MAE 189 Capstone Design

Portable Shoulder Exercise Device
Professor Reinkensmeyer
October 28, 2022
Team Members

Crystal Militante
Lauren Lin
Kameron Ahmed
Leadson Teles da Silva
Tyler Sanchez
Derek Jesus Ortiz
Overview

The UCI Medical Clinic wants a shoulder rehabilitation device that is portable but has self-stability. Patients need assistance with reaching their arm to higher elevations while allowing the extension of the elbow.

- Clinic has self-fabricated and purchased parts
  - Enhances the patient’s available movements
  - Optimizes normal movement patterns
- Self-fabricated Items
  - PVC pipe push frame, PVC pipe (¼”) for overhead movement
- Purchased Items
  - Saebo Glide: a pole that facilitates vertical motion
  - UE Ranger: rotating rod that assists with various movements

Kameron Ahmed
Objective

- Occupational therapists at the UCI Medical Center are looking for a portable shoulder device
  - Rehabilitates the shoulder of patients with weak arms (due to stroke, spinal cord injury, or other diseases)

- Specifications for the device:
  - Portable (the clinic has limited space)
  - Accessible in a sitting and supine position
  - Reproduce the trajectory of the hand during shoulder flexion over the head
  - Provide a counter-weight to support the arm and allow an adjustable range of motion
  - Want to connect the device to a computer and/or a smartphone and watch
    - Track the patient’s progress

- Budget: $1000

Crystal Militante
## Gantt Chart – Progress From Week 2–5

### Figure 1: Gantt Chart for Week 2–5

**Lauren Lin**

<table>
<thead>
<tr>
<th>WBS NUMBER</th>
<th>TASK TITLE</th>
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Research on Mobilization

- Approximate total arm weight:
  Males - 5.70% B.W. & Females - 4.97% B.W.
  - Average weight of 50–60 year old males in the U.S.: ~201 lbs
    - Arm weight is approximately 5.70% = ~11.5 lbs
  - Average weight of 50–60 year old females in the U.S.: ~165 lbs
    - Arm weight is approximately 4.97% = ~8.20 lbs

- New device under guidelines will mainly target the anterior deltoid, the muscle used in shoulder flexion
  - Other muscles involved include the lateral deltoid, serratus anterior, upper and lower trapezius, etc.

Kameron Ahmed
Calculations

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]
Design 1

Landmine Press
Landmine Press – Overview

An adjustable, pivoting rod which supports and assists patients with shoulder movement in the sagittal plane

- Varying resistance bands can be attached to compensate for the weight of the arm
- The rotating rod is adjustable in length and location on the center beam
  - Accommodate for different heights and ranges of motions
- Revolute joint allows for only one degree of freedom
- Usable sitting, standing, or lying down on a yoga mat
Landmine Press – Design Process

- Initial design was complicated, and had limited uses
- Next iterations were inspired by gym equipment
- Biggest issue was finding a way for the device to be used lying down, and finding a suitable base design
Landmine Press – Demonstration

Figure 7: Demonstration of Landmine Press
Landmine Press – CAD Model

- Rod Sizing
  - Rod fully extended – 6.0 ft
  - Rod fully retracted – 3.5 ft
  - Handle – 6 in

- Base Shape
  - Base length from center beam – 2.0 ft
  - Base legs extending from either side – 18 in

Figure 8: CAD model of Landmine Press
Figure 9: CAD fully assembly of Landmine Press
Landmine Press – Animation

- Device
- Movement
- Exploded View
Landmine Press – Calculations

- Torque induced by gravity
  - Sum of the forces will help us determine ideal resistance bands for the average woman and man
  - Calculate the torque when the rod is fully extended and retracted

\[ T_{3g} = -m_3 \left(\frac{1}{2}\right) r_3 \times g = g\left(\frac{1}{2}m_3 l_3 c_{123}\right) \]
\[ T_{2g} = T_{3g} - m_3 \left(\frac{1}{2}\right) r_2 \times g - m_3 r_2 \times g \]
\[ = g\left(\frac{1}{2}m_2 + m_3\right) l_2 c_{12} + \left(\frac{1}{2}\right)m_3 l_3 c_{123}\right) \]
\[ T_{1g} = T_{2g} - m_1 \left(\frac{1}{2}\right) r_1 \times g - (m_2 + m_3) r_1 \times g \]
\[ = g\left(\left(\frac{1}{2}m_1 + m_2 + m_3\right) l_1 c_1 \right) \]
\[ + \left(\frac{1}{2}\right)m_2 + m_3) l_2 c_{12} + \left(\frac{1}{2}\right)m_3 l_3 c_{123}\right) \]

Figure 11: Free body Diagram of a Three bar linkage from Kinematics, Statics, and Dynamics

Figure 12: Equations for the torques induced by gravity from Kinematics, Statics, and Dynamics
## Landmine Press – Bill of Materials (Prototype)

<table>
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<tr>
<th>COMPONENT</th>
<th>MATERIAL</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
<th>*COST</th>
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<tbody>
<tr>
<td>BASE ROD</td>
<td>2” SCH. 40 PVC</td>
<td>3.5’</td>
<td>$2.19/ft</td>
<td>$8.26</td>
</tr>
<tr>
<td>CENTER ROD</td>
<td>1.5” THIN WALL PVC</td>
<td>3.0’</td>
<td>$3.56/ft</td>
<td>$11.51</td>
</tr>
<tr>
<td>HANDLE BAR</td>
<td>2” SCH. 40 PVC</td>
<td>0.5’</td>
<td>$2.19/ft</td>
<td>$1.18</td>
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<tr>
<td>CENTER BEAM</td>
<td>PERFORATED ALUMINUM ROD</td>
<td>5.0’</td>
<td>$12.66/ft</td>
<td>$68.21</td>
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<tr>
<td>H-STAND</td>
<td>ALUMINUM ROD</td>
<td>6.0’</td>
<td>$3.62/ft</td>
<td>$23.42</td>
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<td>MOUNTING PLATE</td>
<td>5/32” ALUMINUM SHEET</td>
<td>144 ft²</td>
<td>$0.15/ft²</td>
<td>$23.69</td>
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<tr>
<td>EYE-BOLTS</td>
<td>¾”X4” ZINC PLATED</td>
<td>2 units</td>
<td>$1.38/unit</td>
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<td><strong>$139.24</strong></td>
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*The costs and total are estimates that include sales tax (7.75%) but are subject to change*
# Landmine Press – Feasibility

<table>
<thead>
<tr>
<th><strong>PROS</strong></th>
<th><strong>CONS</strong></th>
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<tbody>
<tr>
<td>- Usable in various orientations: can work on different arm muscles</td>
<td>- Does not allow bending of the elbow at the highest point</td>
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<td>- Most medical clinics already have resistance bands</td>
<td>- Multiple adjustment points: rod length, position on the center beam</td>
</tr>
<tr>
<td>- Length of the rod and height of the joint are easily adjustable</td>
<td>- Bulky Base</td>
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<tr>
<td>- Simple design</td>
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Tyler Sanchez
Design 2

PinWheel
PinWheel—Overview

A spinning wheel on a supported base that assists arm movement in the sagittal plane

- Multiple hole locations for handlebar attachment:
  - Dual wheels enables use of both arms
  - Accommodates for varying arm lengths & range of motion
- Telescopic square post:
  - Connects the main wheel to the base
  - Adjustable height for sitting, laying down, and standing
- Weight mount attached to the end of the wheels to act as a counterbalance:
  - Different weights available for optimal use
  - Collapsible for ease of portability

Crystal & Kameron
PinWheel – Design Process

Inspiration:
- Upside down bicycle
- Pirate ship wheel
- Pegs for bikes
- Gym equipment for backs

Key decisions:
- Keep wheel idea
- Pegs as handlebars
- Collapsible
- Adjustable holes

Crystal Militante
PinWheel – CAD Model / Animation

PinWheel Sizing
- ~2.5 ft diameter
- Average arm length: 25 in.

Post Sizing
- Fully Extended: 8 feet
- Retracted: 4 feet

Handle Sizing
- Optimal handle diameter is 19.7 percent of the user’s hand length
  - Avg. hand length for males: 7.6 in.
  - Avg. hand length for females: 6.8 in.
  - Therefore, optimal handle diameter ~ 1.5 in.

Derek Ortiz
Design 2- PinWheel Calculations

- Can find force-balance equations due to the gravity loading
  - $m_1$: bicep
  - $m_2$: forearm
- Resultant torques are linear in the applied forces,
  - We can use the principle of superposition
  - Calculate the gravity induced torques separately

No applied force at the tip we find:

These terms can now be added to the torque terms derived for balancing the force applied at the tip.

Crystal Militante
## PinWheel – Bill of Materials (Prototype)

<table>
<thead>
<tr>
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<th>MATERIAL</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
<th>*COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONE HANDLES (3D-PRINTED)</td>
<td>CARBON FIBER FILAMENT</td>
<td>1</td>
<td>$0.85/oz.</td>
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</tr>
<tr>
<td>MAIN WHEEL</td>
<td>WOOD</td>
<td>2</td>
<td>$24.99</td>
<td>$53.86</td>
</tr>
<tr>
<td>SQUARE POST STAND</td>
<td>GALVANIZED STEEL</td>
<td>1</td>
<td>$9.625/ft.</td>
<td>$62.23</td>
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<tr>
<td>WHEELS (FOR BASE)</td>
<td>POLYURETHANE</td>
<td>4</td>
<td>$15 per wheel</td>
<td>$64.65</td>
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<tr>
<td>BOLTS</td>
<td>ZINC PLATED STEEL</td>
<td>16</td>
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<td>HINGE</td>
<td>ZINC ALLOY</td>
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<td>$6.175/ft.</td>
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<td>VELCRO</td>
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<td>PINS</td>
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Figure 25: BOM for the PinWheel prototype
## PinWheel – Feasibility

<table>
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<th>PROS</th>
<th>CONS</th>
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<tr>
<td>- Self set up</td>
<td>- Heavy</td>
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<tr>
<td>- Optimal use for sitting, standing, and laying down</td>
<td>- Bulky</td>
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<td>- Adjustable for any size</td>
<td>- Issues with portability</td>
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<td>- Inner part of wheel: use for smaller stretches reaching forward</td>
<td>- Unable to use both arms when lying down</td>
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<tr>
<td>- Outer part of wheel: higher reach and stretching overhead</td>
<td>- Significantly more expensive materials</td>
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<td>- Able to use both arms if needed</td>
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Next Steps

**Landmine Press**
- Add a joint towards the end of the rod
  - Allow the elbow to bend when elevated
- Make the base able to fold
  - Improves portability of device
- Improve the design of the handle
  - Allows for grip rotation

**PinWheel**
- Update weight mount and handles design
- Material of pinwheel
- Add damper/Stopper
  - Prevent weight from damaging or colliding into the base

*Figure 26: Rotating Handle*
# Gantt Chart – Week 6–10

**GANTT CHART**

**PROJECT TITLE:** Portable Shoulder  
**TEAM MEMBERS:** Crystal Militante, Derek Ortiz, Lauren Lin, Leadson Tele, Kameron Ahmed, Tyler Sanchez  
**DATE:** 10/27/2022

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**Smartsheet Tip ➔** A Gantt chart’s visual timeline allows you to see details about each task as well as project dependencies.

*Figure 27: Gantt Chart for Week 6–10*
Thank You

Any Questions?
Resources

https://www.healthline.com/health/average-hand-size#children
https://robslink.com/SAS/democd79/body_part_weights.htm
https://www.verywellfit.com/average-weight-for-a-man-statistics-2632139
https://people.csail.mit.edu/bkph/articles/Kinematics_Static_Dynamics_2.pdf