Year-End Documentation

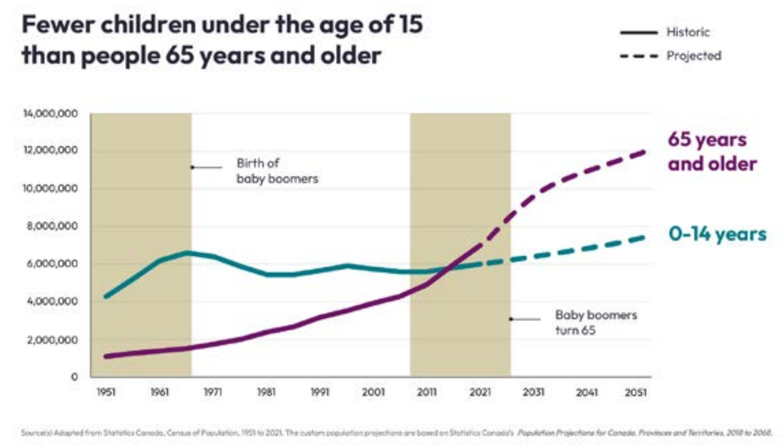
Gait Maintenance For Seniors

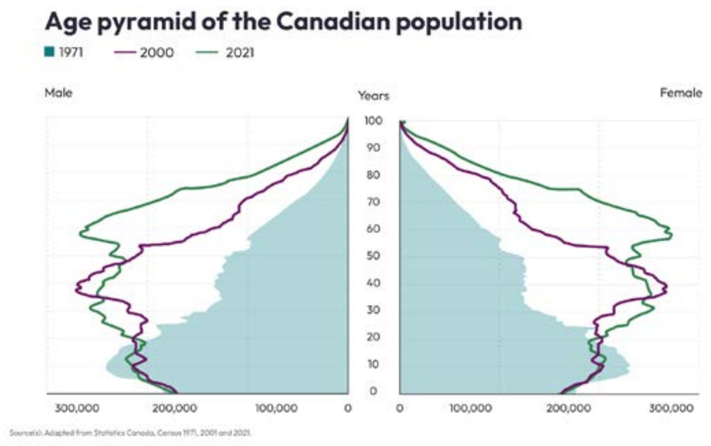
ren

Tom Sun

Contents

Global Context

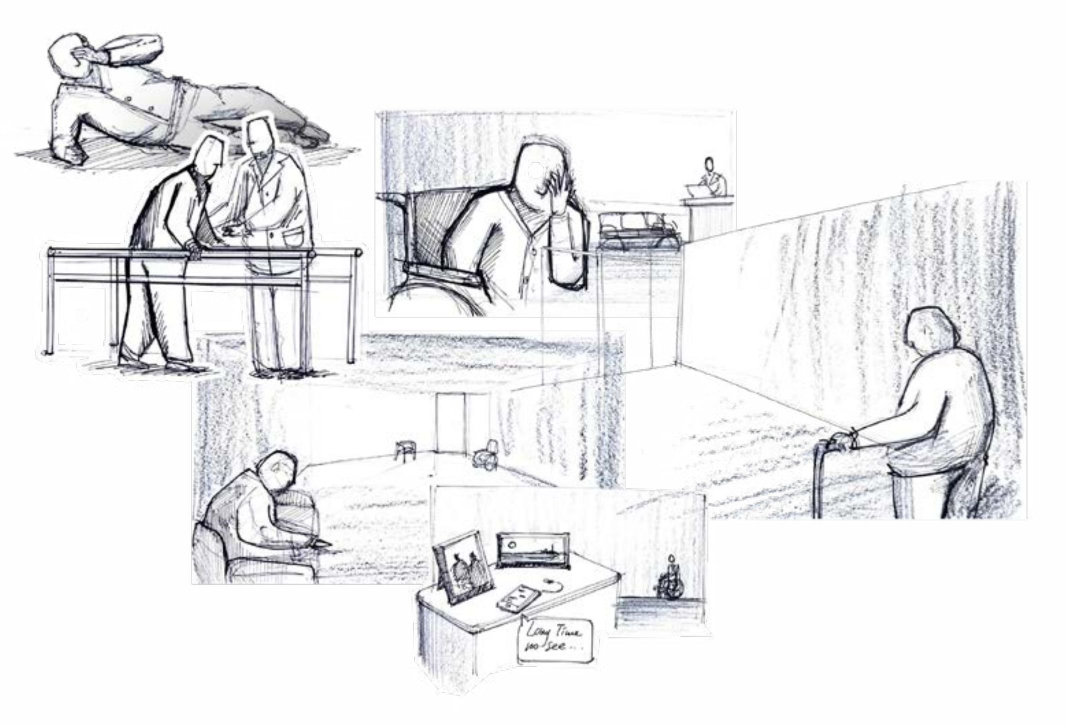




Low birthrate is relevant in many countries across the world. The senior population is rapidly increasing, however care-givers and care-taking resources are limited. As most seniors age in place, mobility and independence becomes a critical issue.

This promotes a longevity perspective of thinking about mobility assistance for the aging population. Devices and systems to help maintain mobility and independence, and to improve quality of life.

User Context



Persona

Grandparents
Age: 75-85
Experiencing sarcopenia
(Age related muscle-loss)

I lives alone in a small rural town. My children live in the near by city where my grand children goes to school. I get visits and frequent calls. Day to day, I find him-self spending less time outside, or with friends, unable to go to the market, and becoming more sedentary. The doctor advices me to exercise daily. However, my regular walkers and rotator no long make me feel confident about walking. I long for the days where I could walk regularly.

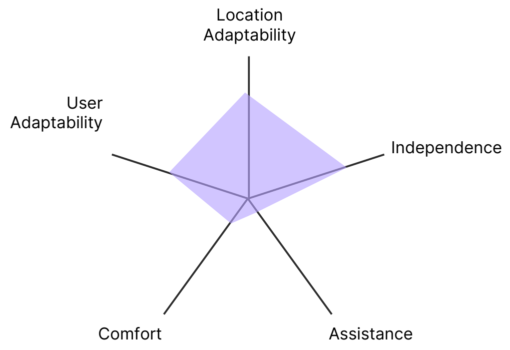
Aging and the Quality of Life

Human mobility begins to decline around the early 50s, and aging-related diseases become more common. Seniors often become less active due to declining confidence, leading to sedentary behavior and accelerated physical decline.

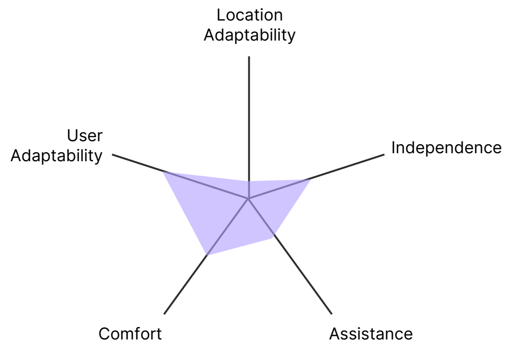
Quality of Life is a subjective view on one's life based on health, comfort, and ability to participate in activities and special occasions. With the decline of physical ability, psy-chological aspects would also be impacted; resulting in low confidence and reluctance.

Market Analysis

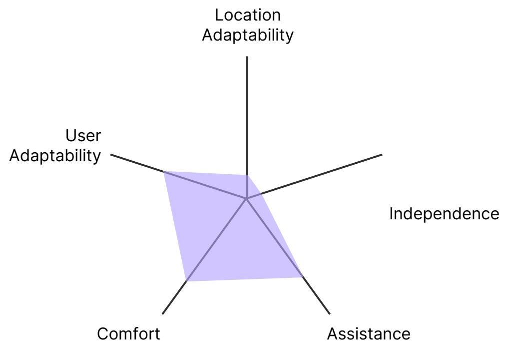
$20 - $100



$350 - $500



- $6000+

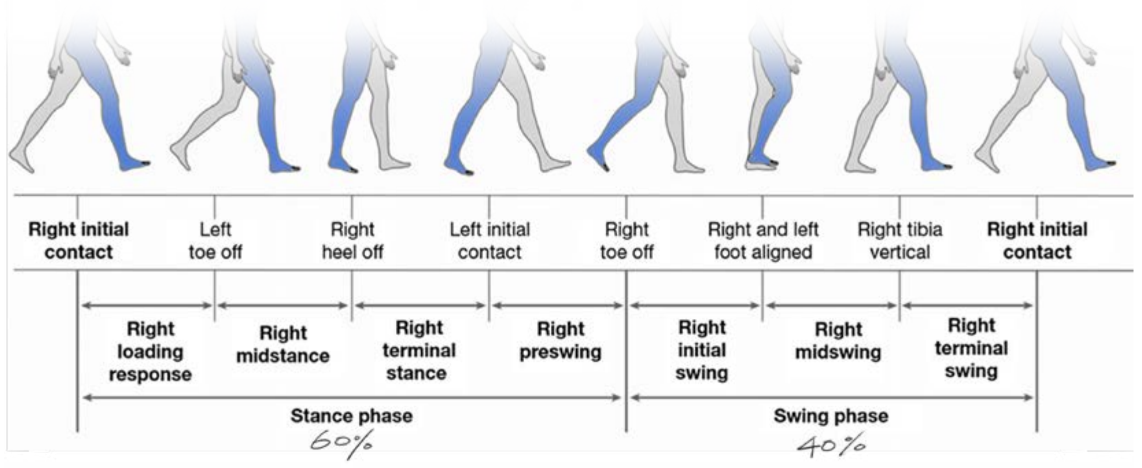


Market Gap

Few solutions provide precise assistance that helps the user just enough without overriding control. By striking a balance between assistance and autonomy, such a solution could help maintain mobility and improve quality of life.

Gait Analysis

Human Gait Cycle



Gait is the action of walking (locomotion). It is a complex, whole-body movement, that requires the coordinated action of many joints and muscles of our musculoskeletal system. It mostly includes the movements of the lower limbs, upper limbs, pelvis and spine.

Gait also depends on the proper functioning of other body systems such as nervous, cardiovascular and respiratory system.

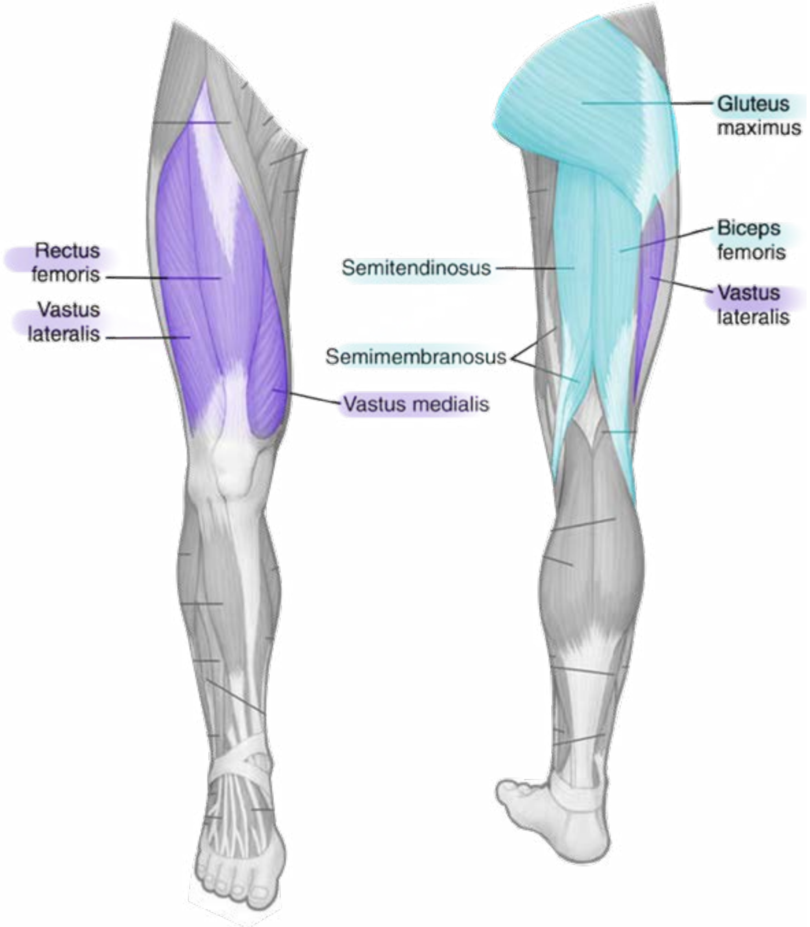
"Regular walking or maintaining a physically active lifestyle is critical to keeping a healthy gait. A regular walking program of 30 minutes each day is the best single activity for maintaining mobility." - MSD Manual

Musculoskeletal
Hips & Balance

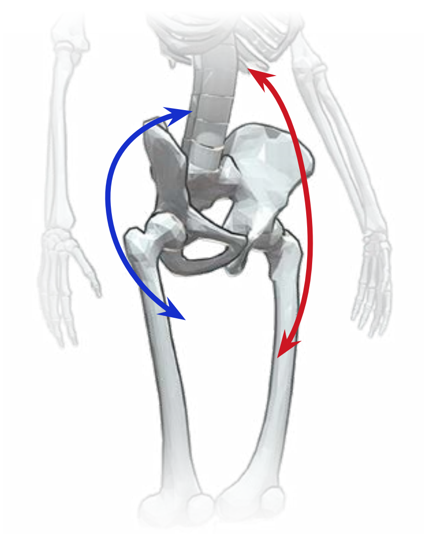
The majority of sarcopenia affected muscles are located in the upper thigh.

Purple - Weakness in the muscles that makes up the quadriceps can lead to difficulty with sit-stand.
Cyan - Weakness in the Gluteus affects walking speed and difficulty with stair climbing. Weak Hamstrings cause imbalance between the quads.

Weakness in the leg muscles result in using the hips for compensation. More force travels to the hips in unusual locations and patterns. Prolonged use the of HFE and HAA muscles in the hip for compensation creates strain and can lead to further damage.



The human gait is a repetitive sequence of motions that occur while walking. A complete cycle takes a complex coordinated action of many joints and muscles of the musculoskeletal system. It mostly includes the movements of the lower limbs, upper limbs, pelvis and spine, but also the nervous, cardiovascular and respiratory systems.



HFE - Hip Flexion/ Extension
Flexion occurs when the thigh moves closer to the abdomen, while extension occurs when the thigh moves away from the abdomen.

HAA - Hip Abduction Adduction
Moving the leg away from the body and adduction occurs when bringing the leg back towards the body.

Robotics for Rehabilitation

Toyota WelWalk WW-2000 Rehabilitation for patients with lower limb paralises

SoloWalk from GAITTRONIC assists lower limb movements in everyday life

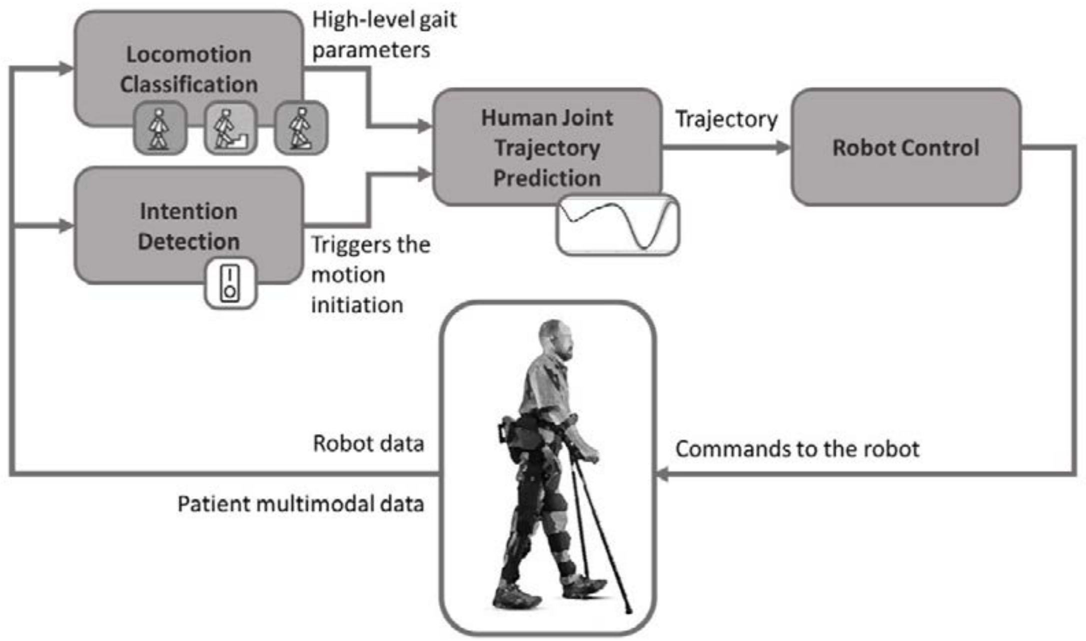
Robotics in rehabilitation emerged in the late 20th century from advances in in-dustrial robotics and biomedical engineering, aiming to assist patients recovering from injuries or neurological conditions. Early research in the 1980s and 1990s produced prototypes like the MIT-MANUS, one of the first robotic arms for stroke therapy that enabled repetitive, precise upper-limb training.

In the 2000s, systems such as the WelWalk and SoloWalk introduced robotic gait training for individuals with spinal cord injuries or stroke, marking the technology's entrance into clinical practice. Modern solutions are increasingly independent, and rely on a system of sensors to capture user data.

INNOVATION MORNING

SoloWalk was introduced to me by Professor Mojtaba Ahmadi when I attended a short lecture of his at Carleton's Innovation Morning. Future collaborations with his team is likely.

Robotics for Rehabilitation
Artificial Intelligence



Coser et al., "AI-Based Methodologies for Exoskeleton-Assisted Rehabilitation of the Lower Limb." (2024), Frontiers in Robotics and AI.

The 2010s saw rapid progress with improved sensors, actuators, and control algorithms, leading to more adaptive and human-centered designs such as soft robotics and wearable exosuits.

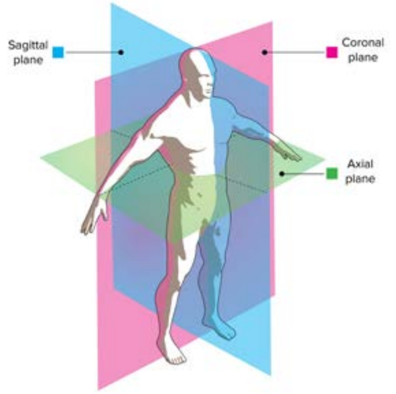
For gait assist, AI can be used to recognize the wearer's intended movement trajectory for more accurate assist. The extensive variables associated with human gait can all be tracked through sensors and analyzed by AI to determine the optimal rehabilitation plan as well as real-time adjustments. Current research proves the possibility of the concept of AI integrated wearable mobility assist devices.

Design Brief
Opportunity

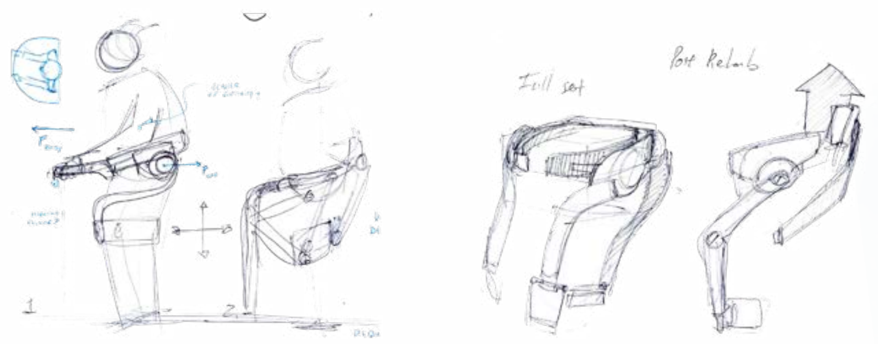
Examining the global aging trend, the quality of life changes of aging, the current products available for seniors, and the gap in the market, there is a unique design opportunity for a product focused on maintaining independence through regular exercise.

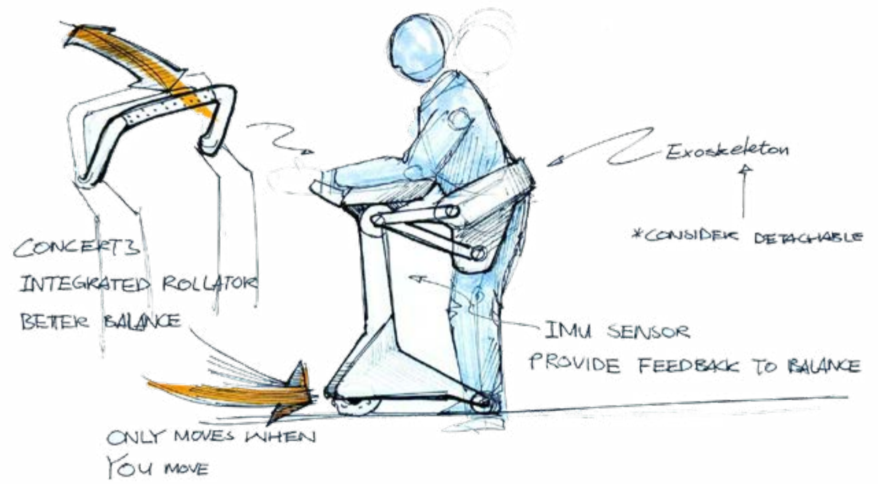
Examining the characteristics of gait in aging, and the technologies available for gait rehabilitation, the opportunity can be further narrowed to a gait assistance device with robotics technologies similar to those used in rehabilitation. It is important the my product avoid the stigma of "elderly design" associated with numerous medical products. Aging is a natural process, not a problem, thus the design must also reflect this to achieve the best user experience.

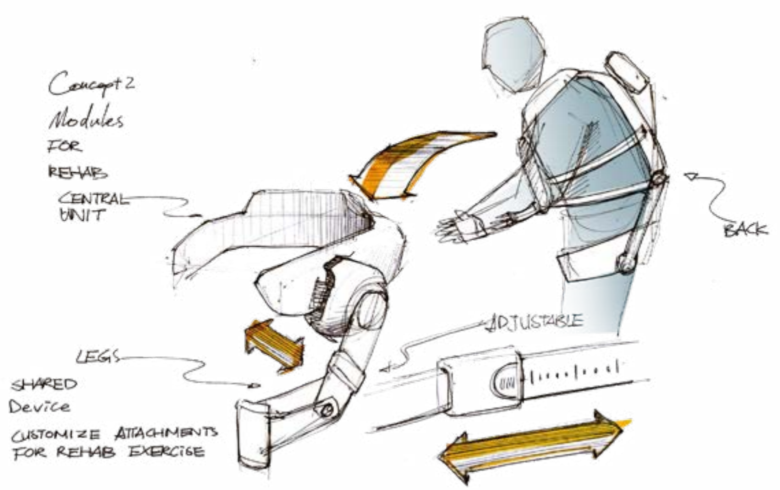
Concept Reveal

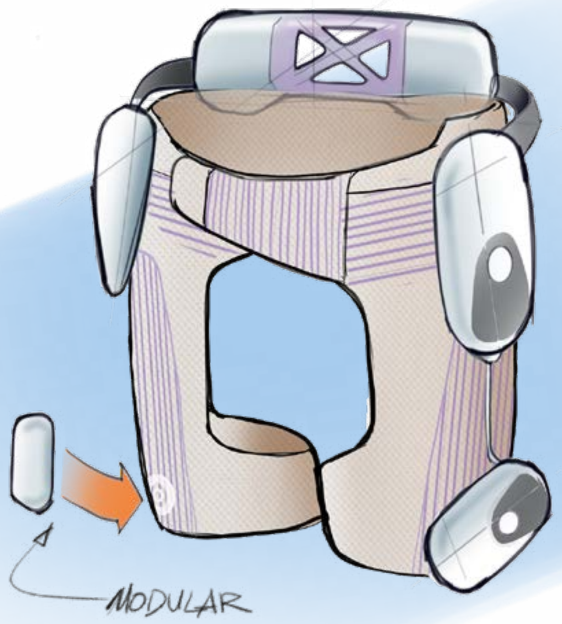


An exoskeleton provides the right amount of assist to accommodate weak hip muscles. Modules on the sides of the thigh facilitate flexion/ extension along the sagittal plane, and module on the back facilitate abduction and adduction along the front plane.



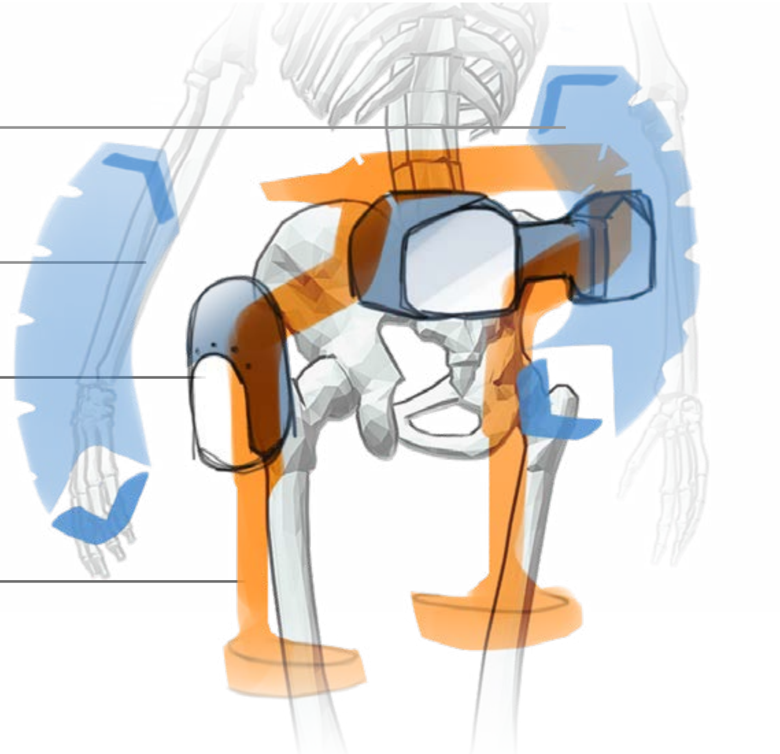






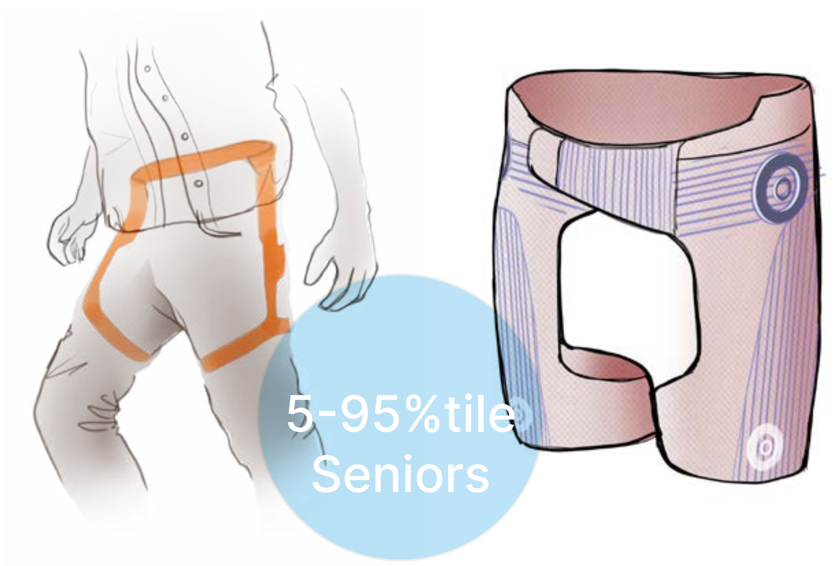
MAX. ~35 Nm

Research supports a good weight-to-torque actuator could provide up to 35 Nm of assist per actuator.



Features

The exoskeleton must be easy to don and doff, simple to maintain, and be comfortable on the body. The product should strive for overall intrusiveness.



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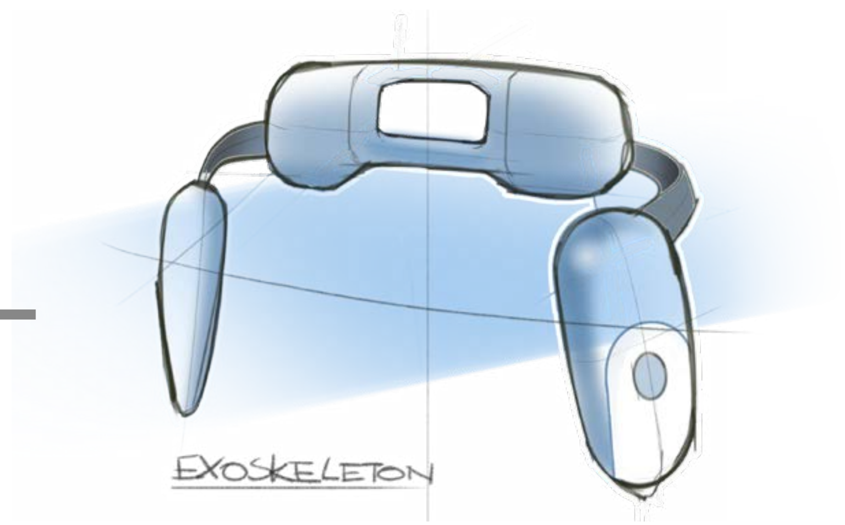


Flexible Frame
|
Give structure to the exoskeleton.

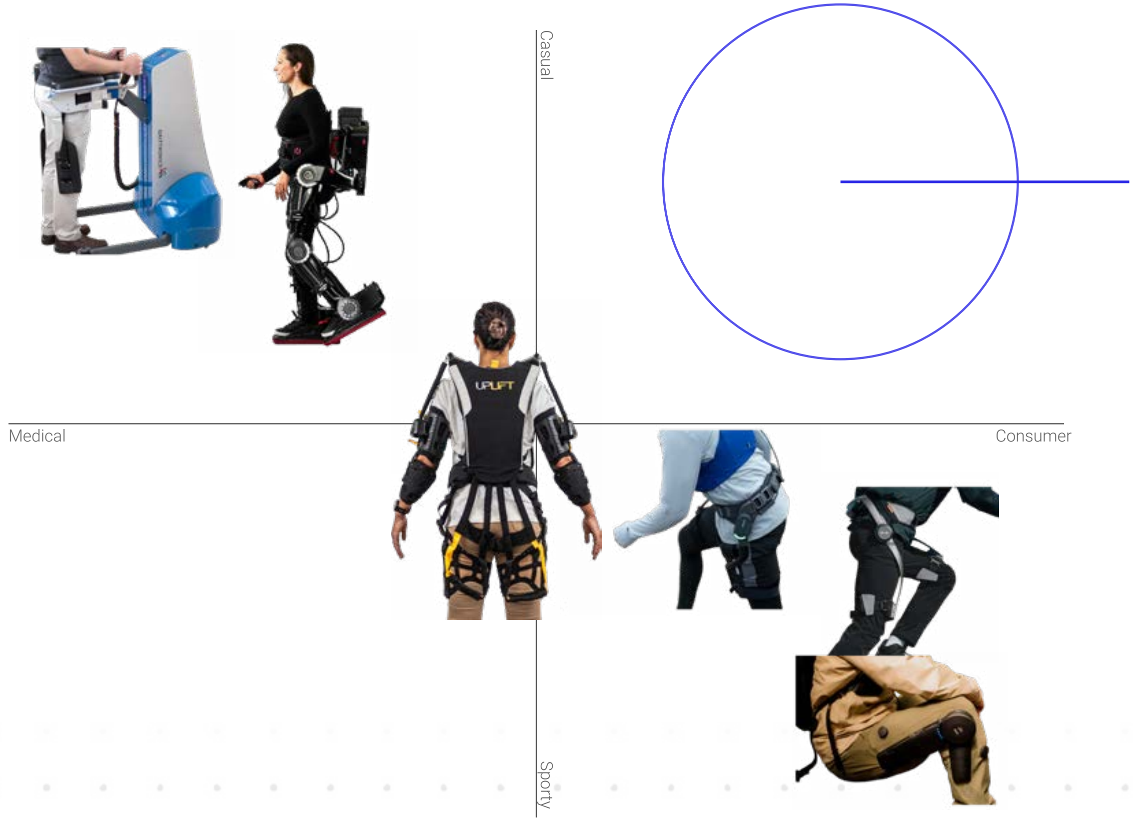
Soft Layer
|
Houses Internal Frame
Attachment Points

Control Layer
|
Light-weight Materials
Battery Location
Size adjustments

Easy maintenance
Better comfort
Subtle Form

Phase 2

Exoskeletons Products



Exoskeleton products range from medical to consumer. Consumer level exoskeletons cater towards outdoor activities and performance; following a homogeneous styling.

Casual devices for senior populations remain a gap in the market. And there is space for different design approaches differentiate new products within the market.

Passive	Lower Cost No Software Issue Simple Maintenance	Limited Assist Fixed Level Pressure Points
VS.		
Powered	More Assist Power Adaptive Levels Better Gait Correction	Battery Limit Bulky More Expansive

Through meetings with Nick from Biokinetics, I was encouraged to consider both passive and powered systems from the users' point of view.

With advantages and drawbacks in both systems, I chose to develop my product on a powered system. A powered system allows and is ultimately more interesting for me to develop.

Aesthetics Considerations

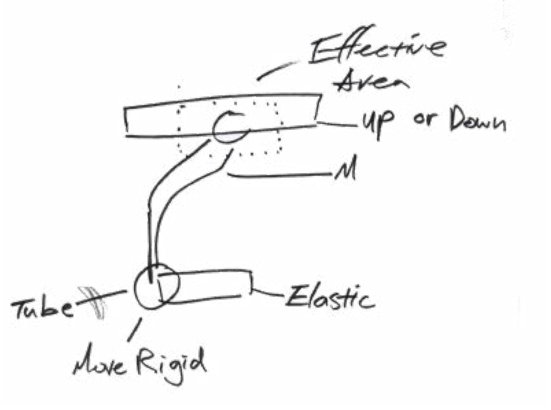
"senior-friendly options are bulky, beige, and condescendingly styled. These products loudly signal fragility or disability—things no one wants to be reminded of." ----- Don Norman

Deeply tied to user experience, the design of the exoskeleton must not conform to the stigmatized style of "elderly design".

Since the goal of the exoskeleton is to help build or maintain confidence of mobility, its design must also reflect this sentiment.

Design considerations should be made for user interface, form and function, and CMF.

Prototyping



A rough draft prototype have been made based on current understanding of the exoskeleton. It is to help conceptualize as a reference for more detailed prototypes to come.

Size adjustments at the thigh and waist.
Avoid using straps for adjustments. Try sliding mechanism for faster don and doff.

Fastening mechanisms.
Strapping setups.
Flexible frame construction.

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Revision 7

Design Brief

Declining birth rates and aging populations are increasing pressure on care-taking systems worldwide. Current technological responses focus either on replacing human caregivers with robotics or enabling seniors to remain independent longer. By examining age-related mobility changes, existing assistive products, and emerging rehabilitation technologies, an opportunity emerges for a solution that supports independence through continued physical activity.

Musculoskeletal strength typically declines after age 65, increasing fatigue and mobility limitations. Negative perceptions of aging can further encourage sedentary lifestyles, accelerating physical decline. Supporting regular movement is therefore essential for maintaining health and independence.

Ren is an exoskeleton walking assist designed to encourage active lifestyles for new seniors and independent aging. Intended for users with normative cognitive function, who can support their own body weight, but are experiencing declining confidence about one's abilities. Ren supplements natural walking rather than replacing it.

The system provides up to 30% fatigue reduction in the hips, thighs, and back combined. Ren offers three adjustable assist levels, and supports approximately 20 km of walking per charge.

A physical interface on the motor unit allows quick control of assistance levels. When worn under clothing, users can adjust settings and view device status through their smartphone. Ren integrates seamlessly into daily life with wireless charging, compact foldable design, and removable components for cleaning, while maintaining a contemporary aesthetic that avoids stereotypical "elderly" product design.

2nd Semester Objectives

Mechanical Understanding
Consult engineers to gain an optimal understanding of the mechanism of my exoskeleton. To estimate the size and weight, and plausibility of the system I am designing.

Mechanical Prototype
To iterate on the interface between components and the wearer. Safety, straps, buckles, size adjustments, ergonomics. Initial testing will be on myself and working together with the ABL team. Prototypes will be in sub-assemblies.

Affordance Prototype
To iterate on the form of the exoskeleton from a user friendly perspective. Iterate on additional form related functions and sensory aspects of the product.

Form Development
Predecessor to final looks-alike prototypes and models. Using foam and digital modeling (blender, Gravity sketch).

Working Prototype
A fully connected and wearable prototype to test overall use cycle, maintenance, and stress testing.

Connection

Dr. Mojtaba Ahmadi

ABL Visit
Scheduled for next week.

Last year, an exoskeleton has been developed as an Engineering capstone/ research project.

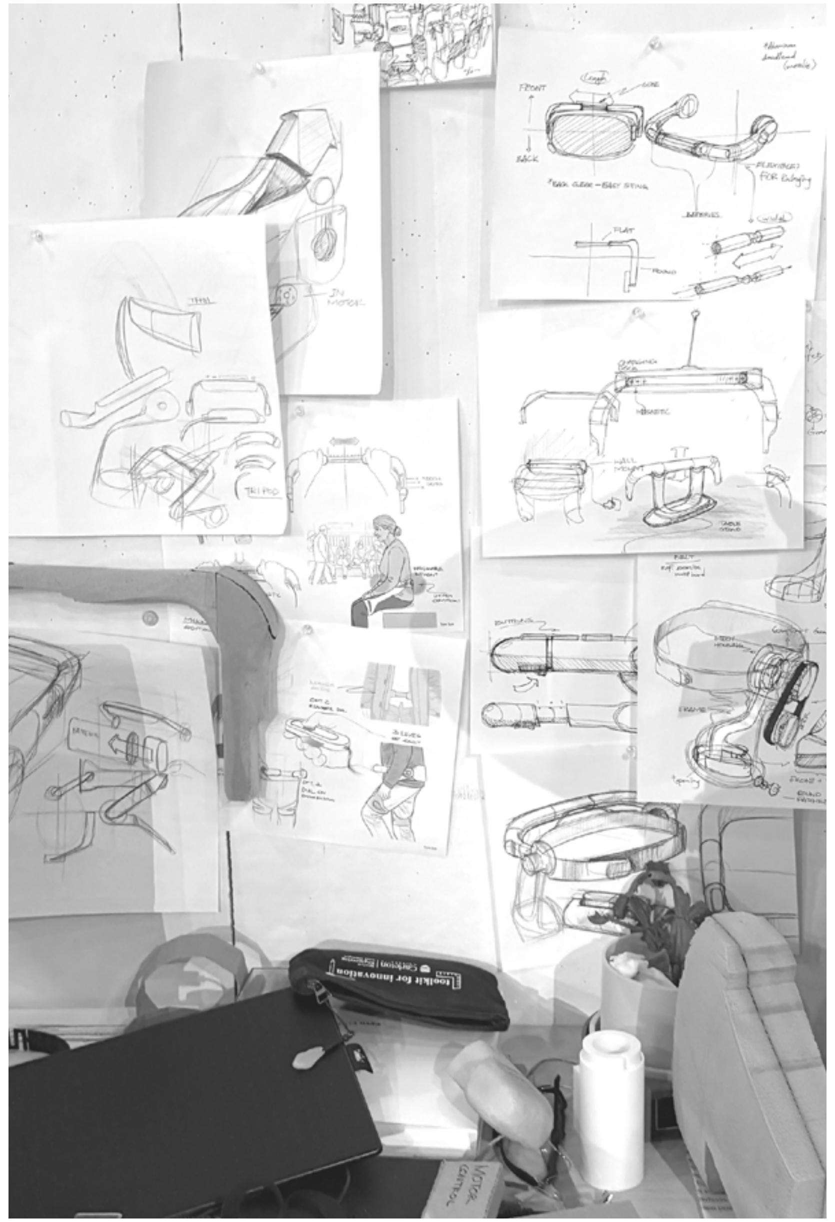
- In-person experience with the exoskeleton
- Research team extensive knowledge of exoskeleton
- Professional testing facility and feedback

Expecting multiple follow-up meetings.

Final Design
Final Definitive Design. The bulk of aspects resolved and frozen. Moving onto refinement and details.
Including the making of the final model, process documentation, poster boards, and video.

January - February 2026

Prototype 2

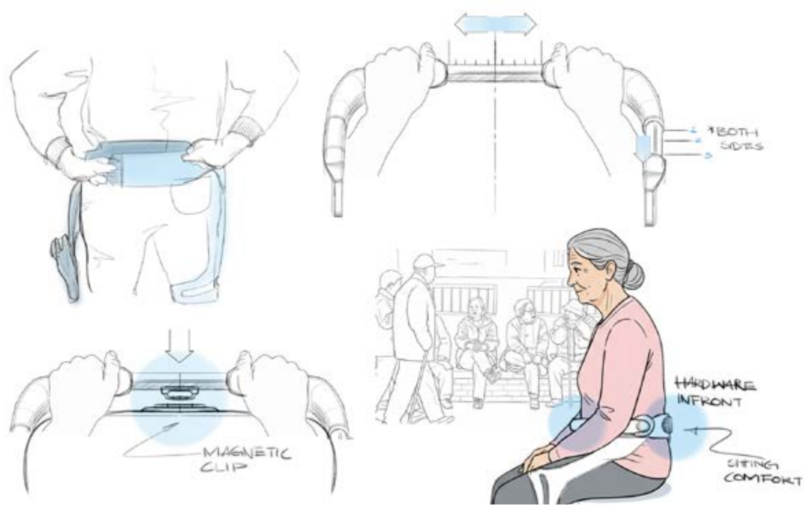


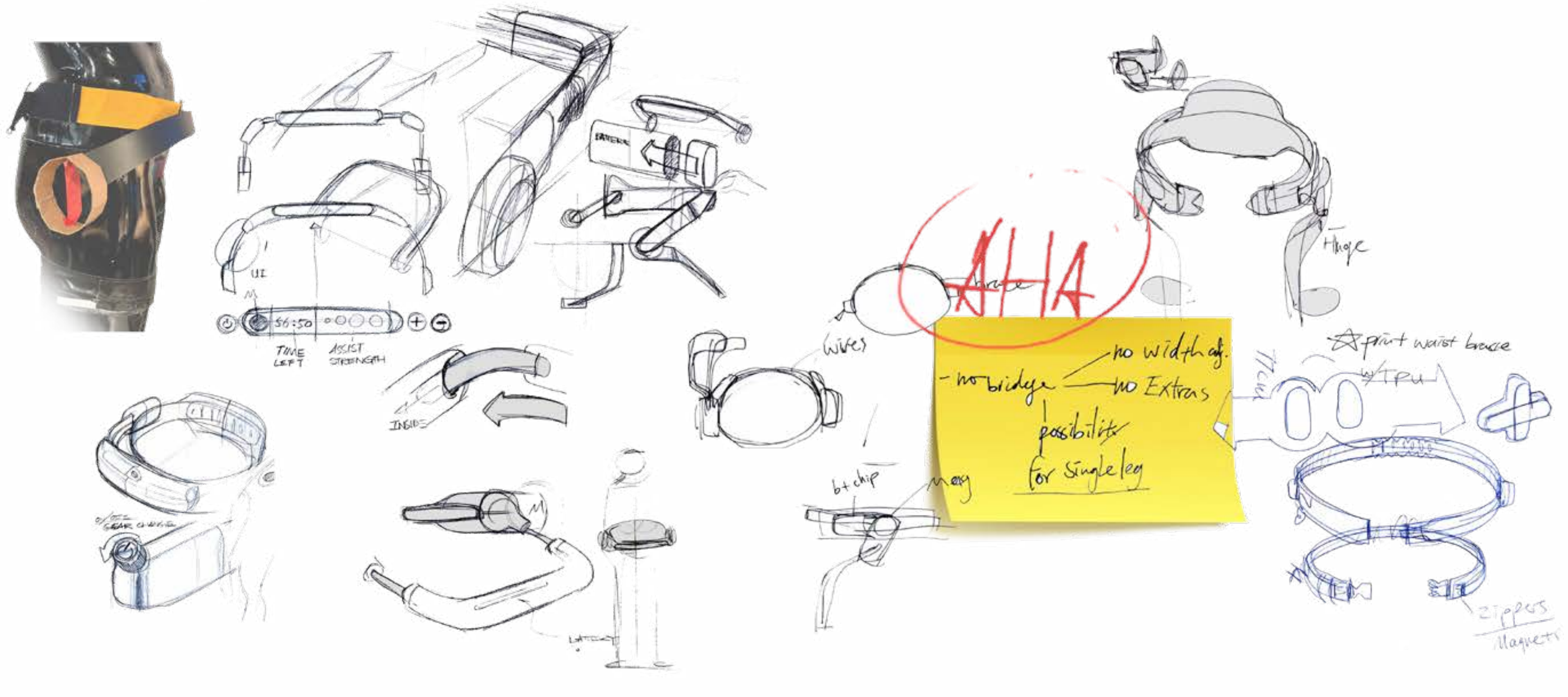
Goals

1. Optimal understanding of the mechanisms of my exoskeleton.
2. Plausibility of the system to design.
3. Use cycle and scenarios
4. Early form factor exploration
5. Preliminary Design

Testing

- Waist band structure and ergonomics
- Motor component structure
- Thigh component structure
- Early CMF, look and feel.





Direction 1

Initially the exoskeleton structure was a connect frame around the front of the wearer. To house the battery, control panel, and width adjustment components to the front.

The results were less than ideal.

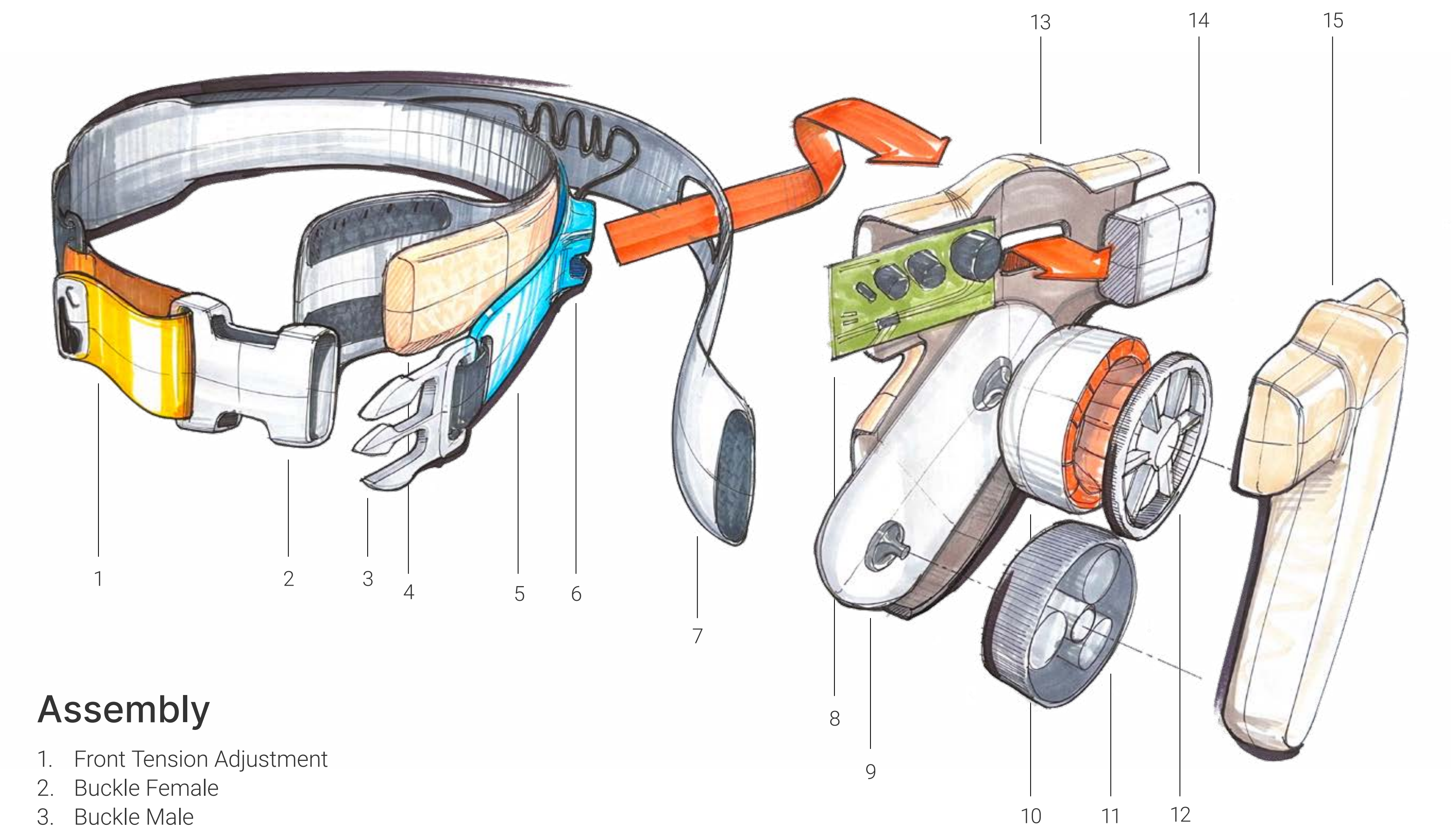
- Uncomfortable weight on the abdomen.
- Adjustment mechanism was getting too complicated.
- And overall form factor is too bulky

Aha Moment

A sudden realization that the two motors doesn't have to be linked by a rigid structure. "Less is More" became the new foundation for the future direction of the design.

Benefits of this new direction

- No complicated mechanisms, lightweight
- Possibility for single leg configuration
- Unified sizing solely in the waistband



Assembly

1. Front Tension Adjustment
2. Buckle Female
3. Buckle Male
4. Padding
5. Electronics connection Frame
6. Motor Mounting Interface
7. Outer Neoprene Layer
8. DC Motor Driver
9. Gear Assembly Housing
10. DC Motor
11. Planetary Gears
12. Gear
13. Motor Housing A
14. Battery
15. Motor Housing B

Preliminary Design

Sub-assemblies

- Waistband
- Motor Enclosure
- Remote controller
- Thigh frame + band

Control Remote

A separate UI element connected to the motors by wire. Intended when exo is worn under clothing, and for giving control to a caretaker

Waistband

Stretchy inside frame where the electronics connect, giving structure and flexibility. Magnetic attachment interface for the motor components.

- Separated motors
- Interesting unique structure

- Bulky
- Consider a phone app
- Need more rigid support to accommodate the torque of the motors.

March W1 2026

Prototype 3

Goals

1. New waistband with more back support
2. Simplify motor mounting mechanism
3. Thigh strap adjustments
4. Iterate towards Definitive Design

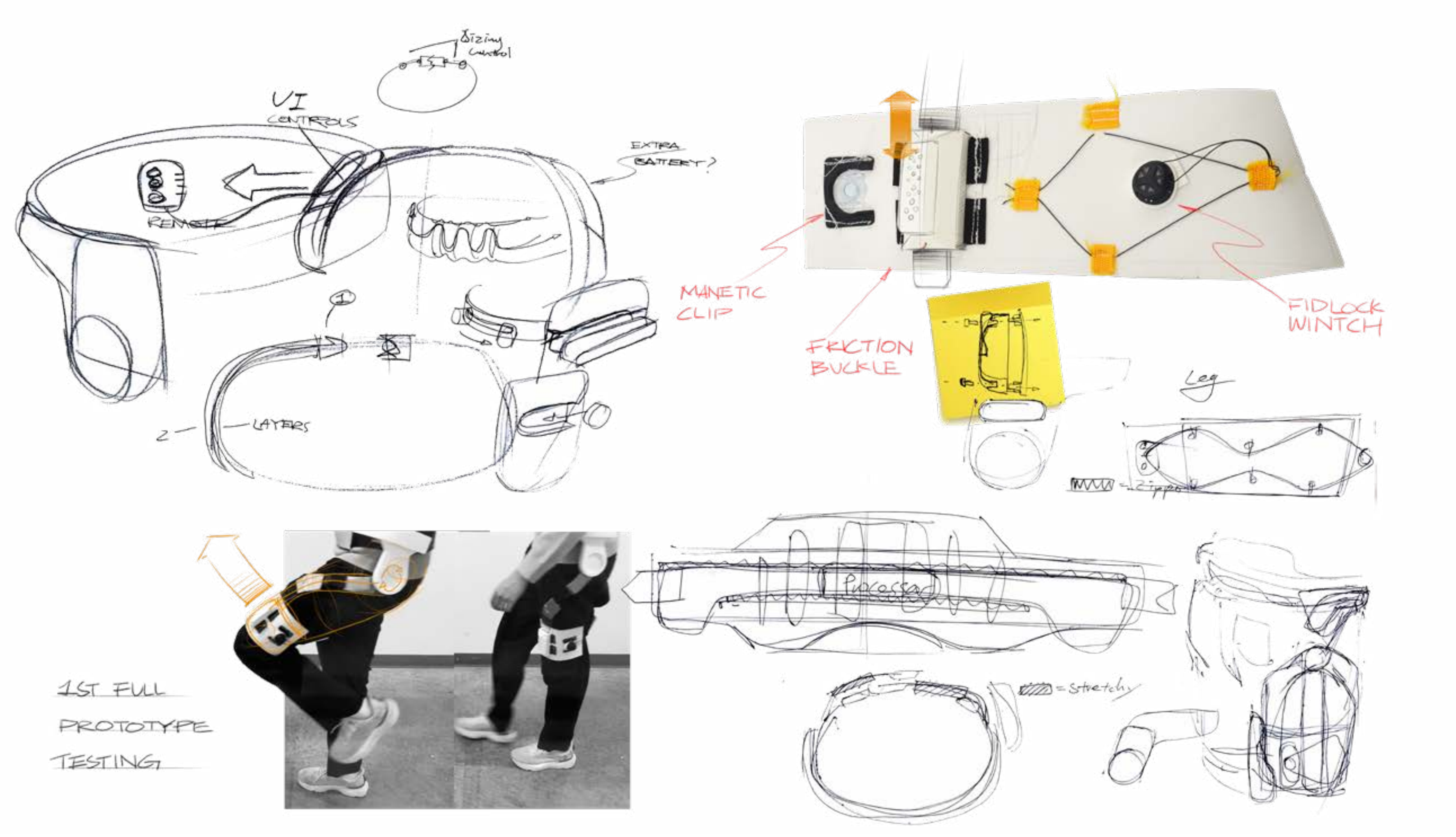
Testing

1. New waistband with more back support:
   Comfort over different types of clothing. Sizing accommodations. Test wear intuitiveness.

2. Simplify motor mounting mechanism:
   New design with auditory or visual feedback. Testing user experience.

3. Thigh strap adjustments:
   Comfort over different types of clothing. Sizing accommodations. Test wear intuitiveness.

4. Overall fit and comfort. Walking, sitting, running, stairs.



Thigh Band

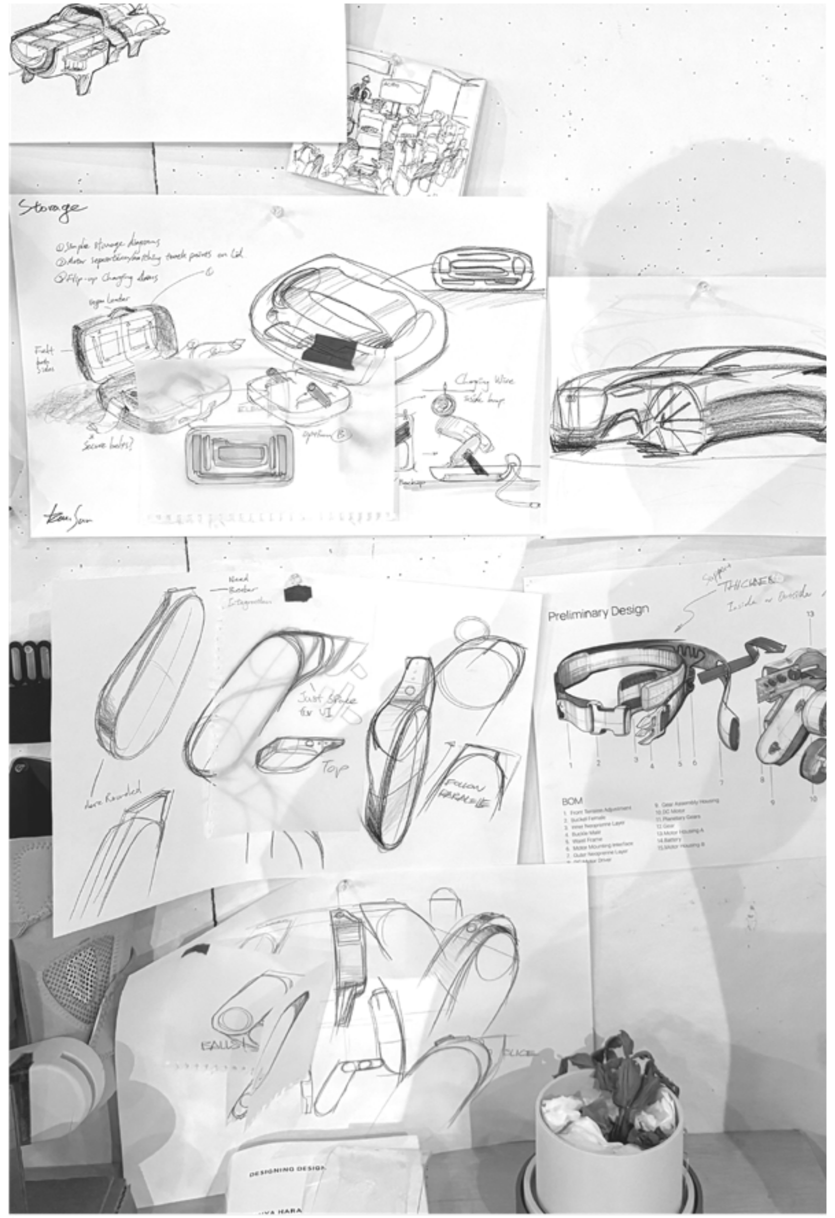
Since the assist is a "lifting" motion, the thighstrap needed to be wide to ensure the comfort on the thighs. Using a ratchet tightening system, the user can adjust the fit on-the-go just by turning the dial. A friction locking mechanism was tested for adjusting the distance of the thighstrap on the thigh.

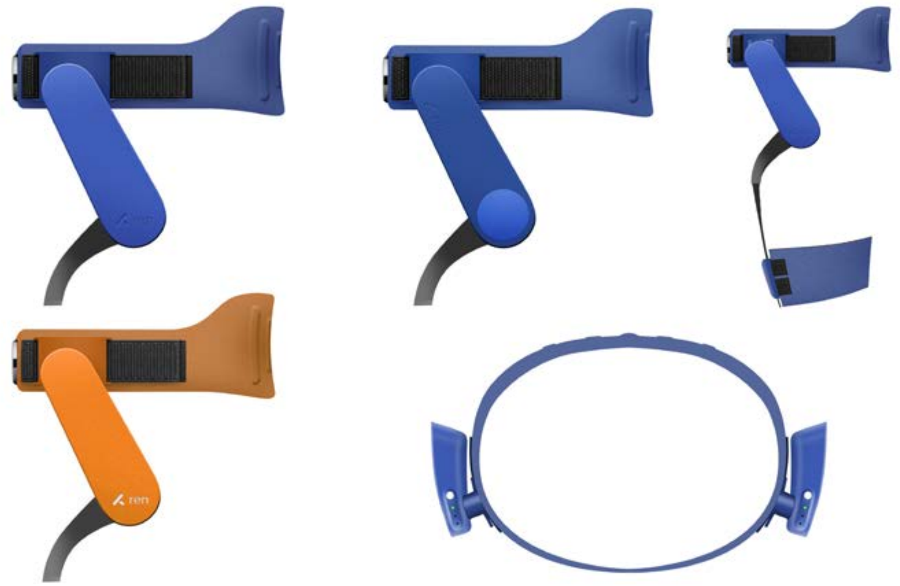
Waistband

Softness doesn't always equal comfort, one size shouldn't fit all. Prototypes 3 introduced a waistband with a wider back support and removed the foam padding. The waistband can stretch but would need at least two sizes to accommodate all users.

March W2 2026

Prototype 4



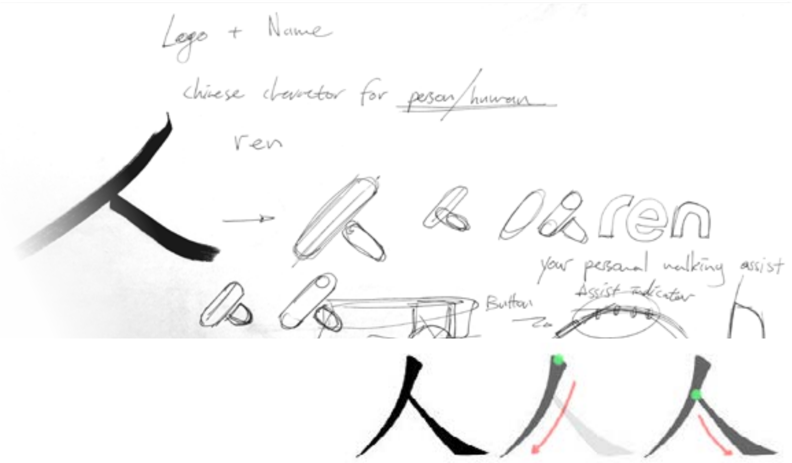


Definitive Design

1. Brand, logo, visual identity
2. Better motor mounting
3. Form refinement
4. Begin detailed refinement

Testing

- Charging stand
- UI/UX of exo and App
- Walking, stairs, pockets, sitting
- Size adjustments

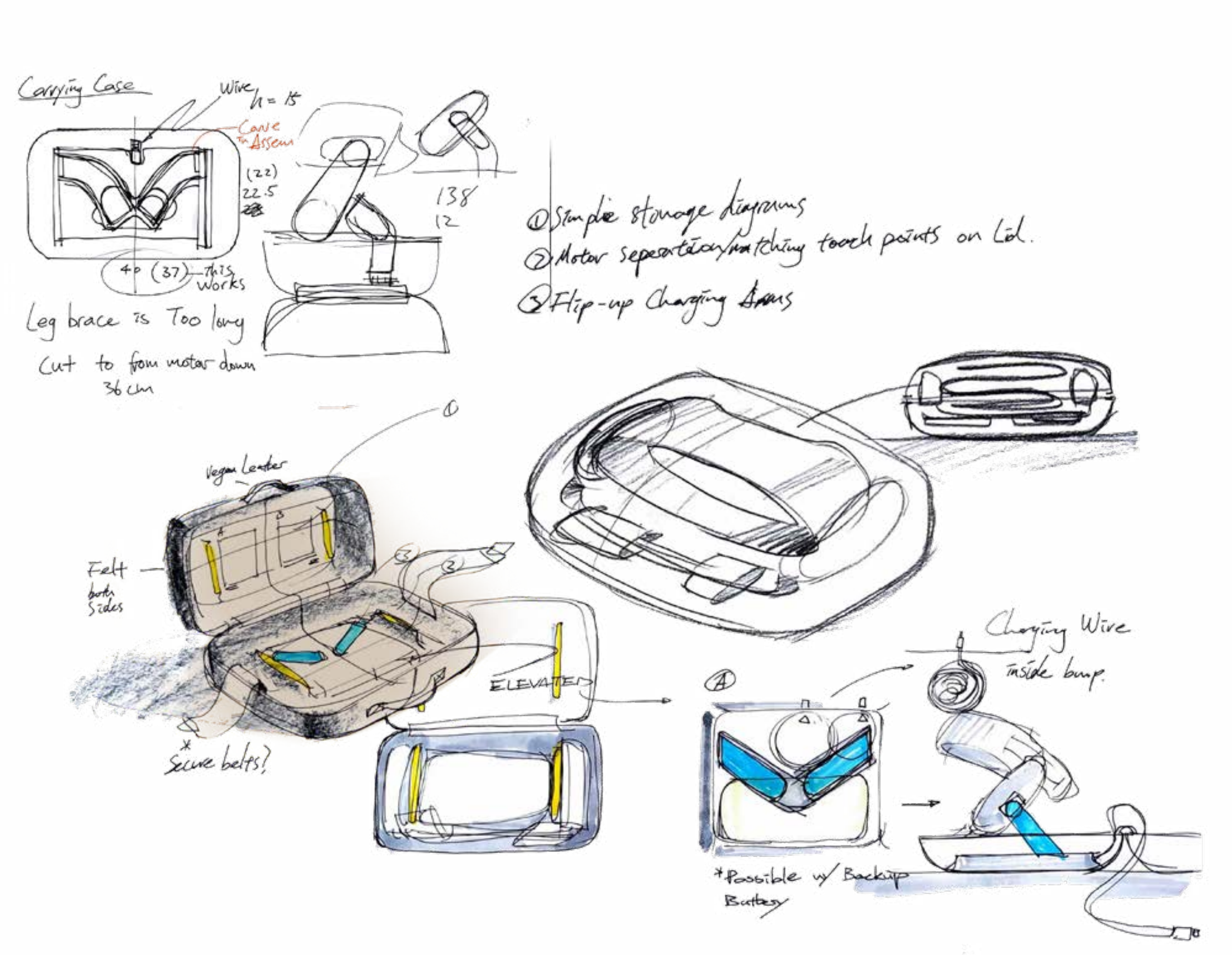


Keywords	Logo Typeface	Logo
Friendly Approachable Optimistic Memorable	**new order** semi-bold All lowercase	

The Logo

Inspired by the Chinese character for human or people. Its written stroke order invoking a human's walk.

Ren's logo takes the shape and spelling to create new meanings that are rooted in human connection. The following form and brand developments referenced the logo to keep the brand cohesive.



1. Folded exoskeleton: 35x20x15 cm
2. Magnetic Charging stand prototype
3. Carrying case closed
4. Carrying case in charging configuration

User Rituals

It was recognized that older adults form daily rituals that they live by. This can mean having specific locations for personal items. In addition, Ren is also intented for outdoor use, meaning it needs a carrying case. Thus, Ren needed a designated storage location that can fit to the user's lifestyle.

1+1=1

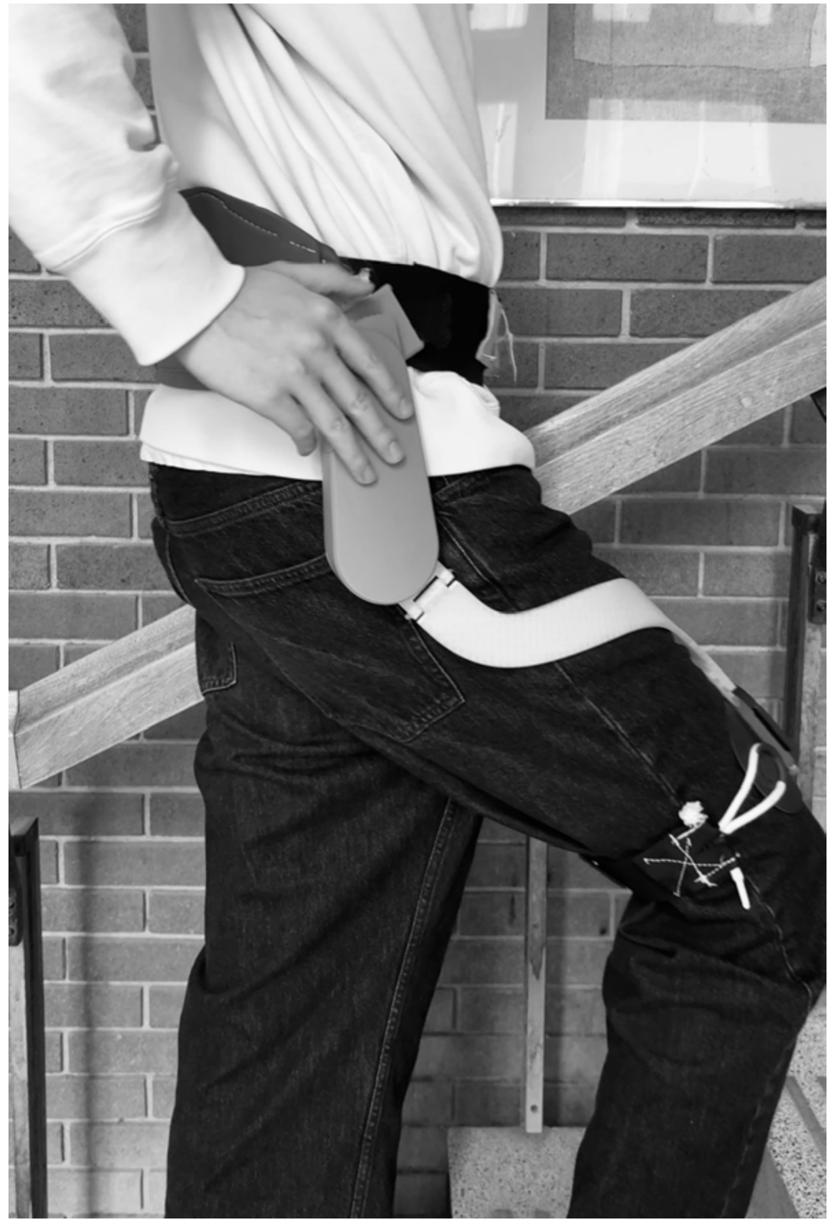
A design approach coined by Muji for home storage solutions that combines similar experiences into one to maximize space. The storage and charging user behaviours were combined into one, creating a designated storage solution that can also be mobile when needed.

Phone App

The smart phone app would control the exoskeleton when its physical controls are hard to access (under clothing). Using the IOS' Live Activities feature, the exoskeleton can be controlled from the lock screen. The app also provides set up, calibration, and maintenance instructions.

March W3-4 2026

Prototype 5

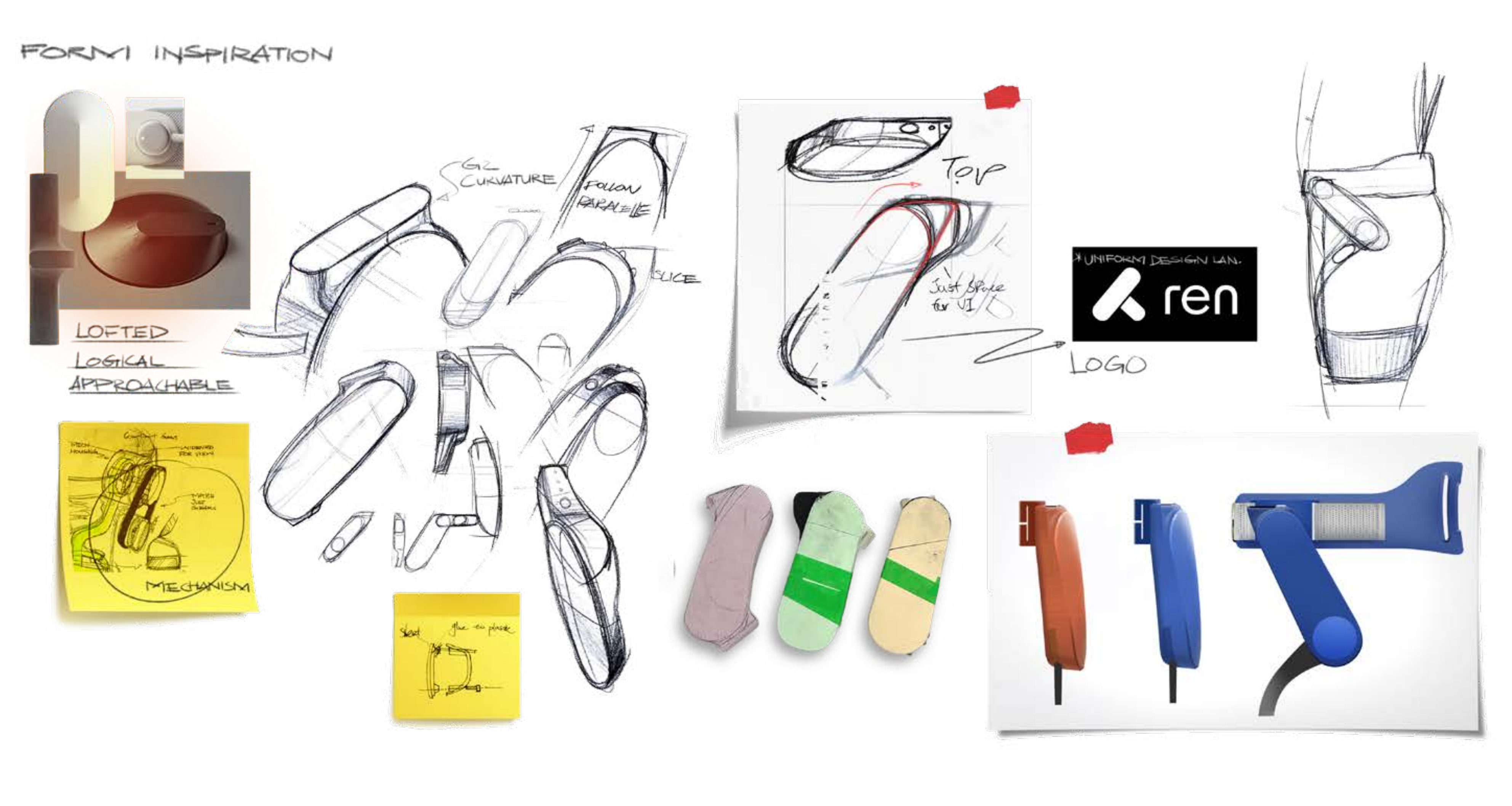


Refine

1. Full working prototype
2. Begin final model
3. Finalize CMF
4. Finalize details

Testing

1. Carrying case and charging stand as one
2. Visual identity recognition
3. Manufacturing feasibility
4. App UI



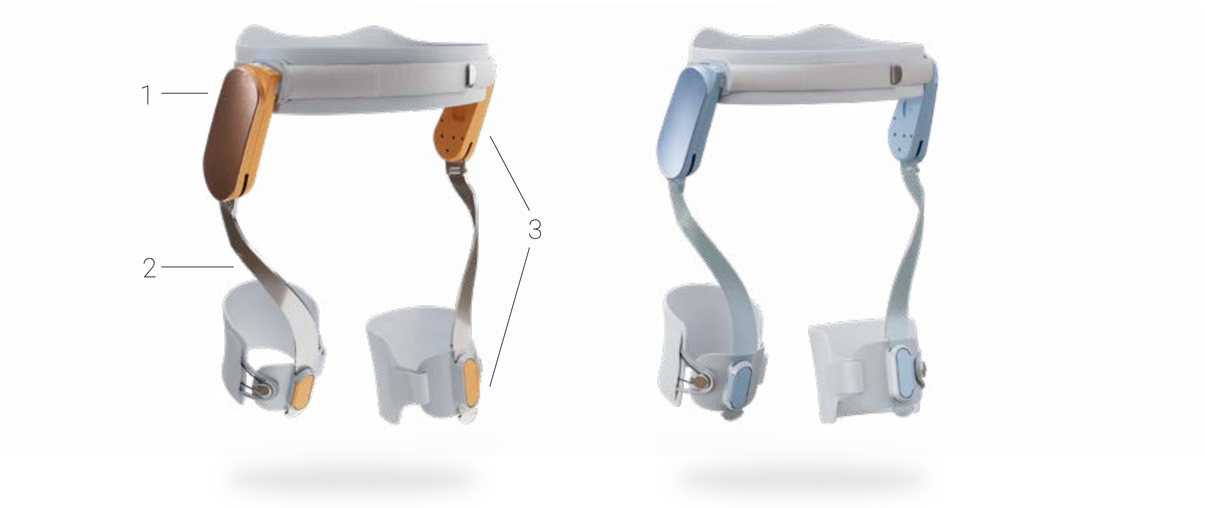
Visual Identity

The motor enclosure represents the key elements of the form. Its rounded shape houses the round DC motor. The forward leaning slant shows intent on movement. The overall silhouette mimics the logo.

Form Keywords

Lofted
Logical
Approachable

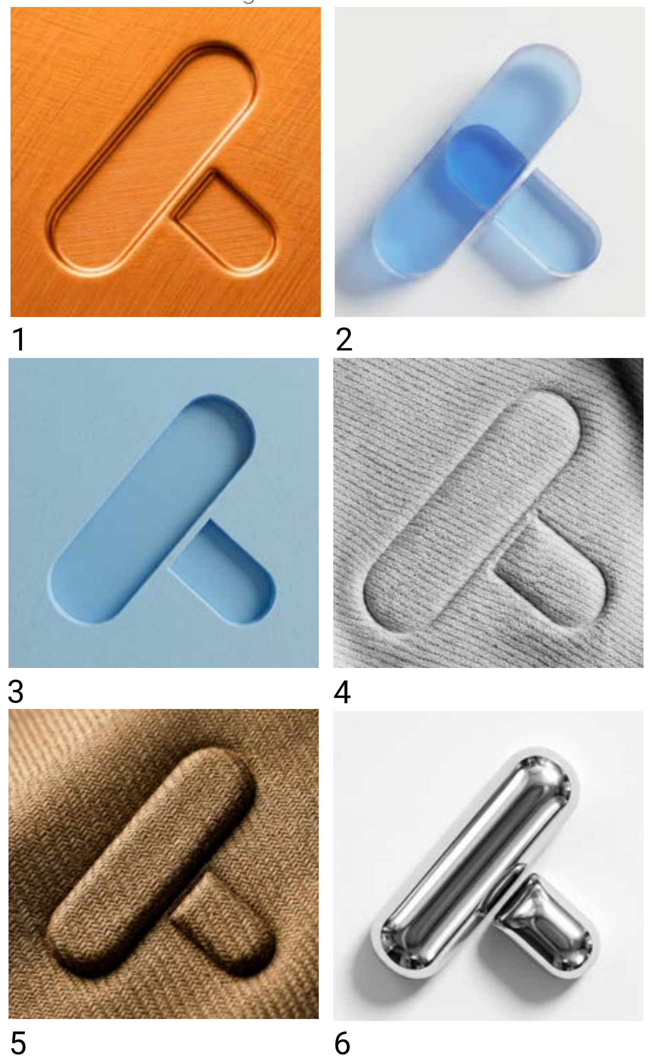
Colourways & CMF



Mandarin Orange

Sky Blue

Image Modified with Nano Banana Pro



Colours

Not conforming to the stigmatized aesthetics of "elderly design", Ren's CMF aims for a more premium and personality-driven feel. Ren uses pastel monochromatic colour scheme across a variety of materials. Material choices reflect comfort, function, brand identity, and weight reduction.

1. Electroplated Textured ABS
2. Translucent PC
3. Textured ABS
4. Sportswear Spandex Weave
5. Flax Fibre Composite
6. Electroplated ABS

Additional Details

Fidlock WINCH Elegance
The magnetic components automatically guide the parts into the correct position, while the fit can be adjusted quickly and precisely via the WINCH dial – even with one hand.

https://www.fidlock.com/components/en/winch

Flax Fibre Composite
Flax fibre requires between 2 and 5 times less energy to produce per unit weight than glass fibre, and, in fact, carbon emissions from its production are often claimed to be negative, owing to the carbon capture during its growth

https://www.easycomposites.co.uk/learning/flax-fibre-in-composites

Brushless DC motor + Planetary
Pancake motor for lower speeds and high torque and compact form. Planetary gear torque conversion. Sensors can be embedded in the motor unit. Torque amount and compactness determines the cost.

Engineering Professor Interview

Ingress Protection: IP52
5: Dust protected
2: Protection against vertically falling water drop when enclosure is tilted up to 15 degrees
https://www.iec.ch/ip-ratings

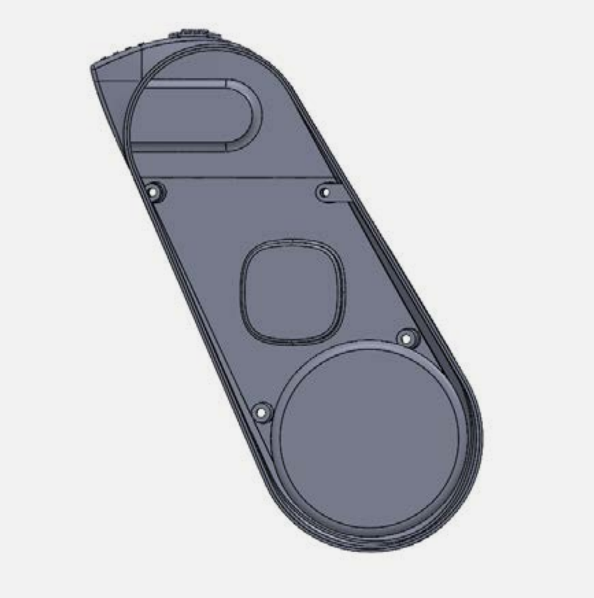
Estimated Exoskeleton NET Weight: 2kg
Estimated Total NET Weight: 3kg

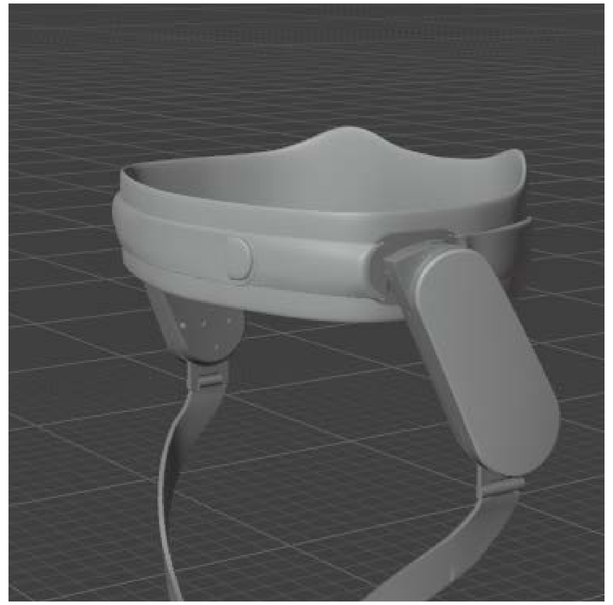
April W1 2026

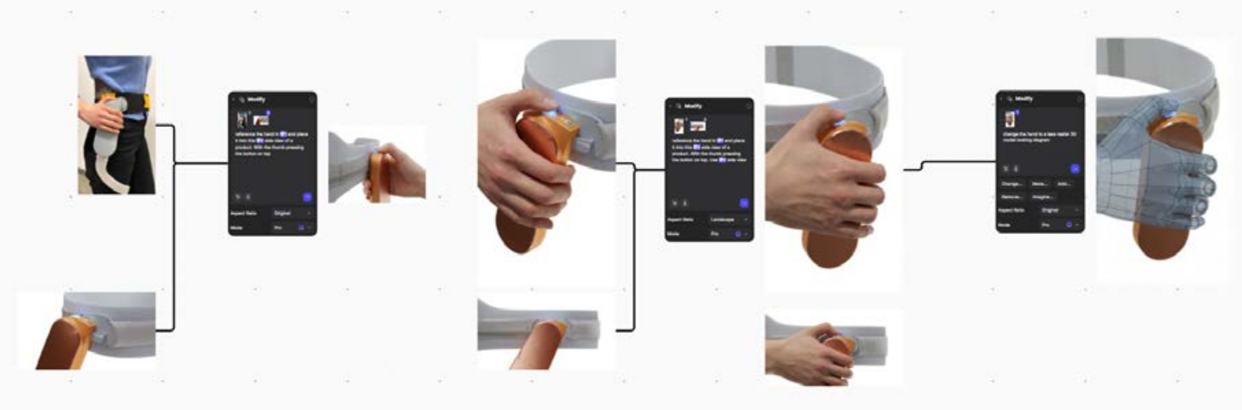
Final Model

Model Making

- Make waistband with PU foam, upholster with spandex
- 3D print motor components, sand, prime, and paint
- Thermoformed 3D printed PETG for the thigh frame
- PU foam and upholster for thighstrap
- 3D print thighstrap components
- Laser engrave logos onto fabrics
- Make half model and display with mirror







Visualization Workflows

For 3D visualization, the exoskeleton hardware was modeled in SolidWorks, the soft components were modeled in Blender, and material application and rendering were done in Blender with cycles.

AI was used to visualize more complex interactions with the product. Using Vizcom's modify feature with reference images for accuracy. Photoshop was used to finalize AI outputs

Special Thanks

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Juan Jimenez Garcia	Feedback on UI/UX, affordances
Professor Mojtaba Ahmadi	Feedback on mechanical, electrical aspects
All my classmates	For a healthy competitive learning environment

Image Modified with Vizcom

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Thank You For Reading :)

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