that will address the drawbacks of the current cold therapy methods being utilized. This product will be affordable, sanitary, and environmentally-friendly. In order to address the needs of the training room, which deals with many athletes each day, this product will need to have a user-interface that does not require professional supervision and will be able to handle consecutive athletes during the busiest times of the day. While this product might not replace all of the single-use ice bags that student-athletes get wrapped on after practices, this could be a more sustainable, reliable, and cost-efficient method of cold therapy used in the Union College training room.

Literature Review

Through various medical studies relating to the effectiveness of different systems for athletes, we see a variety of different approaches to recovery devices. It has been shown that the combination of compression and continuous cryptotherapy is an effective method for healing acute injuries [1]. Currently on the market is the GameReady system; this product works by circulating cold air through tubes connected to the compression sleeve [2]. Not only is this system very messy and cumbersome to use, but it is also very expensive. A more portable and less expensive device on the market is the PowerPlay unit [3]. A drawback of this system is that it uses refreezable ice packs, which do not allow for consecutive use for multiple athletes in a row.

One common cooling method is refrigeration. The main idea behind refrigeration is the removal of heat from the system and prevention of heat entering a system. Common refrigerators prevent heat from entering by being made of insulating materials. In order to remove heat, refrigerators apply a similar method of cooling as the human body. As the body gets hot it produces the liquid sweat. As sweat evaporates and turns into vapor heat is removed and the body is cooled. In order to achieve this, fridges pump in liquid chemicals that can very easily evaporate. As it flows throughout the system it absorbs the heat, evaporates and turns into gas. This gas is brought out of the system where the excess heat is signed off by discharge lines. From here the vapor is passed through a compressor where it is returned to its liquid form before it is pumped back in and the process repeats [4]. This is the most common method used today to induce cooling.

An alternate form of cooling that is found in many systems is the use of thermoelectric modules, which often use the Peltier Effect. This effect tells us that under certain circumstances, an applied voltage can directly cause a temperature gradient [5][6]. This can only occur when the voltage is applied across the transition, or “junction”, between two different conductive materials [5][6]. Each material can be given its own “Peltier coefficient”, which represents how much thermal current a given electrical current carries in different metals [6]. Here, thermal current can be thought of as a sort of potential energy carried by electric currents, not in their magnetic fields, but caused by the electrons interacting with their material. When this coefficient varies at a junction, the energy entering the junction no longer is equal to the energy leaving the junction, so the excess energy is dissipated as heat, or absorbed in a cooling effect [6]. Whether absorption or dissipation occurs at the junction relies on both the direction of electric current and on which Peltier coefficient is larger. Of course, the energy for this must come from somewhere, so the voltage source for this operation will either dissipate the absorbed energy as heat, or absorb energy itself to power the junction's heat dissipation. This means that however much energy is being produced by the junction, that much heat is absorbed by the voltage source. A medical recovery device is a viable application for thermoelectric cooling, which needs to be temperature regulated for long periods of time.

<u>**Design Specifications:**</u>

Performance:

- Has temperature regulation within 5 degrees
- Isn’t cumbersome to set up for the user
- Can be used without athletic trainer supervision
- Has a user-interface that can control the different functions of the system

Economic:

- Must be low cost so that lower budget athletic training facilities can purchase multiple devices
- Does not require many different additional accessories
- Cost below $200
    - Current products on the market can range from $500 to thousands of dollars

Energy:

- Doesn’t require copious amount of energy to power
- Does not overheat during the icing function
- Device is able to stay cold for hours in order to accommodate multiple athletes

Environment:

- Must be able to withstand varying temperatures
- Not be damaged from exposure to bodily fluids
- Must not be susceptible to damage from cleaning instruments like wipes

Safety:

- Maintains temperatures that are not dangerous for use (not colder than 0 degrees C for more than ten minutes)
- Does not compress too tightly on the body parts of larger users
- Able to be wiped down or washed for sanitary purposes

Ergonomics:

- Doesn’t take up a lot of space in a crowded training room

Legal:

- Product must comply with all relevant local state and federal regulations regarding devices of its type
- Need to be careful about copyright/ patents. Many devices exist on the market that can be used for inspiration, but we need to make sure that anything we make is not patented.
- Site sources and previous research used for making such devices.
- Meets healthy and safety standards set by athletic regulating organizations

Materials:

- Cold unit will not be chemical, such that the temperature can be regulated without injury
- Cold unit will not use water or ice, such that the device will not be messy
- Sleeve will able to be cleaned regularly i.e. fabric or rubber

Aesthetics:

- Functionality will be prioritized over aesthetics as much as possible
- Should loosely resemble a boot or sleeve with wire to control unit
- User friendly operating system to control temperature, set timer

Test Plan:

Temperature Regulator: Given that icing is one of the most important recovery methods for an acute injury, making sure the device is at the appropriate temperature will be a high priority. We will test this first by using a temperature monitor to check that it is within five degrees of the desired temperature. It is also important that it has a range of temperatures it can be set to, so that it can be used on a variety of body parts and athletes. Next, we need to ensure that it can be used successive times and stay cold for a consecutive amount of hours. The amount of heat given off and energy needed to power the device will be monitored and tested to make sure it is a sustainable and safe device.

Sleeve: A crucial component of the device is the mechanism that is put on the user's body to deliver the cold. It is important for this part to be comfortable, safe, and sanitary. We will test this material separate from its complementary components in order to ensure that it will be an appropriate fit for an injured athlete. We will need to make sure it is durable to withstand hours of use, can be washed or wiped down frequently, can withstand extreme temperatures, and is not damaged by frequent exposure to bodily fluids. Testing fit on different body parts will be important in keeping the overall cost down so that additional accessories aren't needed, while maintaining a comfortable fit.

User Interface: To properly use the functions of the device, a user interface that has buttons will be needed. This needs to be safe and easy enough for an athlete to be able to operate without a trainer's supervision. Therefore, there will need to be safety buffers for the maximum and minimum temperatures. An adjustable time will be needed so that a low temperature isn't engaged for a long period of time.

Temperature Control: We will use a thermometer and take frequent samples of cooling mechanisms as it is operating on various objects at different temperatures. We will observe if it can stay within 5 degrees of the desired temperature over extended use.

Appendage Container: Using tubes of various width and length to simulate body parts like arms and legs, we will see if the appendage container is able to successfully adjust and fit any size person.

Appendage container + temperature control: We will run similar tests on the temperature control system, but for this test, measurement on the appendage container will be monitored to ensure that the desired temperature is passed from the temperature control system through the appendage container to the user.

Ethical Considerations: [7]

1. *to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment*

The primary hope for this device is to enable trainers to treat injured athletes in an efficient and sustainable way. As such while the device may be upholding health, public welfare, and look to more sustainable practices, we need to ensure that it is not encroaching on other unethical practices. To elaborate, while the device may decrease the use of disposable plastic, if the amount of energy it consumes for usage is more than the making of plastic then it may not be fulfilling its sustainable goal. In addition, to uphold sustainability, parts of the device, say the arm brace, should not be made of materials that are unsustainable. Furthermore, while the device itself may be to help the individuals if we do not show or warn users of possible risks we may violate this ethic. For example, if one of the components heats up during the act of applying the cooling we should put warning labels on said part so that users do not injure themselves on the equipment designed to help them. Furthermore, unless applying some safety mechanism over the heat generating components impedes its functionality or poses an even greater risk of, say catching fire, the user should have a layer of protection from them.

3. to be honest and realistic in stating claims or estimates based on available data;

As scientific research into athletic recovery processes deepen, the amount of conflicting hypotheses as to the best, safest, and most efficient methods increase. To be honest and realistic about the data that we encounter, as the IEEE guidelines state, we must be transparent in the conclusive findings that we read about, and apply that information to our design specifications. For example, one study concluded that compression was not effective in recovery [8]. While concluding that ice was the sole best method for recovery would have led to a simpler design process, more research had to be done. We found evidence from other sources that compression, in conjunction with cold therapy, was the most effective combination of recovery methods [9]. At this time, our focus remains on the implementation of cold therapy on injured areas, but we must continue to be honest about the research we do and the findings that we use to make decisions.

6. *to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;*
While the relevance of this ethical benchmark to our project may seem obvious and one-dimensional, I will attempt to explore its true meaning and, through such an exploration, arrive at a deeper understanding of how we must conduct ourselves in pursuit of our capstone project. As mentioned in the first part of the above clause, the maintenance and improvement of our personal technical skills seems paramount for our first project. After all, we are still only students and our real world experience is limited at best. This project will and already has required us to explore topics outside our current body of knowledge, from refrigeration cycles, to the Peltier effect, to current market availability of athletic recovery devices. However, improving our skills is not just necessary for the successful completion of our project, it is necessary for the fulfillment of our ethical duties as engineers. It is not enough to be competent. An engineer must always strive for self improvement and embrace change, or lose the driving

quality which makes one an engineer in the first place. On the other hand, this drive for self improvement and pride in our accomplishments must not be allowed to disintegrate into arrogance. As alluded to in the second part of the clause, a sober, accurate, and above all, transparent assessment of our abilities will be of the utmost importance in an abundance of areas during the project. From choosing the scope of the project, to the proper division of labor, to communications between the project team and our collaborators and mentors, the proper implementation of the second part of this clause can build trust and confidence in our abilities. It is not as straightforward as this however. Its successful implementation is also central to the quality of our character as engineers. We must maintain the highest level of honesty and frankness, especially when communicating with our project advisor, both about the current state of the project and about our failures, or risk degrading the moral fibre which must define us.

7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

Once again, the IEEE Code of Ethics emphasizes the importance of being honest. During the development of this project, we will need to be open to the constructive evaluation of our work not only by our classmates and advisors, and teammates as we continue to re-adjust our project objective. Furthermore, properly referencing and citing the sources from which we obtain information is necessary to maintain transparency in the origin of our ideas.

9.*to avoid injuring others, their property, reputation, or employment by false or malicious action*

While this device is meant to help people, we must ensure we do not cut corners in order to achieve the final goal. For instance, if we are struggling to find a material that allows for cooling to reach the user, we can not allow ourselves to settle on a material that does so but at the cost of it being bad for the user's skin or hard to clean. Both such cases could lead to determinants to the health of the users. Though we may be so driven to have our product work and do what it was meant to, we can not let this desire drive us to cut corners that could prove detrimental to other parts of the users health. Furthermore, if we did do such an act, not only would it damage the health of our users, it would damage the reputation of the people at the training center who put their faith and trust in our product, and allowed its use on their athletes

10. to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

In the context of this academic setting, it will be imperative to continue to reinforce the habits and standards laid out in the IEEE Code of Ethics. As we continue to grow as students into professional engineers, many of the applicable standards will be new to us. However, focusing on implementing ethical behaviors that lead to a final project result which fulfils the objectives we have set out to accomplish will lead to optimal professional growth.

<u>Standards:</u>

1. IEEE 11073-10408-2019 - IEEE Health informatics--Personal health device communication Part 10408: Device specialization--Thermometer [10]

This standard goes over the thermometers ability to communicate information back to the user. Since our device will need to monitor the temperature the user is exposed and since we are not sure whether it will be through an app or an on console interface this could be important when seeing if we are meeting the standards for measured temperatures.

2. ISO - 5390:1977(was reconfirmed in 2014) Compressor- Classifications [11]

This standard gives lists different types of compressors and definitions related to them. In addition, it gives some diagrams. It specifically focuses on “compressors defined as machines for the displacement and compression of gaseous media for any pressure values, with the exception of fans and vacuum pumps.” Since we are thinking of using some form of pumps and air to apply cold or remove heat, knowing the standards for a compressor will be important.

3. ASME PTC 19.1- Test Uncertainty [12]

This standard details the process of evaluating uncertainties in test measurements, and how to apply those uncertainties to a result. These uncertainties can be due to an effect on the result, or due to the quantification process. Overall, the amount of uncertainty is analyzed to produce the appropriate level of confidence in the result.

4. ISO/TC 86 - Refrigeration and air-conditioning [13]

Developed to standardize the terminology, safety, testing methods, and environmental consideration of refrigeration systems, this standard affects products such as air conditioning, refrigerans, ventilation machines, and other devices not covered by other ISO technical committees. Within this standard are several sub committees that detail the specifications for the different divisions of refrigeration systems.

5. ISO 9241 - Ergonomics of human-system interaction [14]

This standard has a wide variety of applications, all of which focus on the importance of the consistent behavior, functionality, and rendering of user interfaces to allow for full usability. In particular, some of the relevant sub-sections of the standard include the following: design criteria, principles, requirements for physical input devices, and human-centered design for interactive systems.

6. IEEE 1718-2012-IEEE Guide for Temperature Monitoring of Cable Systems [15]

This standard deals with the use of various measurement systems, including thermocouples, for the use of monitoring the temperature of cable systems. The standard focuses on practical methods for measuring these temperatures with an emphasis on more modern systems. The purpose of the standard is to ensure temperature is properly monitored to prevent hazards associated with a cable overheating.

7. ISO 13612-2:2014 Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems — Part 2: Energy calculation [16]

This standard deals with the heating and cooling of buildings, in a myriad of different ways and for different applications. Specifically, this standard deals with the methods used to calculate the power such heating and cooling systems require, which is important for any team trying to design a heating or cooling system. The purpose of this standard is to ensure safe operation and distribution of heat in systems so as not to at any point cause dangerous temperature spikes.

Fall Project Schedule

Week 1: Organize and delegate tasks. Here we will decide which particular areas each member will be focused and what their responsibilities are.

Week 2: Research on general understanding of assigned tasks. Each member will look into their designated part and see what the science is behind it, alternate ways of achieving it, and the pros and cons for each as they relate to the overall project.

Week 3: Collaboration preliminary design matrix and further research. At the start of the week, the group meets to look at which set of methods would be best to combine for the development of the end product. Once decided on a method, each member will do further research into their designated area to see if and how they could accomplish their specific task.

Week 4: Analysis and confirmation. Members bring individual research they have done on their specific section and see if each can do their part and if the overall system is viable and if the group can move forward under the current plan. If not, repeat week 3, until we settle on an idea.

Week 5: If did not confirm ideas from previous week, do Week 4 task. Preliminary work: each member will begin to work on designing their section. Include listing materials, parameters of their system and how they could be integrated with the other members section.

Week 6: Meet with the group and inform them about how to integrate them with other parts. Discuss and do more of the same tasks as in Week 5.

Week 7: Start looking for and decide on components.

Week 8: Finalize components and order.

Week 9: Plan out schedules for winter term, and tasks and difficultes need to be dealt with.

Week 10: Extra time should we need to push anything back.

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