PaddleOn(e)

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Motivation, Goal, Impact

Motivation Accessibility & Inclusivity
Over a hundred thousand Americans are living with upper limb loss or differences, and millions more suffer from loss of mobility. They face significant barriers to participation in paddle sports such as dragon boat or canoeing. Our sponsor, Adaptive Adventures, is seeking a device that promotes the inclusion of para-athletes.

Goal A Thigh-Mounted Design
Our goal is to create an adaptive paddle attachment that mounts to the thigh. Leveraging the input of experienced paradragon Gary Verrazono, our design addresses pain points of current solutions which present safety hazards, cause discomfort, or are not competition-legal.

Impact Competition and Recreation
Our device makes single-armed paddling safer and more accessible to para-athletes of all levels, from competitive dragon boat racers to recreational canoers.

Requirements

Customer Requirements

- **Accessibility** – Designed specifically for users with one functional arm
- **Operates as Normal Paddle** – Mimics conventional usage of a two-handed paddler
- **Safety** – Does not injure/endanger user during use

Essential Product Functions

- **Stable Mounting** – Attaches securely to a stable point on the user or boat
- **Paddle Connection** – Provides a reliable link between the paddle and the mount
- **Emergency Release** – Designed to break away safely in emergency situations

Engineering Standards

According to International Dragon Boat Federation,

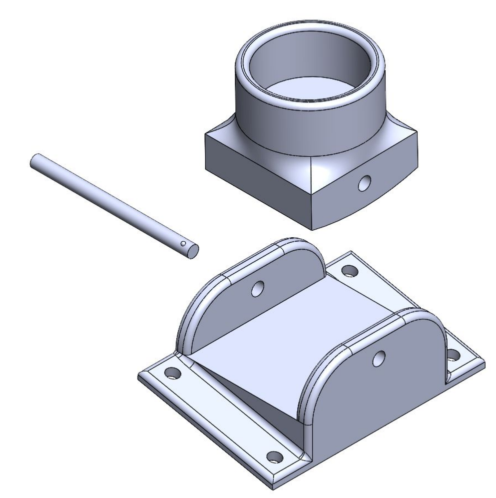
- No motorized or stored-energy assistance
- Device must attach >30 cm above paddle blade
- Quick-release mechanism required

Engineering Characteristics

- **Transmits Force** – Effectively transmits force from user to the water
- **Withstands Stresses** – Can support maximum applied rowing forces during stroke

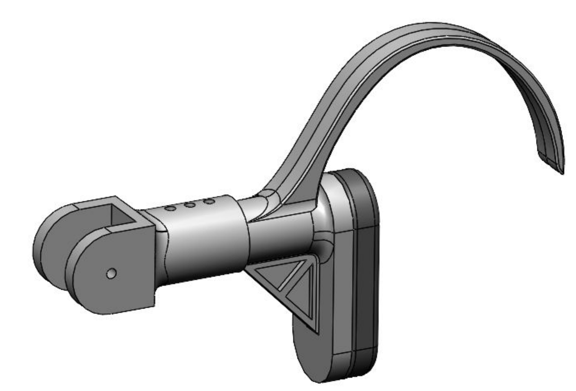
Final Design

Thigh Mount – Inspired by an athletic compression wrap for ergonomic fit, which ensures and stabilizes device movement at the thigh

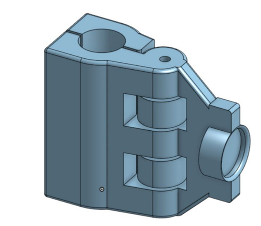


Rocker – Enables natural stroke mechanics by allowing forward and backward rotation at the thigh mount

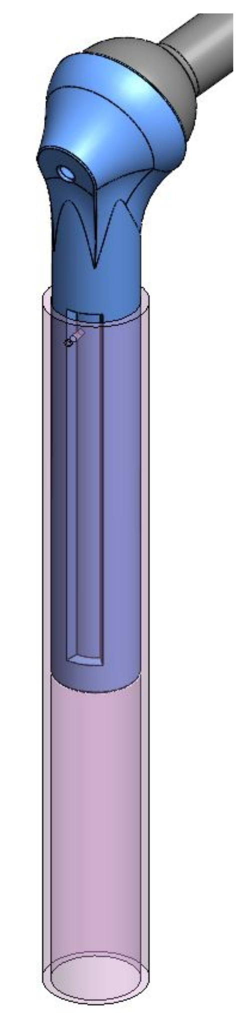
Safety Release – Pull-pin system serves as a hinge for the rocker, and allows the device to disconnect from the thigh mount in case of a capsize emergency.



Shoulder Stock – Provides additional leverage and stability by bracing against the chest and hooking over the shoulder during the stroke. Mimics the second hand by supplying the reactive force on the shaft.



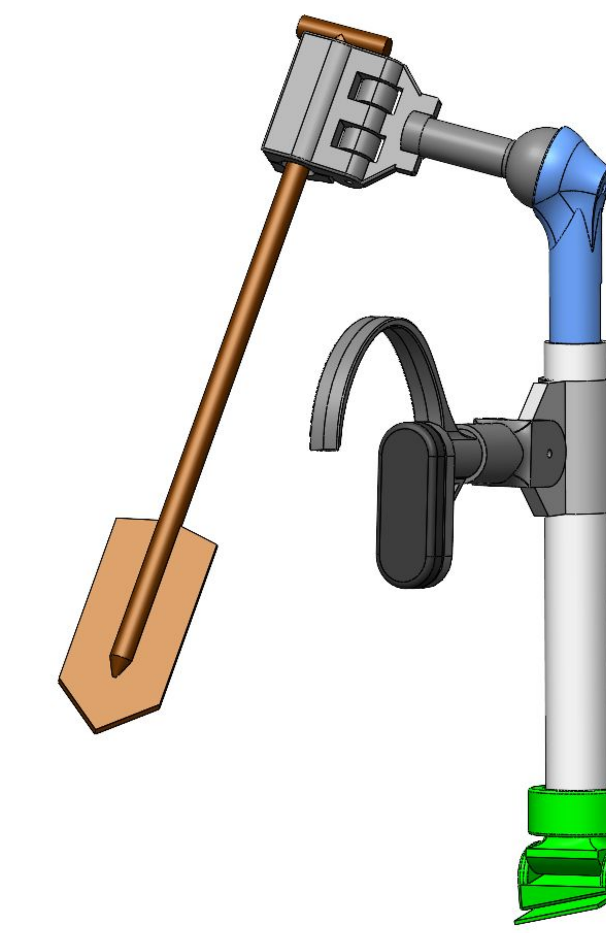
Paddle Attachment – Utilizes a hinging clamp for a firm grip, with a compression based fit usable with both canoe and dragon boat paddles



Ball Joint – Selected based on low-fidelity prototype testing. Allows full range of motion, enabling the user to, angle the paddle forward/backward and lift the paddle easily from the water

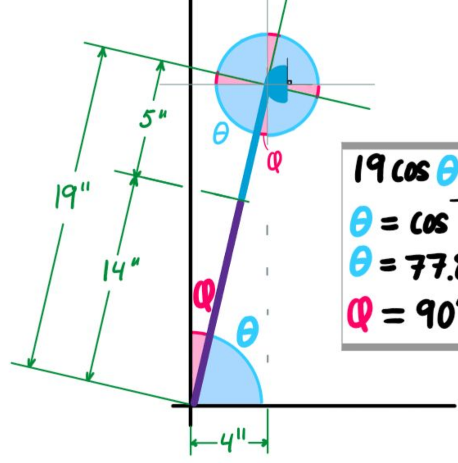
Adjustable Shaft – Extends and rotates, allowing full extension of paddle forward and contraction backward during stroke. Rotation ensures paddle stays perpendicular to user during stroke for optimal propulsion.

Design Assembly



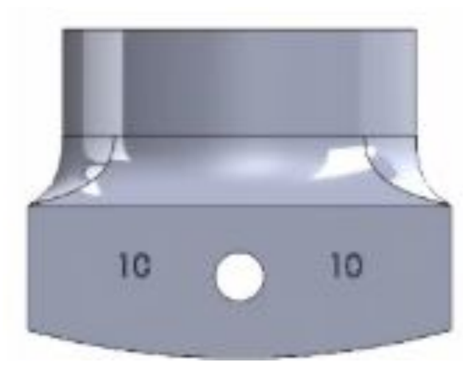
Design Calculations & Decisions

Angle of Departure
Based on the distance from the rower to the side of the boat, and minimum height of our adjustable length shaft, we determined the angle we needed to set the rocker base pointing out of the boat to allow effective paddling.



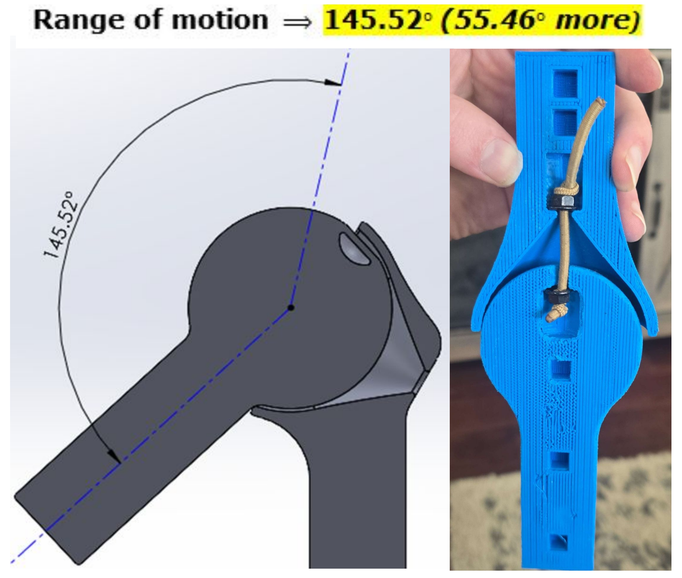
$$19\cos\theta = 4$$
$$\theta = \cos^{-1}(4/19)$$
$$\theta = 77.85^\circ \approx 78^\circ$$
$$\varphi = 90^\circ - \theta = 12^\circ$$

Rocker Range
The curvature of the rocker was calculated to restrict the forward and backward freedom of the paddle. After testing various prototypes, 10° in both directions was found to provide the most freedom, while keeping the shaft from falling away from the user.

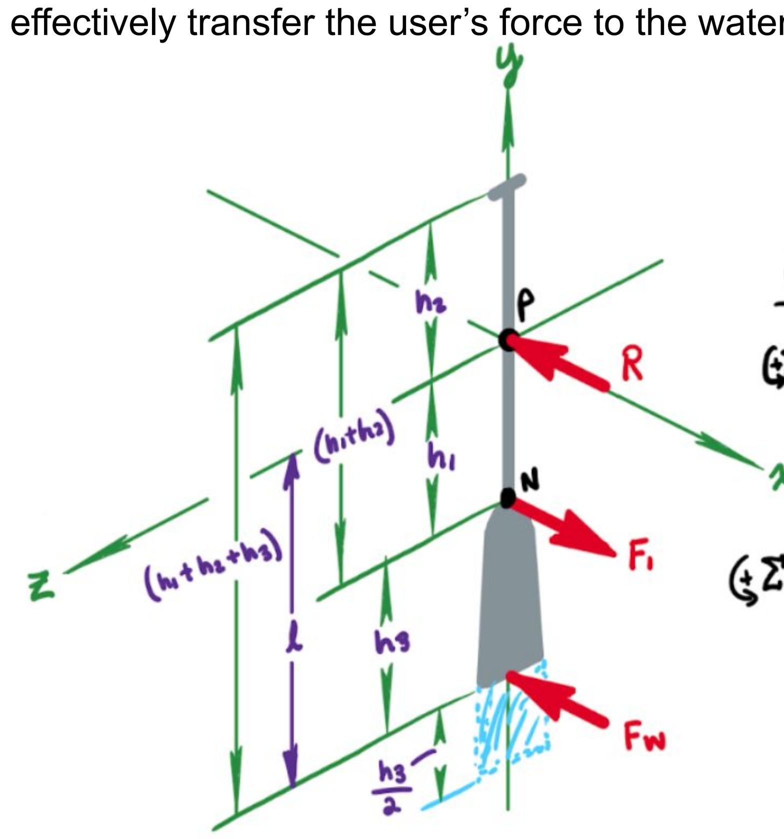


Ball Joint Range
To accommodate stroke variability, we developed an expanded-range ball joint achieving 145.52° of motion. By using an elastic band inspired by human ligaments, we reduced socket coverage while maintaining security. The design increases the range of motion by 55° compared to a 70% coverage joint

Range of motion ⇒ 145.52° (55.46° more)



Paddle Reactions
Assuming the paddle is vertical during the drive phase of the stroke (when paddling force is greatest), we applied moment equilibrium to derive an equation relating the user's pulling force (F_1), the reaction force at the attachment (R), and the water resistance force (Fw). This analysis defines the mechanical requirements the design must meet to effectively transfer the user's force to the water.



One - Arm

Equillibrium: $\circlearrowleft^{+} \sum M_{P_z} = 0$

$$\circlearrowleft^{+} \sum M_{P_z} = F_1(h_1) - F_w(l) = 0$$
$$\boxed{\frac{F_w}{F_1} = \frac{h_1}{l} = 0.3725}$$
$$\circlearrowleft^{+} \sum M_{N_z} = 0 = R h_1 - F_w h_3$$
$$\Rightarrow \boxed{R = \frac{F_w h_3}{h_1}}$$

Clamp Inner Diameter
The clamp fits tightly to the paddle to restrict any motion. Its inner diameter matches the outer diameter of the paddle. To ensure a secure grip and prevent damage the paddle, the inner diameter of the clamp is lined with a flexible 80A resin that compresses around the paddle shaft. Additionally, the resin has a high coefficient of friction (0.9) that will prevent sliding.

Prototype & Test Results

Thigh Mount Pull Tests
The thigh mount was tested to see how secure it is to the user by applying a force to pull the mount down or across the user. The dry tests were performed on a user with athletic shorts, whereas in the wet tests the user wore a wet swimsuit under a wet thigh strap.

Downwards Tests:

Test Type	Average Force (lbs)
Dry - Bent Leg	14.3
Wet - Straight Leg	4.4
Wet - Bent Leg	6.2

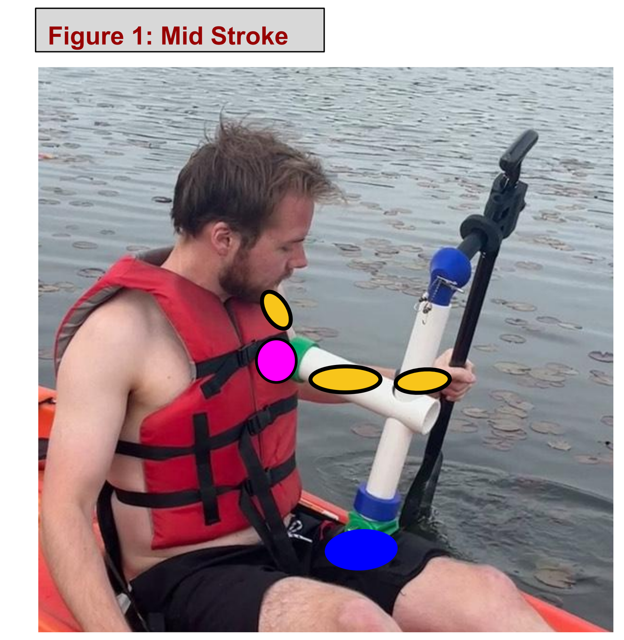
Sideways Tests:

Test Type	Average Force (lbs)
Dry - Bent Leg	18.5
Dry - Bent Leg w/ Neoprene	13.5

This data gave us insight into the effectiveness of our thigh strap as a secure connection to the body. We found that when wet, the strap becomes more susceptible to motion. However, because the shoulder stock absorbs most of the force from the paddle, shifting is limited and the thigh strap nonetheless offers a secure connection to the user.

Force and Exertion on Body

Figure 1: Mid Stroke



Key:
Exertion: Light Heavy
Pressure on Body: Light Heavy

Figure 2: Stroke Start

Note: The red and yellow circles reference the forearm, bicep, and shoulder

Safety Pin Pull Tests
The most important subsystem of our device is the safety pin, which allows the user to detach the device from their body in a capsize event. We tested the amount of force required to pull the pin out by hand and by moving the leg.

Test Type	Average Force (lbs)
Hand Pull Pin Test	7.2
Leg Pull Pin Test	3.5

According to the ISO Ergonomics data from the BSI Standards Publication, for the weakest age group of 80+ individuals, the average pulling force for men and women is 58 and 35 lbs. Only 0.03% and 0.1% of men and women respectively would fall below the strength threshold of 7.2 lbs. Therefore, our safety pin is adequately accessible for disabled individuals.