Fieldwork Orthosis

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Abstract

A variety of measurement tools are used for sample and data collection in ecological environments. This is the first work where an orthotic is designed to minimize the risk of finger and joint damage, and it's hypothesized that using this device will enable researchers to effectively gather data samples without suffering re-occurring injuries. The design encompasses a finger splint attached to the user via a glove, with a detachable shovel to help remove mud samples. The glove interfaces with a pad to reduce stress on the wrist while conducting traditional data collection techniques. In order to evaluate the design, data will be gathered on one individual while performing 2 bimanual tasks in an environmental setting. The data will enable us to examine if the force at the tip of the finger decreased and if the user experienced hyperextension during the process. The orthotic will significantly improve the quality of life for researchers who need to constantly load their fingers and joints. By reducing these compressive loads, researchers will be able to conduct fieldwork with greater ease.

I. Introduction

Environmental scientists and marine biologists often work in various ecological communities such as wetlands, grasslands, and forests. These settings have difficult terrains that individuals must work in to conduct fieldwork. As a result, it is difficult for researchers to retrieve samples for analysis because different ecosystems require different methods of removal. A common tool for retrieving mud samples is polyvinyl chloride (PVC) pipes. However, given the terrain is near frozen when collecting data, individuals must exert large forces on the PVC to push the instrument through the mud. Researchers also use their hands and fingers to help the PVC pipe dig into the soil. Large compressive forces are exerted onto the user's joints, which can lead to potential injuries over time. Therefore, there is a need to develop a tool that facilitates support to researchers when gathering data samples while eliminating the risk of injury from occurring.

A. Background

Tools utilized for sample and data collection vary depending on the animal or ecosystem of interest. Different types of tools can be categorized by measurement tools, collection tools, and surveying tools. Measurement tools include thermometers, pH meters, tape measures, and any other measurement tools specific to scientists' research goals [1]. Collection tools include nets, buckets, various sizes of pipettes, and custom tools created by researchers. Surveying tools include datasheets, clipboards, cameras, and quadrats [2]. Quadrats are uniquely used by marine biologists and ecologists to ensure the area of land they are surveying remains uniform between each site. Within the area as defined by the quadrat, the size of each unique species and plant populations are recorded. As depicted in 1, taking multiple data collections using the quadrat system at one field site can estimate the biodiversity of the fieldsite. Researchers often create their own quadrat using PVC pipe in order to customize tools for their specific research needs [3].

Quadrats aren't the only tool marine biologists create independently. Researchers often create unique tools to collect samples and navigate field sites. Fieldwork requires immense physical activity. Many occupations are regulated by government regulations, such as the Occupational Safety and Health Administration, to ensure the safety of the workers [5]. However, due to the small number of fieldwork researchers and niche occupational demands, fieldwork is not regulated. As a result, many tasks required for fieldwork can lead to injury and occupational hazards. Our project aims to understand different risks as a fieldwork scientist and propose methods for minimizing injury.

Fig. 1. Fieldwork scientists utilizing quadrats in order to survey intertidal pools [4].

B. Overview

Section II decomposes our interview with a field scientist, providing the audience with critical insight into the user. We summarize key quotes from the user as well as lay the foundation for what our design will be centered around. Section III implements the design requirements stated in Section II by describing our novel device that will enable our users to gather data samples while preventing work-related injuries. In order to evaluate the effectiveness of our design, we will implement electrical sensors to evaluate compression loads on the user during active digging. This will allow the team to test our hypothesis to validate the design minimizes loads on the user's joints.

II. Interview case study

Our team interviewed an Assistant Professor who is passionate about scientific communication and community engagement. Their lab is focused on ecophysiological research, mentoring undergraduate and graduate students. Interviewing a marine biologist and ecologist professor provided insight to the difficulties of fieldwork beyond information publicly available. Each type of field site poses different challenges. The researcher focuses on fieldwork related to the following research themes: "seagrasses as coastal climate effects buffers", "nudibranchs: stress adaptation and physiology", "wetlands for urban conservation and development", and "intertidal mollusks: biological variation across traits".

One pain point described by the marine biologist was collecting mud samples in wetland field sites. In order to take mud samples from wetland environments, researchers create another PVC pipe based tool. A small portion of the PVC pipe is pushed into the ground by the researcher to collect a sample of the mud. As described by the Assistant Professor, the process to insert the PVC pipe into the ground requires immense physical effort. The collection process is shown in Figure 2.

Fig. 2. Progression of how to collect a mud sample. A custom PVC pipe tool is inserted into the ground, the researcher pushes tool into the ground, the sample is removed with additional tool, and additional sample is added to the collection bag.

Since areas of interest are only accessible during low tide, researchers must conduct field work during low tide, which is usually early in the morning. The lower temperatures due to the time of day often freeze the dirt. To take adequate volumetric samples of the dirt, researchers must use their fingers to break through the ground and use their body weight to push the PVC pipe into the ground. Utilizing the tool requires immense physical effort, which contributed to the interviewee suffering degradation of cartilage in their first finger metacarpophalangeal joint. The interviewee explored alternative methods for mud collection such as a modified clam-gun developed by a peer. Researchers could step or push down on the modified clam gun to insert the tube into the ground. However, this method was abandoned because it was cumbersome to carry and repetitive maintenance was required to upkeep the tool. The edges of the tool that were inserted to the ground frequently became dull, causing researchers to sharpen the tool after every field work session.

Through the marine biologist's descriptions of necessary tasks during fieldwork and persistent frustrations as a fieldwork scientist, four critical needs were determined for an assistive device design. While needs can overlap to other terrains, the critical needs were specifically developed for a tool being used in the wetlands. The most frustrating and painful task the need knower described was collecting mud samples from wetlands. Since the multiple researchers within the need knower's lab suffered injuries from using the current technology for collecting mud samples, the focus of the interview centered on understanding the needs of collecting mud samples.

Identified Needs	Need-Knower Quotes
Durable in the Water	"I tend to carry everything in a waterproof backpack" "Sometimes we collect samples underwater" "Just because it's [research equipment] constantly in the water and it gets gross it just never really lasts very long. We glue everything together [PVC pipe tools] because it makes it last longer"
Reduces Risk of Injury	"The mud core PVC pipe is not efficient and it doesn't cut through the mud. So you have to use your hands to do it instead and it destroys… it just rips up all of your skin. I had an injury for 9 months after the last season that the doctor thought was rheumatoid arthritis but it was just from shoving my hands in the mud too many times. I couldn't bend my finger for 9 months" "My lab tech complains that it breaks her nails" "We dread every new grant that has this [wetland mud core samples]"
Allows User to Maintain Balance	"You have to break your own path and trample down vegetation to move forward. I recommend students do strength training, or hip flexor training. As you're breaking through vegetation, you're also sinking from your knees into the mud. So you have to take your whole leg out of the mud to take a step forward"
User Friendly	"We have special thermometers. They're highly sensitive thermometers. The casing is incredibly poorly designed. It doesn't have room for the probe so the students get lazy taking the probe out every time. They leave the case unzipped. They bend it every time they put it back in the case so they stop putting the probe back in and it falls in the water. The students would say that's a tedious thing they deal with" "You get frustrated with the modular capabilities of research equipment. Even when there are solutions for what you want, they're usually cost prohibitive. That's why people turn to DIY. You could pay someone for it but grants will not allow those types of payments, these contractor equipment services. But researcher time is allowed. So what ends up happening is people end up learning these amateur skills because that's how we can pay for the work to be done"

TABLE I
IDENTIFIED NEEDS FROM NEED-KNOWER INTERVIEW

The highest priority requirement is to prevent injury. Work related injuries not only affect researchers ability to do their job, but also affect the personal lives of researchers. Therefore, creating a tool that is functional and safe is crucial. Since wetlands are often submerged in water, equipment must be durable in the water. The interviewee voiced that the researchers often create custom tools that are specifically made to last longer in the water. Additionally, since tools are used repetitively throughout a fieldwork session, equipment should not be prone to cyclic failure. For example, the modified clam gun was abandoned as a potential tool because the effectiveness of the tool rapidly decreased with each usage. Using tools repetitively throughout a fieldwork session also requires equipment to be convenient and easy to use for researchers. If a tool requires a long set up process, researchers get frustrated with the time needed to maintain tools when their time should be focused on data collection. Navigating wetlands takes expertise and practice. As a associate professor who runs a research lab, the interviewee recommended that fieldwork scientists partake in strength training to prepare for walking in wetlands since researchers sink into the mud as they walk. Since the ground in wetlands is not stable, the proposed design must not interfere with researchers' ability to maintain their balance. Detailed quotes that led to our identified needs are shown in Table I.

III. Proposed Device & Test Methods

A. Proposed Device

After conducting an interview with our interviewee, we concluded that one of the largest pain points was their fingers being under excessive stress and wear when collecting mud samples in the wetlands. To address this issue, we proposed an approach by reducing force directly transferred into finger joints from direct contact with frozen mud. Our proposed design is a finger splint with a detachable shovel to help remove the mud, and a palm pad to further help reduce stress on the wrist when pressing the PVC pipe into the mud as a part of the collection process.

The finger splint is fixed onto both the middle and ring fingers to prevent movement of the interphalangeal joints and ultimately relax the fingers during the mud sample collection. We chose only the middle finger and the ring finger instead of all fingers as the middle finger and the ring finger are usually the longest ones on a human hand, which made them the most vulnerable under such tasks. The low-profile finger splint also does not restrict mobility, instead, it allows the thumb, index finger, and pinky finger to move freely during any task. This also simplified the device to lower the cost and increase stability. The shovel is detachable and can be fixed onto the finger splint tip when performing tasks such as removing mud, and it can easily be removed and stored in the other direction on the modular mount to be unobtrusive when performing other tasks during the fieldwork. The finger splint itself contains two segments, with one part connected to the fingers and a base attached to the back of the hand. There is a hinge design at the metacarpophalangeal (MCP) joints with a hard stop to prevent fingers from bending past a horizontal line to essentially prevent hyperextension in the MCP joints. The two parts are also connected by an elastic band to provide feedback force when bending the finger and reduce the force required to use the shovel.

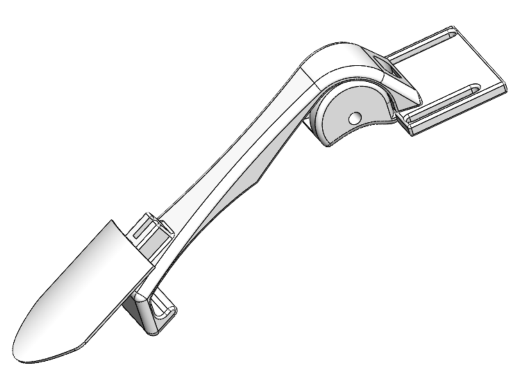

Fig. 3. Finger splint design to prevent hyperextension and reduce stress in the finger joints.

Another part of the process of mud sample collection is to press a PVC pipe into the mud. This is usually done by pressing with bare hands when the wrists are under full extension. This causes a lot of stress on the wrist due to the preload in the tendons and muscles from wrist extension and the additional force applied to press the PVC pipe down into the frozen mud. With our design of the angled palm pad, the interviewee can now press down the PVC pipe without fully bending their wrists and use the muscles from the shoulder and the entire arm instead of the forearm muscles alone. Therefore, the angled palm pad will reduce the risk of wrist injuries.

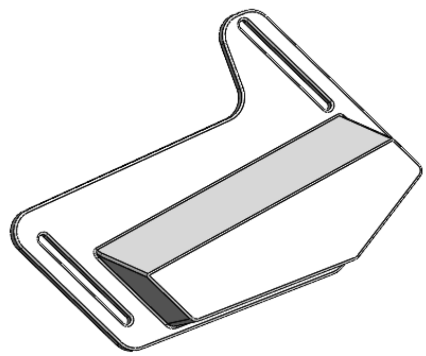

Fig. 4. Palm pad design to redirect force applied to the wrist

B. Test Methods

Our finger splint will reduce the force in the interphalangeal joints when the interviewee collects mud samples. To verify this hypothesis, we will use several pressure sensors and attach them to each fingertip. By connecting the pressure sensors to a circuit with an Arduino, we will first record the pressure readings from digging mud with bare hands and then compare them with the readings from digging mud with the finger splints and the shovel. If the readings show that the pressure is reduced after the device is equipped, then the function of reducing force within the interphalangeal joints is verified. We will then connect the pressure sensor to the palms and record the readings when the hands are pressing on a PVC pipe into the frozen mud. We will then perform a second test with the angled palm pad attached and have the pressure sensor placed between the palm pad and the palm to record the readings from the pressure sensor again. If the recorded pressure readings reduce after the angled palm pad is equipped, then we will conclude that the angled palm pad reduces stress in the wrist. We can also compare the readings and calculate the force reduced in percentage and study the efficiency of the device.

The hinge design with the extruded bump-stops will prevent hyperextension. To verify this hypothesis, we will measure the angle and track the motion of the MCP joint. If the collected data shows that the angle does now exceed the horizontal line, then the hypothesis is verified and that hyperextension will not happen at the MCP joint with this device equipped. We will also test the rigidity of the device, especially on the extruded bump stops, to ensure that there is no visible crack or deformation after certain cycles of load and unload to make sure the device maintains its consistency.

Finally, we will conduct another interview with the interviewee and her colleagues, if they agree to participate. We will present the prototype to them and ask for feedback from the group of researchers to understand whether they think the device will be comfortable to use, easy to carry during fieldwork, and whether it reduces stress from fingers and wrists for them when performing certain tasks during fieldwork. With their feedback, we will further evaluate the design and make changes if necessary. To perform human subjects tests, we will submit a protocol that includes the purposes of our device, how it functions, and the test methods mentioned above. Then, we will submit the protocol for review to the Internal Review Board for the Protection of Human Subjects. Our team members have completed the CITI training Group 1: Biomedical Research Investigators as of April 17, 2023.

IV. Intellectual Merit

The orthotic's ability to create mud samples from wetland environments will have a significant impact that will influence other researchers. Novel developments in mud sample removal are attributed to the creativity of marine biologists and ecologists. However, these devices are solely intended to collect mud samples without considering the potential risk of injury to joints or hands.

Our device offers a unique rotational capacity that allows individuals to actuate the device about their metacarpophalangeal joints. This provides users the ability to replicate a digging motion with the orthotic, while still providing protection to the phalanges. More importantly, it prevents users from hyperextending their fingers while increasing the compressive loads in various ecological environments. This is an innovative solution that has not been introduced to a research environment.

V. Broader Impact

Through the development of this orthotic, marine biologists and environmental researchers will be able to collect data while eliminating the risk of injury. This tool enables users to gather hundreds of samples yearly while removing the need to dig into the terrain with their hands. Given the potential integration of electrical components for reading the environment's temperature, designers considering this adoption must determine how to preserve the sensors when exposed to damp ecosystems. This device will reduce the amount of equipment needed for field sites, decreasing the load on users and helping them maintain their balance while navigating difficult terrains.

References

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[2] "Research equipment." [Online]. Available: https://oimb.uoregon.edu/traveling-to-oimb/research-equipment/

[3] "Quadrat sampling," 2009. [Online]. Available: http://www.coml.org/investigating/observing/quadrat$_sampling.html$

[4] R. Tanner, "Research themes," 2021. [Online]. Available: https://www.seacrlab.com/research-themes

[5] "Department of labor logo united states department of labor," 2023. [Online]. Available: https://www.osha.gov/laws-regs

APPENDIX A
INVESTIGATIONAL DEVICE DETAILS

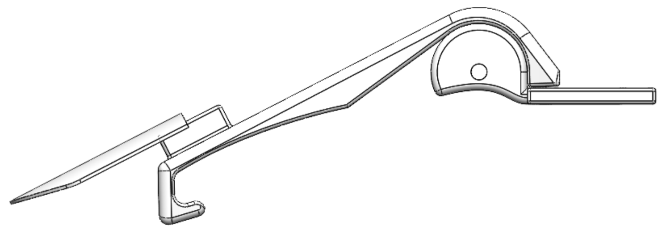

Fig. 5. The finger splint provides a curvature that follows the natural resting hand position

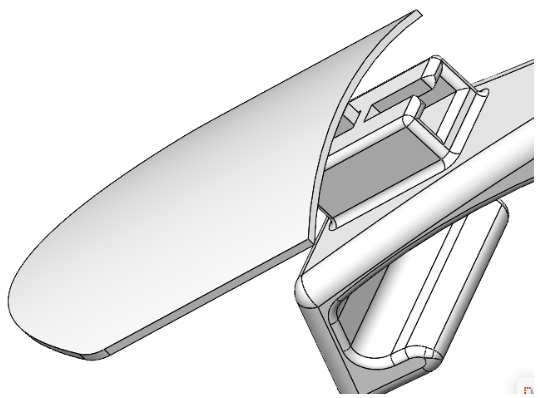

Fig. 6. Modular mount to attach the shovel

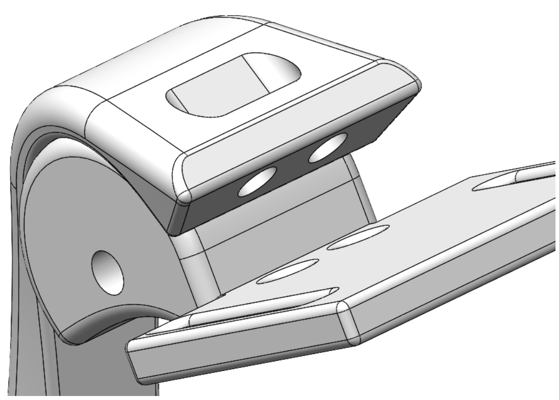

Fig. 7. Elastic band attachment

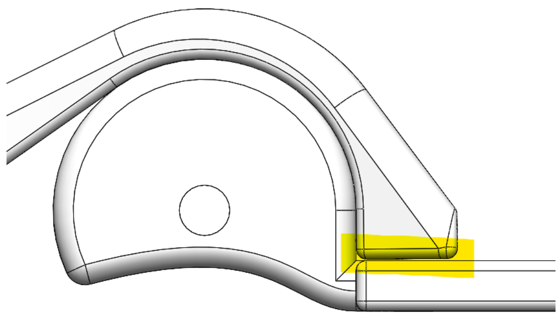

Fig. 8. Hard stop that physically prevents the finger splint from bending past the horizontal line

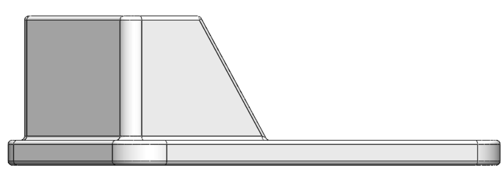

Fig. 9. Angled palm pad to redirect the force when pressing on an object. Reduces stress in the wrist