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

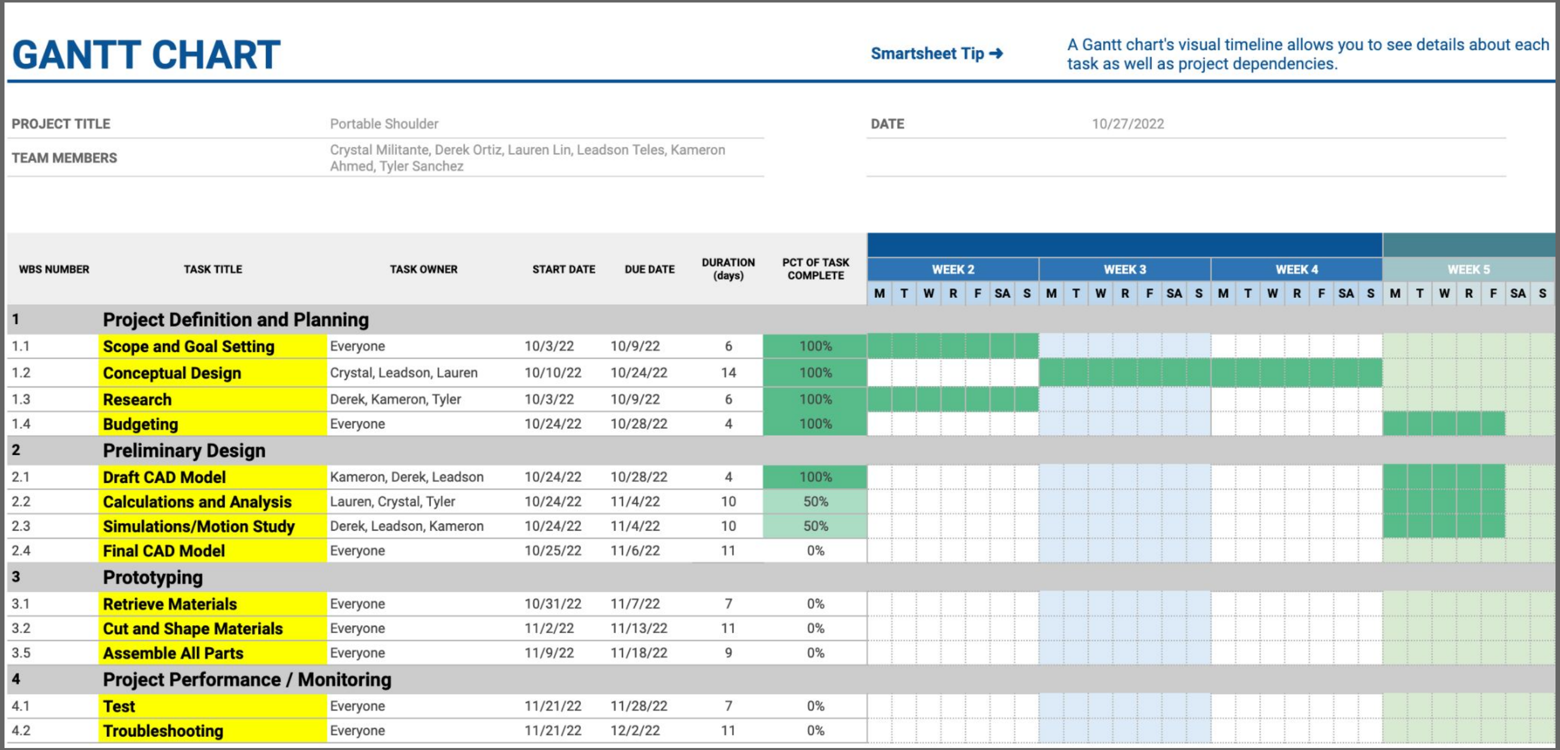
Kameron Ahmed

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



GANTT CHART

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

PROJECT TITLE Portable Shoulder

TEAM MEMBERS Crystal Militante, Derek Ortiz, Lauren Lin, Leadson Teles, Kameron Ahmed, Tyler Sanchez

DATE 10/27/2022

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION (days)	PCT OF TASK COMPLETE	WEEK 2							WEEK 3							WEEK 4							WEEK 5						
							M	T	W	R	F	SA	S	M	T	W	R	F	SA	S	M	T	W	R	F	SA	S	M	T	W	R	F	SA	S
1	Project Definition and Planning																																	
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1.3	Research	Derek, Kameron, Tyler	10/3/22	10/9/22	6	100%	🟩	🟩	🟩	🟩	🟩	🟩	🟩																					
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Lauren Lin

Figure 1: Gantt Chart for Week 2-5

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.: ~165lbs
    - 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.

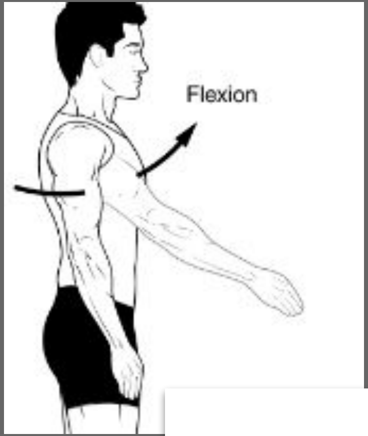

Figure 2: Shoulder Flexion

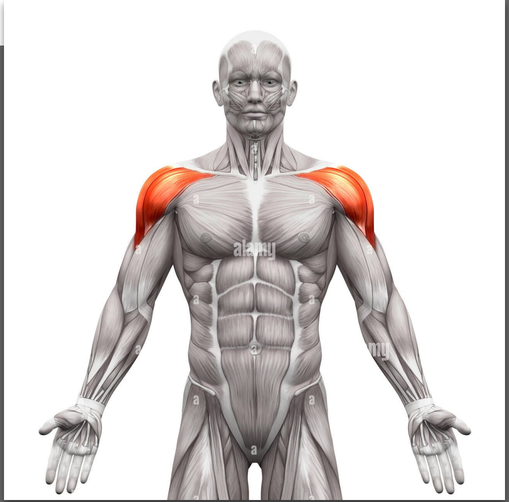

Figure 3: Anterior Deltoid Muscle

Kameron Ahmed

Calculations

Figure x: image of calculation

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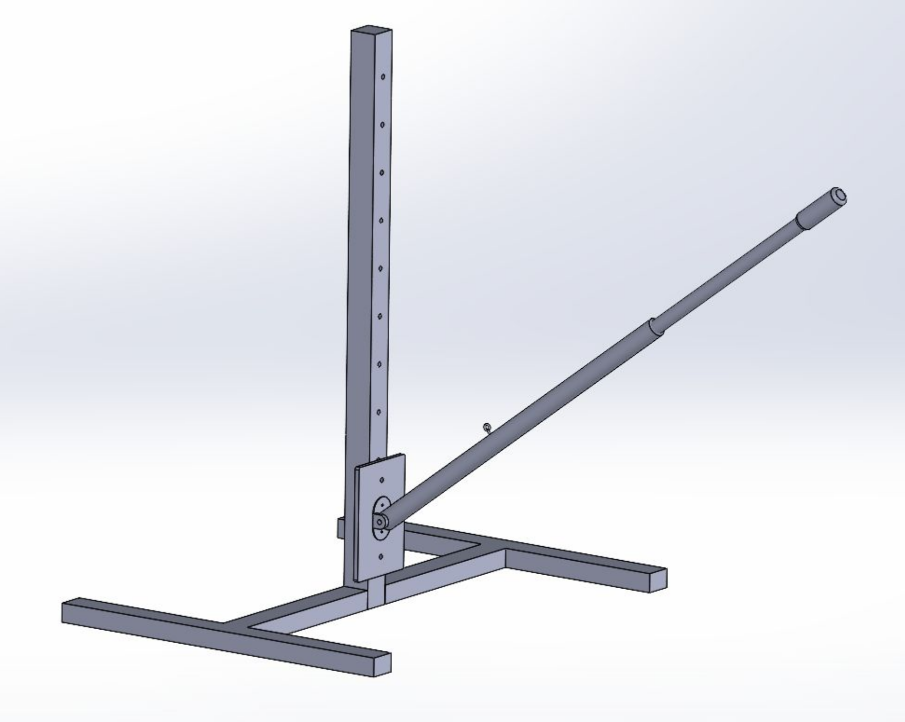
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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

Lauren Lin

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

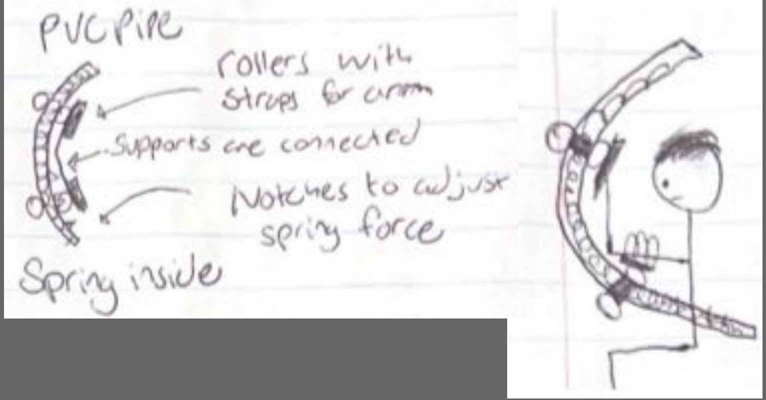


Figure 4: Initial sketch

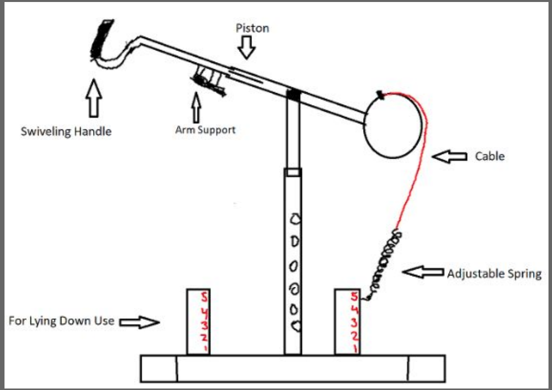


Figure 5: Second Redesign

Figure 6: Landmine Press

Tyler Sanchez

Landmine Press – Demonstration

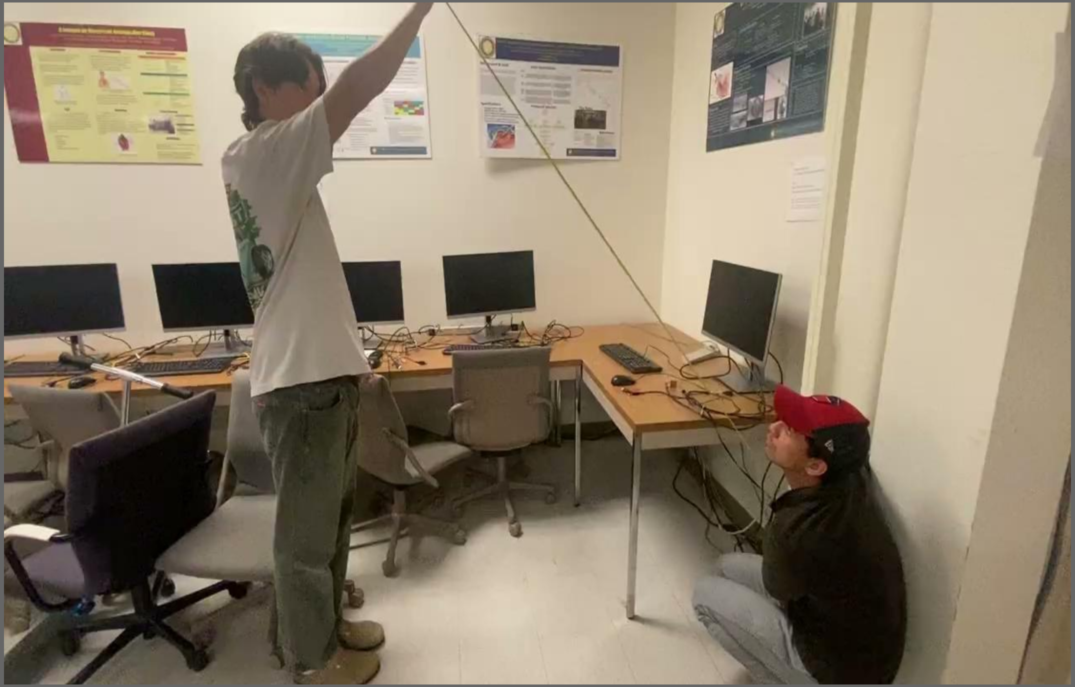


Figure 7: Demonstration of Landmine Press

Tyler Sanchez

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

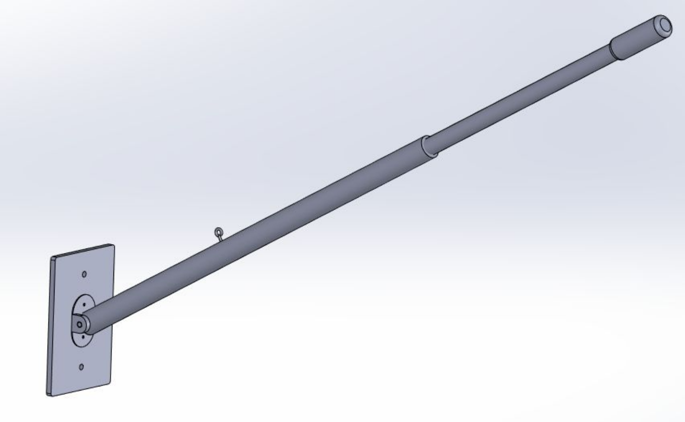


Figure 8: CAD model of Landmine Press

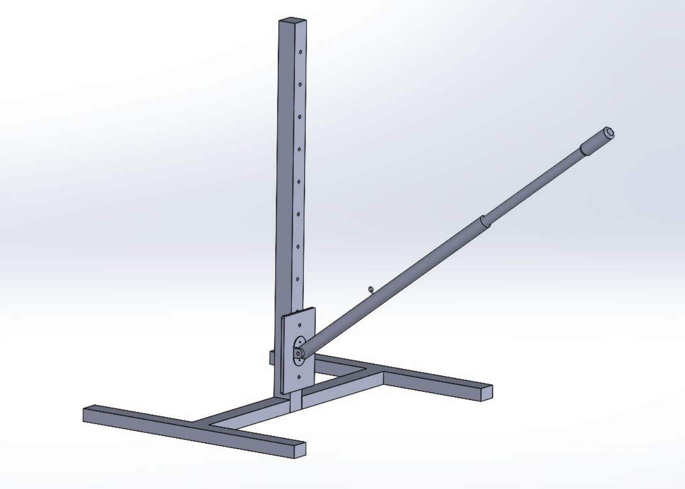


Figure 9: CAD fully assembly of Landmine Press

Leadson Teles

Landmine Press- Animation

- Device Movement
- Exploded View

Figure 10: Animation of Landmine Press

Leadson Teles

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

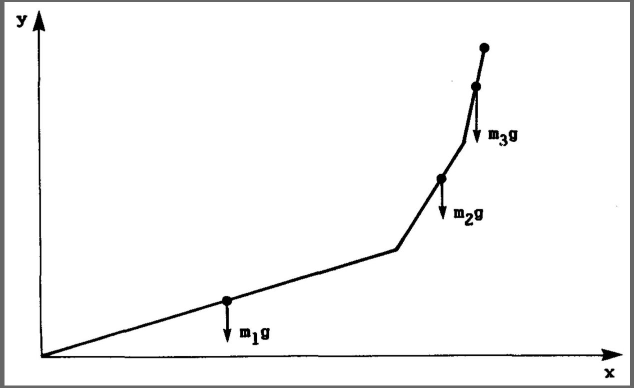
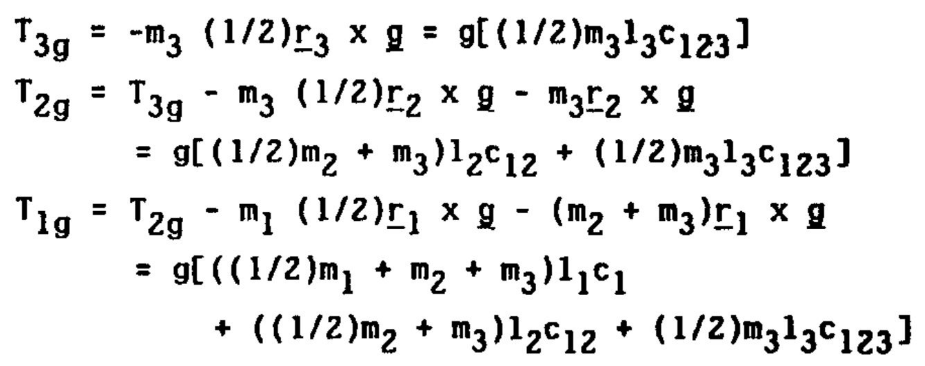


Figure 11: Free body Diagram of a Three bar linkage from Kinematics, Statics, and Dynamics



$$T_{3g} = -m_3\ (1/2)\underline{r}_3 \ x\ \underline{g} = g[(1/2)m_3 l_3 c_{123}]$$

$$T_{2g} = T_{3g} - m_3\ (1/2)\underline{r}_2 \ x\ \underline{g} - m_3\underline{r}_2 \ x\ \underline{g}$$

$$= g[(1/2)m_2 + m_3)l_2 c_{12} + (1/2)m_3 l_3 c_{123}]$$

$$T_{1g} = T_{2g} - m_1\ (1/2)\underline{r}_1 \ x\ \underline{g} - (m_2 + m_3)\underline{r}_1 \ x\ \underline{g}$$

$$= g[((1/2)m_1 + m_2 + m_3)l_1 c_1$$

$$+ ((1/2)m_2 + m_3)l_2 c_{12} + (1/2)m_3 l_3 c_{123}]$$

Figure 12: Equations for the torques induced by gravity from Kinematics, Statics, and Dynamics

Lauren Lin

Landmine Press – Bill of Materials (Prototype)

COMPONENT	MATERIAL	QUANTITY	UNIT COST	*COST
BASE ROD	2" SCH. 40 PVC	3.5'	$2.19/ft	$8.26
CENTER ROD	1.5" THIN WALL PVC	3.0'	$3.56/ft	$11.51
HANDLE BAR	2" SCH. 40 PVC	0.5'	$2.19/ft	$1.18
CENTER BEAM	PERFORATED ALUMINUM ROD	5.0'	$12.66/ft	$68.21
H-STAND	ALUMINUM ROD	6.0'	$3.62/ft	$23.42
MOUNTING PLATE	5/32" ALUMINUM SHEET	144 ft^2	$0.15/$ft^2$	$23.69
EYE-BOLTS	⅜"X4" ZINC PLATED	2 units	$1.38/unit	$2.97
***TOTAL**				**$139.24**

Figure 13: BOM for the Landmine Press prototype

Lauren Lin

**The costs and total are estimates that include sales tax (7.75%) but are subject to change*

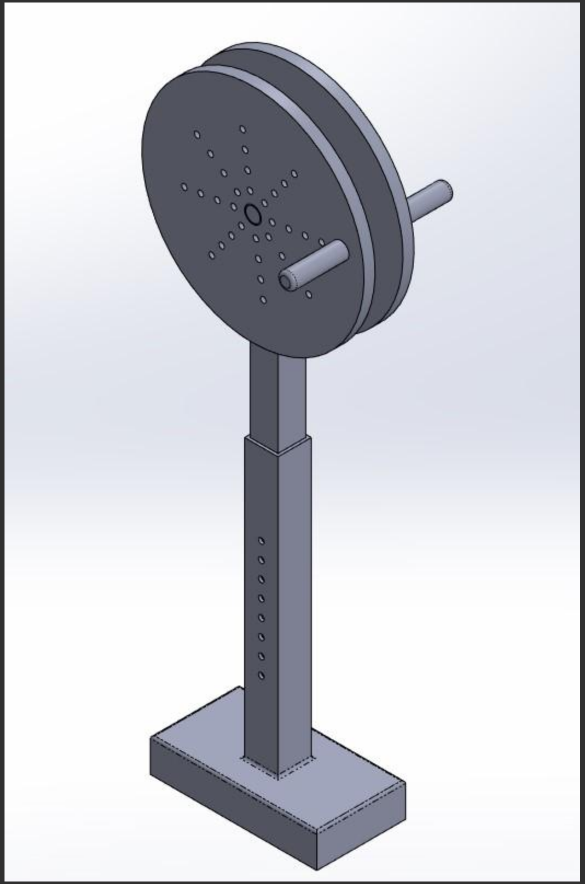
Landmine Press- Feasibility

PROS	**CONS**
- Usable in various orientations: can work on different arm muscles - Most medical clinics already have resistance bands - Length of the rod and height of the joint are easily adjustable - Simple design	- Does not allow bending of the elbow at the highest point - Multiple adjustment points: rod length, position on the center beam - Bulky Base

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

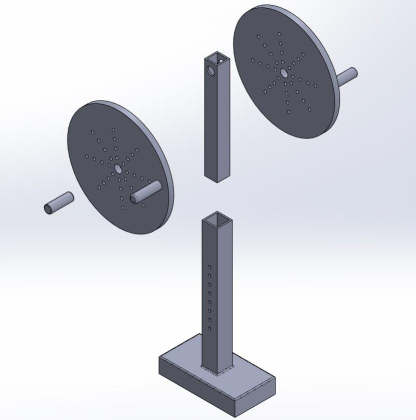


Figure 14: Exploded View of PinWheel

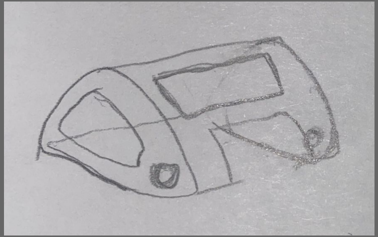


Figure 15: Weight Mount Sketch

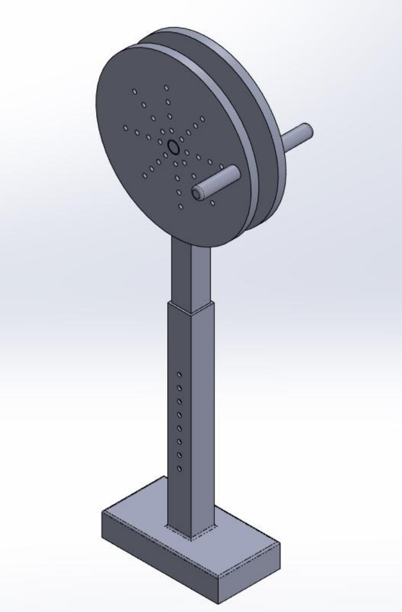


Figure 16: CAD model of PinWheel

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

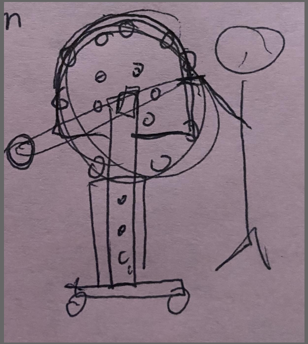


Figure 17: Initial Sketch

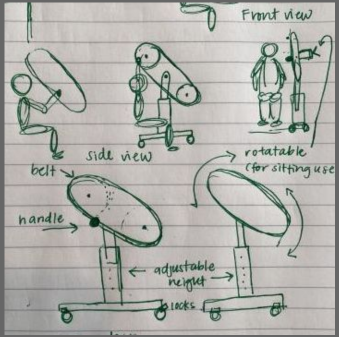


Figure 18: Redesign

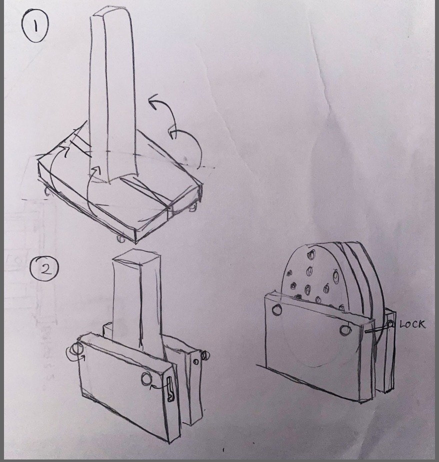


Figure 19: Collapsible Sketch of Design

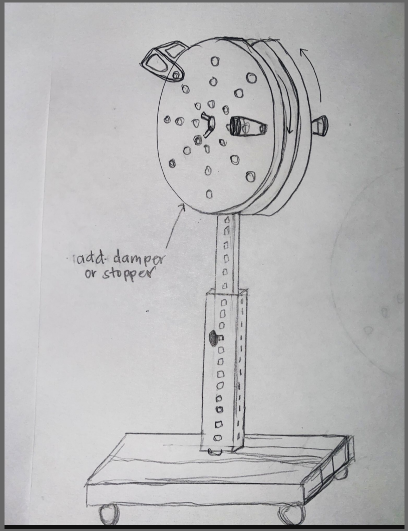


Figure 20: Current Sketch of Design

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.

Figure 21: Animation of PinWheel

Derek Ortiz

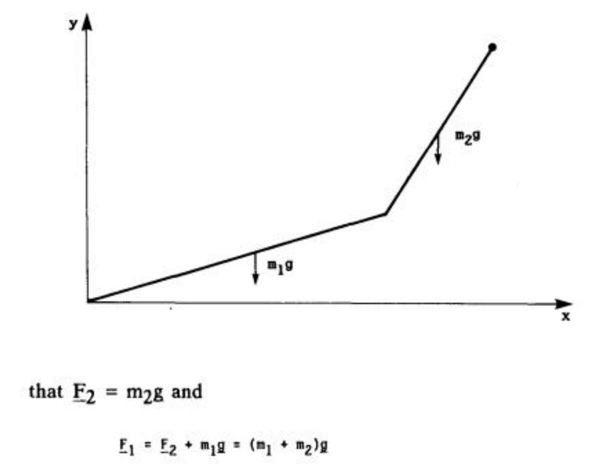
Design 2- PinWheel Calculations

- Can find force-balance equations due to the gravity loading
    - m1: bicep
    - m2: 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.

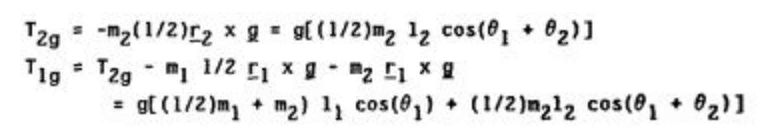
Crystal Militante



that $\underline{F}_2 = m_2g$ and

$$\underline{F}_1 = \underline{F}_2 + m_1\underline{g} = (m_1 + m_2)\underline{g}$$

Figure 23: Diagram shows the linkage of the user's arm



$$T_{2g} = -m_2(1/2)\underline{r}_2 \times \underline{g} = g[(1/2)m_2\ l_2 \cos(\theta_1 + \theta_2)]$$

$$T_{1g} = T_{2g} - m_1\ 1/2\ \underline{r}_1 \times \underline{g} - m_2\ \underline{r}_1 \times \underline{g}$$

$$= g[(1/2)m_1 + m_2)\ l_1 \cos(\theta_1) + (1/2)m_2l_2 \cos(\theta_1 + \theta_2)]$$

Figure 24: 2 Bar Linkage torque equation

PinWheel – Bill of Materials (Prototype)

COMPONENT	MATERIAL	QUANTITY	UNIT COST	*COST
CONE HANDLES (3D-PRINTED)	CARBON FIBER FILAMENT	1	$0.85/oz.	$32.31
MAIN WHEEL	WOOD	2	$24.99	$53.86
SQUARE POST STAND	GALVANIZED STEEL	1	$9.625/ft.	$62.23
WHEELS (FOR BASE)	POLYURETHANE	4	$15 per wheel	$64.65
BOLTS	ZINC PLATED STEEL	16	$0.3264/pc.	$5.63
HINGE	ZINC ALLOY	4	$6.175/ft.	$26.61
VELCRO	NEOPRENE/NYLON	30 in.	$1.983/ft.	$5.34
PINS	STAINLESS STEEL	2	$4.645/pc.	$10.01
***TOTAL**				**$260.64**

Figure 25: BOM for the PinWheel prototype

Derek Ortiz

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PinWheel – Feasibility

PROS	**CONS**

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

Crystal & Kameron

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

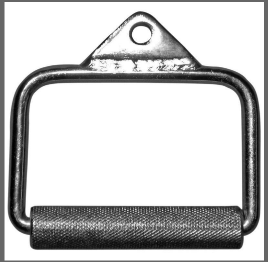


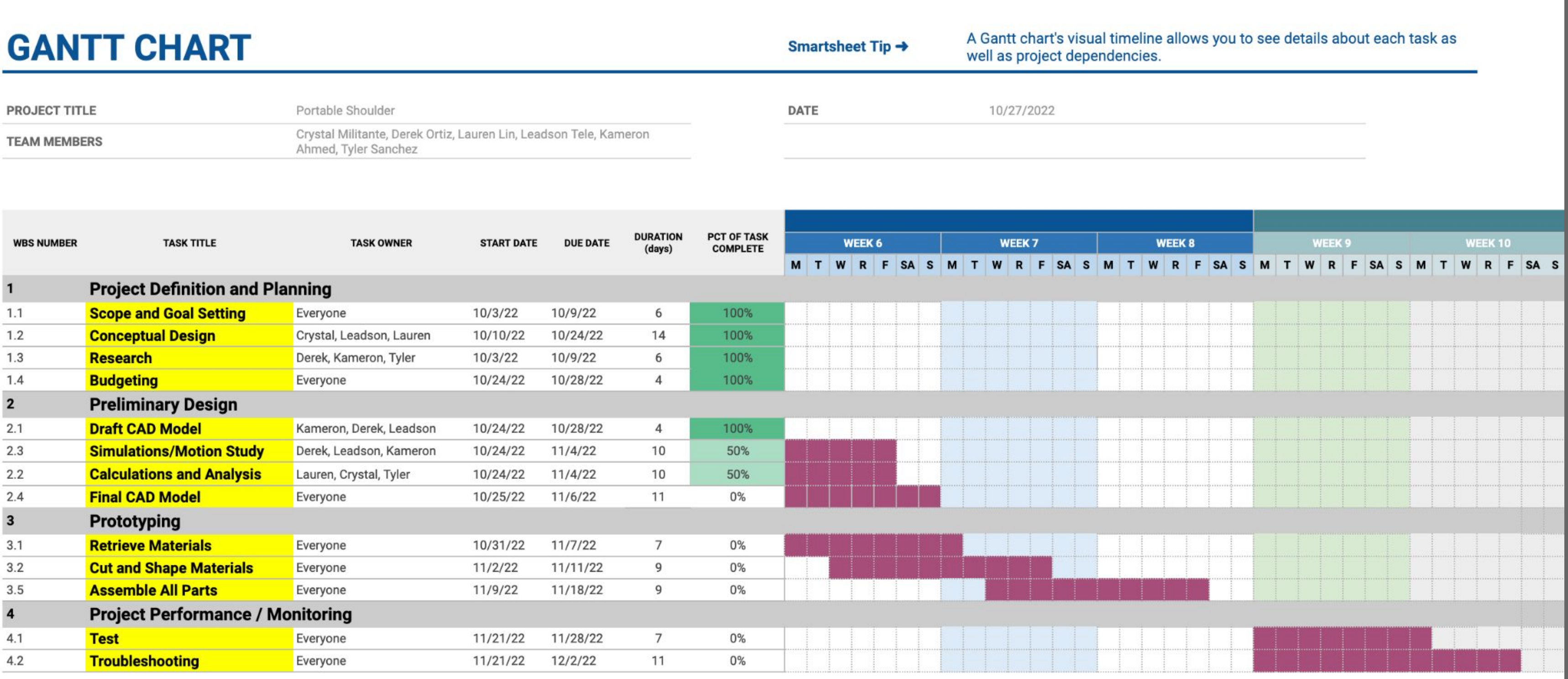
Figure 26: Rotating Handle

PinWheel

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

Leadson & Derek

Gantt Chart – Week 6-10



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WBS NUMBER	WEEK 6							WEEK 7							WEEK 8							WEEK 9							WEEK 10						
	M	T	W	R	F	SA	S	M	T	W	R	F	SA	S	M	T	W	R	F	SA	S	M	T	W	R	F	SA	S	M	T	W	R	F	SA	S
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Figure 27: Gantt Chart for Week 6-10

Lauren Lin

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_Statics_Dynamics_2.pdf