LightWeight: Wearable Resistance Rehab Visualization

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ABSTRACT
People recovering from arm injuries are often prescribed limits to the amount of strain they can place on their muscles at a given point during the recovery process. However, it is sometimes difficult for them to know when a given activity creates strain in excess of these limits. To inform this process, we have developed a prototype, the LightWeight, and describe it here. The aim of the LightWeight is to inform users of the strain on targeted muscles as the activity occurs, and to display the relationship of that strain to the aforementioned limits. LightWeight is embedded within a compression sleeve that measures muscle strain through conductive fabric and EMG while displaying that information through an intuitive circular LED display.

Author Keywords
Wearable technology, User Interface, rehabilitation, human factors.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User interfaces – Prototyping.

INTRODUCTION
After injuries, student-athletes often undergo drastic lifestyle changes as they are not only unable to physically exert themselves at their usual high levels of performance, but also struggle with performing simple daily tasks. Regular sessions with trainers are often implemented as part of the rehabilitation process for these student-athletes.

Student-athletes are also often prescribed lifting restrictions for their activities outside of rehabilitation (e.g. limits on the amount of weight they can lift, push, or pull). However, they are not always well informed as to whether a given activity, such as opening a door, strains their muscles past their prescribed limits. Furthermore, because of this lack of knowledge, they are sometimes hesitant to do anything that might create muscle strain anywhere close to their limit and can sometimes experience muscle atrophy from low levels of exertion. A device that conveys this knowledge of muscle strain is the prototype presented here, and although the target user group here is student-athletes recovering from injuries, other potential users that could find this device useful include a variety of post-surgery patients and those working in occupations that require a significant amount of lifting or risk of overexertion.

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PROTOTYPE DESIGN
The LightWeight is made of two main parts: A) A sport compression sleeve (Figure 1) embedded with conductive fabric electrodes, which is connected to a nearby electromyography (EMG) amplifier, and B) A circular array of sixteen individually-addressable RGB LED pixels to display muscle strain. The sleeve, which is made to be breathable and to shield the user from the electronics, is placed around the targeted muscle group to measure strain and relay that information to the user via the LED display.

When the device is turned on, the pixels in the LED display light up in sequence to orient the user to the display; similar activity occurs when the device is synchronized with the user's smartphone. Users will also be able to track progress and data through the LightWeight phone application when the two are paired (Figure 2).

Typically during rehabilitation and training sessions, users are not only prescribed an upper lifting restriction, but a lower one as well (to prevent the aforementioned muscle atrophy). These limits are displayed proportionally along the circular array of LEDs, informing the user of the desired muscle strain limitations. These lights are reconfigurable so that the display can adapt to changing prescribed lifting restrictions as the recovery process continues. These limits are shown distinctively in blue on the LED display (Figure 3); the other pixels fill the spaces in between the limits. The colors of those pixels change depending on the user's muscle strain relative to the limits: too little strain (yellow; Figure 4), an appropriate amount (yellow plus green; Figure 5), or too much (yellow, green, and red, with haptic

Fig. 1 Student athlete wearing the LightWeight sleeve.

Fig. 2 LightWeight mobile app tracking user data.

Fig. 3 Calibration Lights

Fig. 4 Strain below limit

Fig. 5 Strain within limit

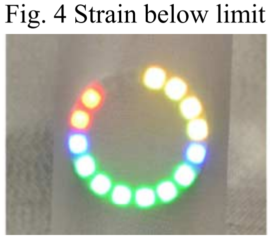

Fig. 6 Strain above limit

feedback also provided in upper portion of sleeve; Figure 6). These colors were chosen because their meanings are roughly equivalent to those of the colors on standard American stoplights (Nielsen, 1993, "Consistency and standards," para. 1): green denoting "proceed," yellow denoting "caution," and red denoting "stop." Similarly, the orientation of the circular array is set such that it can be read much like a standard analog clock: no weight (12 o'clock), lower limit (3 o'clock), and upper limit (9 o'clock) (Nielsen, 1993, "Match between system and the real world"). These design features will allow users to interpret output from the device in a way that is consistent with conventions learned from the outside world.

DISCUSSION

The next step to improving the LightWeight is to perform user evaluation/testing. Initial testing will focus on training mode because the device requires more attention from users there than in everyday mode. Due to various problems of testing the device on injured student-athletes (e.g. logistics, sample size, interruption of recovery schedules), tests will be carried out with healthy students as participants. The tests for participants will include lifting objects and performing workout activities while interpreting device feedback regarding muscle strain relative to prescribed lifting restrictions. Participants will also have the opportunity to provide feedback about the LightWeight's usability, comfort, and phone application.

To test the viability of the system, a set of user tests will determine not only users' weight perception accuracy with the device, but also measure how well users are able to interpret the information it provides. During the study, participants will place items of unmarked weight onto a segmented line drawn on the floor according to how heavy they believe the item to be. The segmented line will be divided into 16 equal portions, and markers will indicate on the line where the user's recommended lower and upper limits occur. Immediately after picking up a weighted item, users will place each one on the line relative to how much they think it weighs in relation to their recommended limits. For example, a user that believes an item is just under the upper limit may place the item left of and relatively close to the upper limit marker. This procedure eliminates the need for participants to remember multiple weights (and therefore getting them mixed up when reporting the weights) and more easily allows them to show understanding of the weights' relative order (important if user already knows generally what some reference weights feel like). The participants will be evaluated based on the average distance each placed weight is from the known, correct position on the line.

CONCLUSION

The LightWeight informs users of muscle strain, whether it occurs during rehabilitation or daily life, using intuitive design embedded within a comfortable athletic sleeve. Formal participant experiments in the future will test the practicality and display design of the device, spurring the next stages of improvement for the LightWeight.

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