Mid-Term Progress Report

IPRO 332 – Tournitech: Smart Clothing for Sensing Muscle Development
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Project Objectives:
This IPRO is the second of a two phase design project. Its objective is to continue the work of the Summer 2004 IPRO 332 team, advancing from feasibility study and conceptual design to prototype development. This IPRO will focus on the specific material selection and design specifications of a successful prototype that meets the following design objectives: easy to use, easy to produce, and meets the requirements of safety to the consumer.

Results to Date:
Each subgroup of this project has compiled their findings and results up to this point in the following reports.

Background/Safety:

Lactic Acid:
The Research of British physiologist, Archibald Hill who analyzed frog legs in 1929 stated that muscles cramping and fatigued is the result of lactic acid build up in the muscles. Researchers now are proving him wrong. Lactic acid, once blamed for muscle soreness and fatigue has now been found to play a critical role in generating energy when exercising. It has been found that lactic acid becomes split into lactate ions and hydrogen ions. The muscle burn you feel during heavy workouts is due to the hydrogen ion. "Normal blood lactate concentration in unstressed patients is 1-0.5 mmol/L," (Sharma, 1). When looking into lactic acid there are things to worry about: hyperglycemia and lactate acidosis. Hyperglycemia has a blood lactate concentration of 2-5 mmol/L, while lactate acidosis produces a blood lactate concentration of >5 mmol/L. Further investigation of these two serious lactic acid downsides will allow us to know the gray area of lactic acid.

Moderate Blood Flow Restriction during ACL Surgery Recovery:
Effects of low-load muscular training with moderate restriction of blood flow during the first 16 weeks after reconstruction of the anterior cruciate ligament were studied in the article "Low-load resistance muscular training with moderate restriction of blood flow after anterior cruciate ligament reconstruction" by Harutasu Ohta, Hisashi Kurosawa, Hiroshi Ikeda, Yoshiyuki Iwase, Naohiro Satou and Shinji Nakamura. Forty four subjects participated in the study. Half trained with blood flow restriction (R-group), another half trained without restriction (N-group) for comparison. Evaluations of knee extensor and flexor torques before surgery and 16 weeks after it showed a significant increase in muscular strength in group R. Resent reports have indicated that low-load resistance muscular training of the limb with moderate restriction of blood flow (air tourniquet) may induce the same increase and enlargement of the muscles as high-load muscular training. In this study an air tourniquet was worn on the proximal part of the thigh on the operated side, and a pressure about 180mmHg was applied to induce moderate restriction of blood flow. The intensity of training was low and performed mainly by the closed kinetic chain exercise method. Significant recovery of knee extensor muscular strength was observed in group R 4 months after surgery in both isokinetic and isometric contraction strengths. The knee flexor muscle torque also showed significant recon=very of muscular strength in group R. For exercises done in a locally low oxygen state, the type 1 fibers do not function adequately, while type 2 fibers preferentially mobilized. Muscular anthrophy was suppressed regardless of fiber type in group R

compared to group N, and there was no difference in the change in single fiber diameter between type 1 and type 2 fibers.
Muscular training under the pressure of 180 mmHg exerted by a tourniquet was accompanied by slight discomfort and dull pain in the lower extremities during training. No problems during the first 10 min of training. Pain started after about 12 min for some people. The patients were instructed to relieve the blood flow restriction after a maximum of 15 min, stop for 15-20 min and then resume the training.

The relation between lactate and blood flow restriction while exercising was studied in the article "Lactate concentrations in human skeletal muscle biopsy, microdialysate and venous blood during dynamic exercise under blood flow restriction" by G. Lundberg, P. Olofsson, U. Ungestedt, E. Jansson, and C. J. Sundberg. Nine healthy males performed legged knee extension exercises. Blood flow restriction was applied stepwise. Three serious of exercises were performed for 15 min each after resting for 1 hour. Exercise 1 was performed under normal atmospheric pressure. Exercises 2 and 3 were performed under 30 mmHg and 50 mmHg (blood flow reduced by 15-20%) supra-atmospheric pressures respectively. The more blood flow was restricted, the higher lactate concentration was measured.

	Microdialysate lactate concentration	Muscle biopsy lactate (mmol/kg dry muscle)	Lactate concentration in a vein in the ante-cubital fossa
Exercise 1	3.2 (0.5-6.6) mmol/L	21 (7-48)	1.3 (0.8-2.1) mmol/L
Exercise 2	4.4 (1.1-9.8) mmol/L	31 (13-67)	2.0 (1.2-4.1) mmol/L
Exercise 3	7.9 (1.1-11.6) mmol/L	48 (8-86)	2.6 (1.3-5.8) mmol/L
Post-exercise			3.4 (1.4-5.2) mmol/L

In conclusion, microdialysaate lactate concentration in the working muscle increased stepwise with increasing blood flow restriction. It showed better correlation to venous than to muscle biopsy lactate.

Measurement of Lactate Acid:
A lot of the work I did was mostly in obtaining some background on current technologies in the sports lactate measurements field, the next step would be to do a detail investigation of Near-Infrared spectroscopy instrument components and see if they could be miniaturize in order for it to be useful in our product.

Mechanical Prototype:
One idea for a prototype was for a mechanical design, which used no electrical components, therefore would be inexpensive and easy to produce. The idea was first brought up when the idea of a constant force spring was discovered. A constant force spring works by applying a constant pulling force at any extended length. We realized that to achieve a constant pressure, you must have a variable force for different strap sizes. So a conventional spring, with a certain k value, was our next idea. This plan was dropped because we realized that he strap could not be adjustable, only the spring could stretch, and this was not a large enough adjustment to accommodate the large variations in arm diameters. Our current idea is a combination of these old ideas.

There are still many details that need to be worked out. The current design calls for pressure to be applied over a set length to the vein/artery by a spring. We are still in the process or locating exactly where that is. The type of spring has not yet been determined either. Ideally, the part of the band that applies the force to the arm should have a constant area. Since this design calls for constant pressure, that means that we need a constant force spring. While there is mention of a constant force compression spring from BYU, it is doubtful that this can be incorporated into our design since no details are known. This leaves the problem of what kind of spring can be used to accomplish the task at hand. Most likely the spring will be an adaptation of a constant force torsion spring.

In addition to the type of spring, we also need to find the optimum means of attaching the spring to the strap to best apply pressure where necessary. This becomes tricky because the area of the arm where pressure needs to be applied is on the underside. This means that, depending on the size of the spring attachment, the strap could become very uncomfortable and restraining. Beyond just comfort, we also need to look at the most effective way to hold the strap at the right pressure. The strap has to be able to adjust and the spring must apply the force effectively and consistently.

We will continue to look at the viability of using the spring design. Depending on our findings, it is possible that the spring device will be cheaper and more effective than an air pump unit. Our goal for the end of the semester is to come up with a design that is both safe and effective. Therefore it will fit on the arm and leg of different sizes, and apply a correct force, and constant force, over the vein/artery to achieve required oxygen supply depletion to the major muscles to promote muscle development. Our main concerns for the project are safety, cost, and easy of use/comfort.

Electronic Controlled Air Pressure Prototype:
One of the original concepts for the blood restriction device consisted of an air bladder that was pumped up to a predetermined pressure. This pressure would be held constant during a workout session to allow only a partial blood flow into the target muscle groups. A bladder setup was devised using only a small manual pump and some pressure release valves for protection. During some preliminary testing, however, we discovered that flexing and movement caused the pressure to fluctuate (higher than the initial pressure.) We also found that certain inadequate bladders lost pressure over time. In all, there are three main problems with a manually controlled bladder:

1) An overpressure valve is required for safety, so that a user cannot over inflate the bladder and cut off all blood circulation. Because the pressure can increase for short periods of time during flexing, this valve would release air and render the device useless without constant inflation.
2) There is no way to alert a user to under pressure (short of a bulky pressure dial on the cuff). The bladder could easily fall below the desired pressure and become ineffective.
3) Restriction of blood flow can be a good muscle growth technique if used properly. However, extended periods of reduced blood flow can easily damage tissues and kill cells. With a manual device, the user is required to manage the time interval of use. It may be too easy to leave the device on long enough to cause damage.

These problems led us to use an electronically controlled pressure system, consisting of a control circuit, small electric air pump and a solenoid release valve. A microcontroller constantly monitors the pressure in the bladder, and can make any adjustments necessary. It initially pumps up the bladder to the desired level (around 110 mmHg). Once done, the user can begin to exercise. During the workout, small spikes in pressure can be ignored and no air is released. If the bladder falls below pressure, the circuit can turn on the pump to keep it at an effective level. In addition, a microcontroller can measure the amount of time elapsed, and automatically release pressure in the bladder and end the workout before any dangerous conditions occur.

Other improvements using an electronic brain were considered:

A) Two small sensors, spaced a distance apart on the armband, could be used to sense artery pulses and help the user place the bladder directly over the veins on the underside of the arm. Using this technique, the bladder size could be drastically reduced, and thus decrease the size of the air pump and solenoid, allowing the control unit to be further miniaturized. The sensors for armband placement are feasible in production, but will not be included in the prototype simply due to size and complexity. A prototype is generally more bulky and constructed by hand, and this addition would be too difficult with the resources and time available to our group.

B) Using a lactic acid or glucose sensor, actual conditions in the blood stream could be monitored, and the device could respond according to preprogrammed settings and excess acid or sugar levels. There are currently no economically feasible lactic acid/glucose sensors for such a device. These sensors may be available in the near future, and so this idea should be revisited. Instead, the pressure level and duration of use will be determined based on research studies of lactic acid and glucose levels to ensure that dangerous quantities are not reached.

Microprocessors in applications such as these are now relatively inexpensive and offer many advantages. Even after the prototype is built, pressure levels, time intervals and safety measures can be adjusted simply by changing a few lines of code. Tweaking, testing and customizing of such a device would be easily accomplished. Microprocessors today are designed to run on battery power and have only minimal energy requirements. The bulk of the battery power will go to the air pump, which can be reduced using a smaller bladder and other conservation techniques. In turn, the size of the battery will also decrease substantially, and the entire control unit can be built in a very small, unobtrusive package suitable for strapping onto an arm or leg.

Project Schedule:
The following is a schedule of events and deliverables that must be turned into the IPRO office.

Mid-Term Progress Report & Seminar-Style Discussion	October 22
Professional-Exhibit is Organized	November 29
One-Page Abstract	November 29
Web Site	December 1
Final Oral Presentation	December 1
Final Project Report	December 3
Team Information	December 3
Comprehensive Deliverables CD	December 3
IPRO Projects Day Conference	December 3
IPRO Team Debriefing	December 6 -13

Individual Team Member Assignments:
Each team member has been assigned or has volunteered to one of two design groups to help accomplish the objectives stated above.

Prototype Design:
Team Members:
Craig Rohe
Jonathan Beckman
Jose Zamzcona
Hakan Ozmen

Background/Safety/Website:
Team Members:
Jotvinge Vaicekauskaite
Dan Latuszek
Alexis Dulinskas
Nate Godfrey

Obstacles:
One of the obstacles up to this point has been the need to regroup and redefine our desired outcome for this project after losing our sponsor. Along with that we have also faced an issue that affects all new technology. That is we have had a difficult time finding information and research that directly relates to the project. In recent weeks we have been able obtain articles that correlate with the current project through inter-library loans and hope that with this new information we will be able to define the safety issues that are a concern. The prototype designs are progressing and the electrical design will be built upon receiving the purchased items.