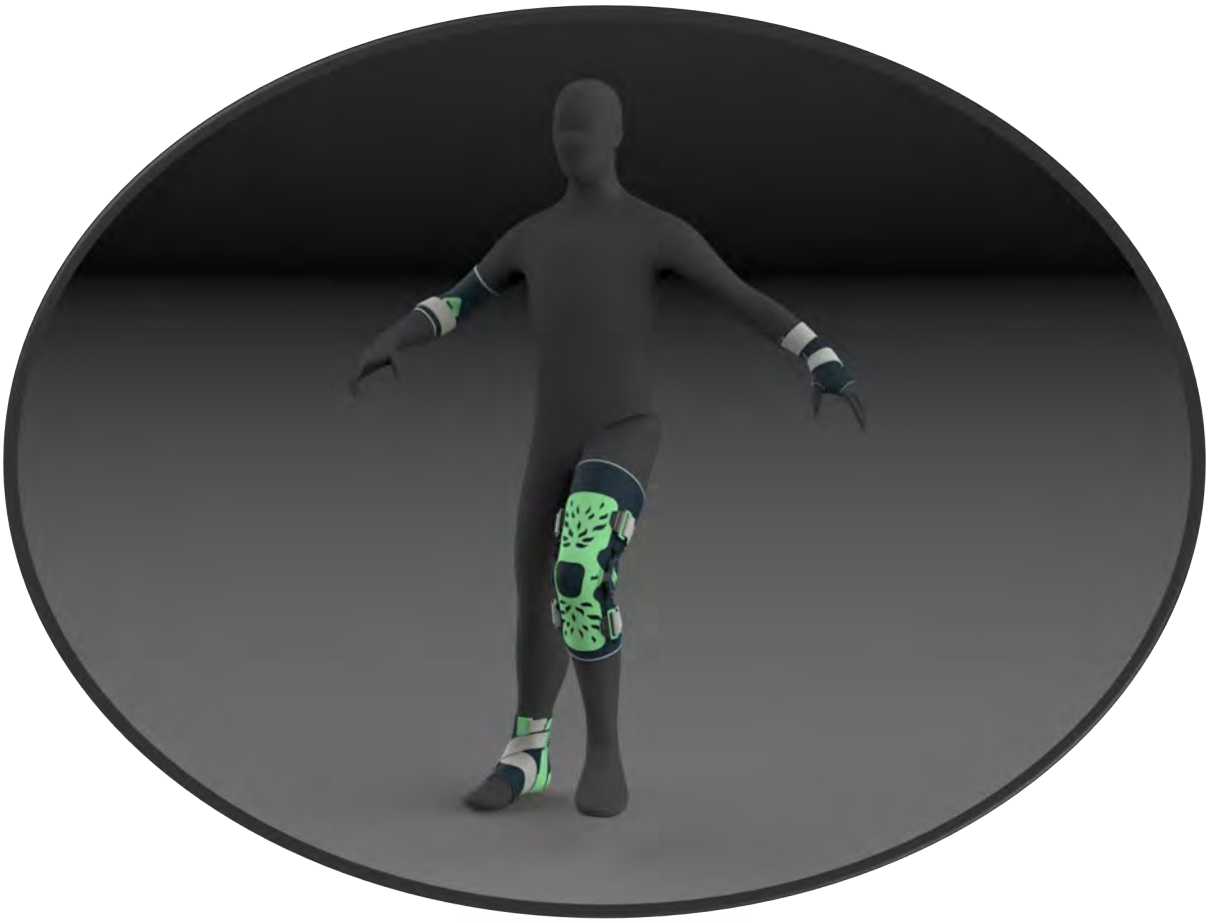
# FLOAT



**Bachelor of Industrial Design 2021**

**Thesis Report**

**Thomas Edmonds**

# Float: Arthritic Braces for rehabilitation

by

**Thomas Edmonds**

Submitted in partial fulfillment of the requirements for the degree of

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Float

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Bachelor of Industrial Design

Humber College of Technology and Advanced Learning

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Abstract:

One of the main health concerns faced by people above the age of forty is arthritis, which can be very painful and difficult to treat. Arthritis is the swelling of one or more joints in the body, the most common types of arthritis are Osteoarthritis and Rheumatoid. Osteoarthritis affects millions of people worldwide, this form of arthritis occurs by the deterioration of the protective cartilage at the end of bones, over time. In most cases Osteoarthritis effects, the joints in the hands, hips, spine, and knees. People suffering from moderate to major damage to these joints, tend to have mobility issues that can cause significant strain on people's everyday lives. Elderly people often struggle with impairing joint pain, which can lead to them needing more support from others to complete everyday tasks. User research into products on the market and observational research on people with arthritis to gain further understanding on how people go about their day-to-day tasks, by contacting primary and secondary users. Discovering user pain points from all areas of the user's life (home, stores, out-doors) to find the best suited area to focus on and that will demand considerations for full-body human interaction design. The aim of this thesis project is to develop a product that will improve on the mobility and rehabilitation of elderly people suffering from Osteoarthritis and to help them be more self-sufficient.

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Signature: *Thomas Edmonds* Student Name: Thomas Edmonds

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# 1. Problem Definition

## 1.1 Problem Definition

Osteoarthritis is one of the leading causes for seniors over the age of 65 to have mobility issues. Living with this bone disease can cause significant hardships among the elderly population in all areas of the world. In cases from moderate to severe, users face a multitude of mobility disabilities caused by joint pain, stiffness, loss of flexibility, swelling, etc. Osteoarthritis affects many areas throughout the body, that would influence how the user navigates through the day, from their knee joints to their wrists and hands. Affected lower limbs can have an effect on the user's gait which can cause further damage to other joints throughout the body. This could also cause additional stress to the muscles surrounding the affected area from improper movements such as a limp (Hogan, 2019). While there are options for mobility aids, such as walkers and canes, there are not many options that are focused on the rehabilitation and informational aspect. "Rehabilitation professionals also emphasized that the objective measures could potentially be used as a "teaching tool" to assist patients in understanding how activity levels could be linked to arthritis symptoms" (Leese et al. 2018). This problem comprises of full body interaction and ergonomics to further assist users with Osteoarthritis, improving mobility, rehabilitation, comfort, and safety among many patients. The final product will be aesthetically pleasing, unlike todays assisted devices and will accommodate a wide range of users.

**1.2 Rationale & Significance**

Before diving into any design solutions, a great deal of information about the user, needs to be observed and documented. In order to gain information on the user, various design research methods must be conducted. These observations will reveal information on the topic and provide a baseline for the proposed design. The research methods are as follows:

- One-on-one user observations
- Literature research
- Online video observations
- Exciting product benchmarking
- Ergonomic studies
- One-on-one user/expert interviews
- Surveying
- Online discussion group research

Gaining a better understanding of the users and the problem at hand by conducting one-on-one user observations, while also asking pre-thought questions pertaining to the high problematic issues faced by Osteoarthritis patients is required to determine the best course of action. Pre-made interview questions will allow for thought provoking discussions, ranging from mobility to styling and comfort. The discussions will answer some of the big unknowns regarding Osteoarthritis and rehabilitation. Further information will be gathered by conducting one-on-one interviews with experts, to gather a better understanding of Osteoarthritis and rehabilitation. Some of these unknowns are as follows:

- Rehabilitation aspects of Osteoarthritis
- Exercises to limit discomfort
- Mobility aids currently being used
- Problematic areas for the user
- Duration of use regarding mobility aids
- High traffic areas for the user

- Effects of Osteoarthritis on the user's joints

### 1.3 Background / History / Social Context

Osteoarthritis is a degenerative joint disease and the most common form of arthritis; this form causes the tissues in the joints to break down over time. Arthritis is most common among people aged 65 and up and is becoming an ever more pressing health concern with the worlds aging population. "By 2032 there may be over 26,000 more doctor diagnosed OA prevalent cases per 1,000,000 population aged 45 or older as compared to 2012" (Turkiewicz et al. 2014). This aging generation has many more advanced and superior options in mobility aids than they would have 100 years ago, when the best mobility aid people could get their hands on was a cane.

Arthritis can cause more than mobility issues such as joint pain that can contribute to the loss of a job, loss of a social circle and can have an impact on the persons mental health. Arthritis can lead to a major lifestyle change, which be hard for some people to adapt to, having to learn to use assisted devices and to learn how to relive pains through exercises. Products available today offer functional assisted devices but leave little to the imagination. Many people decide against using these devices as it showcases their disabilities. With ongoing advancements in technology, it has opened the doors to create a design solution that people will be comfortable using at home, work, in-town and not solely designed for function.

**Chapter 2**

### 2.1 Introduction to User Research

An important step in any thesis is the user research, the study of a target user will allow for design decisions to be made in a clean and sharp manner. Having a clear understanding of the target user's personal experiences, needs, wants and their pain points will give the opportunity for a thoughtful innovative design. As per the thesis topic, users will be utilizing the future proposed design daily and need to be comfortable while using the product making Ergonomics another important user research topic. All these considerations will have to be accounted for while Creating a product that will improve mobility and rehabilitation.

**Research Objectives**

- Demographics of the target user
- Rehabilitation strategies
- Primary users, secondary users, tertiary users
- User profile
- Potential for Full-bodied interaction design
- Current products

**Research Methods**

In order to collect all and any necessary data various methods of research had been done. Starting with creating a user profile by researching the various users of mobility aids. By gaining an understanding of the user, questions asked to an expert in the topic will be well defined and catered better to the target user. These conversations open new unknown

opportunities for research which can be done through online searches. Some of these methods are as follow:

- Scholarly articles
- One-on-one interviews
- Online surveys
- Journey mapping
- Empathy mapping
- Expert interview

### 2.1.1 User Profile / Persona

Creating a user profile and persona, using the preliminary research gathered on the proposed target user will be a helpful tool moving forward to later define the user. This persona is used to gather information and outline the user's behaviour, demographics, needs and in turn will provide empathy for the user and give a much better picture of the average users that struggle with arthritis and mobility.

**User profile objectives**

- Create a preliminary user persona
- Determine user behaviour
- Determine user demographics
- Determine users (Primary, Secondary, Tertiary)

## Method

A user persona will be generated by research and data collection on relevant information regarding to the avg. user that uses mobility aids for arthritis.

## Results

### Primary User

The primary user can be described by a person aged 65 + that is diagnosed with Osteoarthritis and has moderate to severe mobility issues.

### Secondary User

The secondary user can be described as a physiotherapist that specializes in arthritis and rehabilitation.

### Tertiary User

The tertiary user can be described as Community workers / storefront workers that may need to aid the primary user.

## Demographics

### Gender

“the effects of age on hip and knee OA risk in women follow similar patterns, increasing rapidly between ages 50 years and 75 years, and then decreasing in the oldest” (Prieto-Alhambra et al. 2014). “Age-specific incidence of knee, hip and hand OA follow parallel trends in men, increasing continuously with age until the last stages of life” (Prieto-Alhambra et al. 2014). “3.5-fold higher rates in women aged 50 years to 60 years when compared with men of similar age” (Prieto-Alhambra et al. 2014).

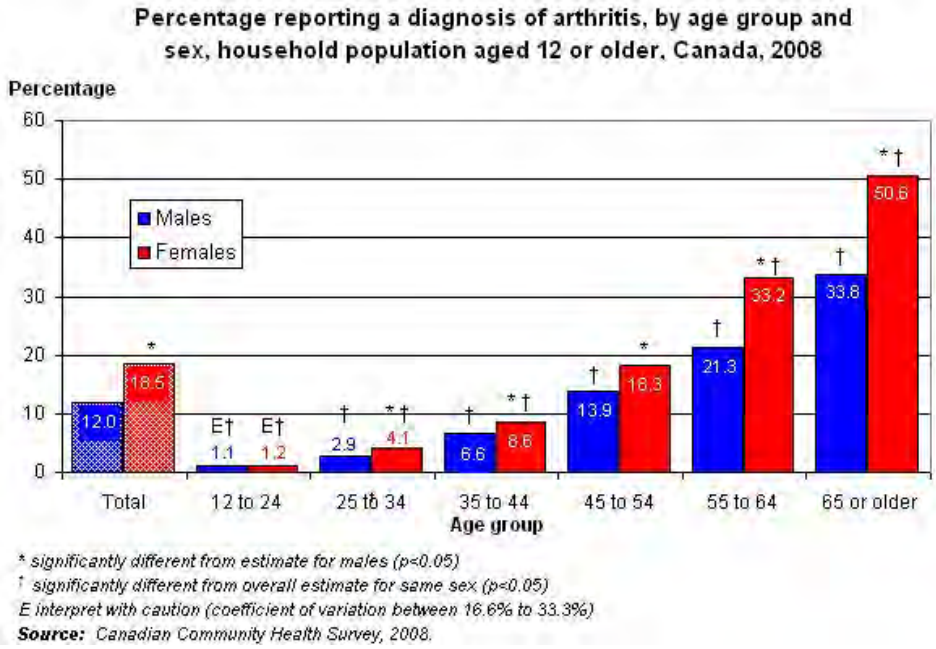



Figure 1 -Age group and sex [Photograph found in Statistics Canada]. (n.d.). Retrieved from https://www150.statcan.gc.ca/n1/pub/82-229-x/2009001/status/art-eng.htm (Originally photographed 2008)

Age as seen in literature research, elderly people from the ages 60 and up. In the below figure it shows the extent of mobility issues of people suffering from arthritis as well as the age groups for each extent of mobility issues.

Causes Reported (%) for at Least 1% of All Persons by Extent of Mobility Difficulties and Age Range* (in Years)

| | Extent of Mobility Difficulties and Age Range (Estimated *N* in Millions) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Minor | | | Moderate | | | Major | | |
| Causes | 18–49 (2.45) | 50–69 (2.72) | ≥70 (2.76) | 18–49 (1.48) | 50–69 (1.91) | ≥70 (1.84) | 18–49 (0.98) | 50–69 (1.96) | ≥70 (2.88) |
| Arthritis and musculoskeletal | 18.1 | 26.0 | 30.1 | 18.6 | 26.4 | 32.5 | 15.0 | 21.7 | 29.6 |

Figure 2 - Iezzoni, L., McCarthy, E., Davis, R., & Siebens, H. (2001, April). Mobility difficulties are not only a problem of old age. Retrieved October 14, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1495195/

## Race and Ethnicity

78% of individuals with OA (Osteoarthritis) are non-Hispanic whites. However, within their own race/ethnic groups, non-Hispanic black and Hispanic populations have higher rates of OA than non-Hispanic whites.

Table 2

Proportion of Adults With Arthritis[a] Who Have Arthritis-Attributable Activity Limitation, Severe Joint Pain, or Arthritis-Attributable Work Limitation, by Race/Ethnicity, National Health Interview Survey, United States, 2002, 2003, and 2006

| Characteristic | Total, % (95% CI) N = 85,784 | White[b], % (95% CI) n = 54,493 | Black[b], % (95% CI) n = 12,063 | Hispanic, % (95% CI) n = 14,880 | AI/AN, % (95% CI) n = 391 | API, % (95% CI) n = 3,009 | MRO[c], % (95% CI) n = 948 |
|---|---|---|---|---|---|---|---|
| **Activity limitation[d]** | | | | | | | |
| Unadjusted | 37.7 (36.9-38.6) | 36.2 (35.2-37.3) | 44.6 (42.6-46.7) | 43.2 (40.2-46.3) | 39.1 (29.0-50.2) | 38.2 (31.8-45.1) | 49.5 (41.8-57.2) |
| Adjusted[e] | 35.8 (34.8-36.9) | 34.3 (33.0–35.6) | 43.3 (40.4-46.2) | 41.7 (37.9-45.5) | 31.6 (24.1-40.2) | 32.2 (24.7-40.8) | 47.6 (39.1-56.1) |
| **Severe joint pain[f]** | | | | | | | |
| Unadjusted | 25.6 (24.9-26.4) | 23.1 (22.3-24.0) | 38.3 (36.0-40.5) | 36.4 (33.8-39.1) | 28.7 (21.9-36.6) | 18.5 (13.4-25.0) | 36.6 (29.7-44.1) |
| Adjusted | 25.4 (24.3-26.5) | 23.0 (21.8-24.3) | 36.7 (33.8-39.8) | 35.5 (32.1-39.0) | 26.5 (20.0-34.2) | 17.8 (12.3-25.0) | 33.7 (26.5-41.8) |
| **Work limitation[g]** | | | | | | | |
| Unadjusted | 31.2 (30.2-32.3) | 28.8 (27.6-30.0) | 41.6 (38.9-44.4) | 39.7 (36.4-43.1) | 37.7 (27.3-49.4) | 28.2 (19.9-38.2) | 46.4 (37.6-55.4) |
| Adjusted | 30.8 (29.6-32.1) | 28.6 (27.1-30.2) | 40.8 (37.3-44.3) | 38.7 (34.9-42.7) | 30.2 (21.9-40.0) | 27.0 (18.4-37.9) | 42.7 (33.4-52.6) |

Figure 3- Bolen, J., Schieb, L., Hootman, J., Helmick, C., Theis, K., Murphy, L., & Langmaid, G. (2010, May). Differences in the prevalence and severity of arthritis among racial/ethnic groups in the United States, National Health Interview Survey, 2002, 2003, and 2006. Retrieved October 15, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2879996/

## Education

This is hard to determine for people suffering from arthritis as it affects many different people and is not a specific group, therefore educational backgrounds can be completely different from one another.

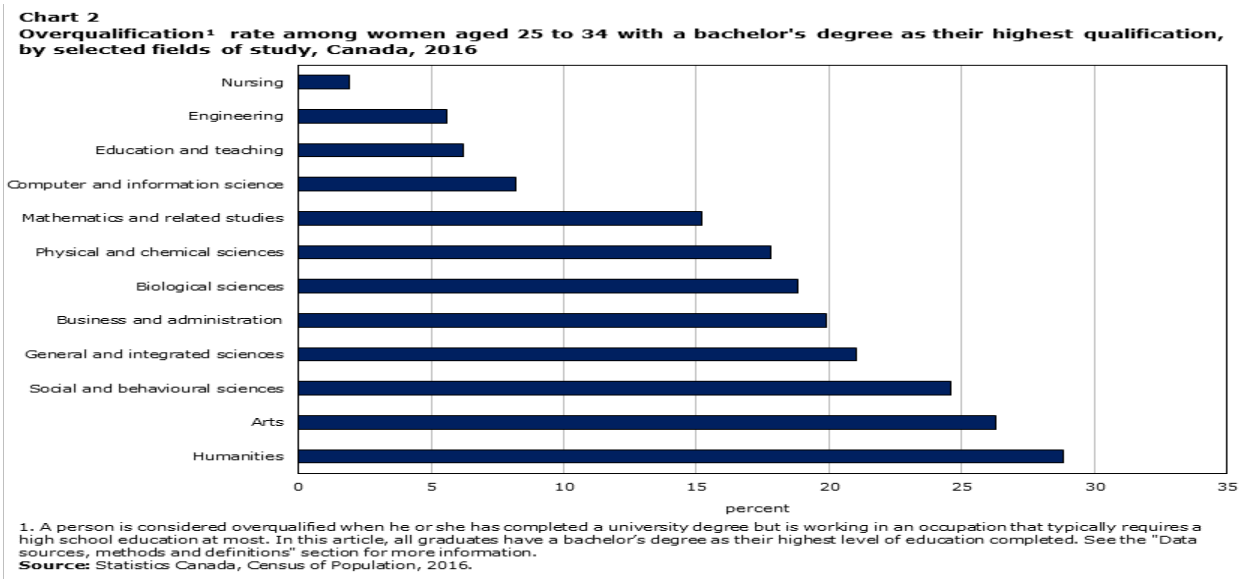



Figure 4 This Census in Brief article examines the jobs of young bachelor's degree holders. (2017, November 29). Retrieved October 15, 2020, from https://www12.statcan.gc.ca/census-recensement/2016/as-sa/98-200-x/2016025/98-200-x2016025-eng.cfm

## Income

As mentioned above arthritis affect many different people and it is difficult to determine the income of arthritis suffers. Focusing on the cost of Osteoarthritis in 2013 (USA), the national arthritis-attributable medical costs were $140 billion. Which is $2,117 in extra medical costs per adult with arthritis. (CDC.gov. 2020)

## Results

Based on the images above we get a general overview of who suffers from Osteoarthritis and what they look like. OA can pop up at any age depending on the person, but most of the time OA suffers are

approximately 60+. It is also apparent that most people suffering from arthritis are none Hispanic white. When it comes to income its difficult to determine and may be better off focusing on the costs faced by OA suffers. In the USA alone, OA was the second most expensive health condition treated at US hospitals in 2013. Using the statistical data found during user research, its easy to see the Avg Osteoarthritis suffer.

### 2.1.2 User Observation – Current User Practice / User Behaviour

#### Activity Frequency

People that suffer from Osteoarthritis Above the age of 60 are usually retried or working a part time job, that they would have to travel to. As far as daily activates go they would be similar to someone without OA, but OA suffers may have a harder time completing these everyday tasks. These activities can range from shopping or just going outside for a walk.

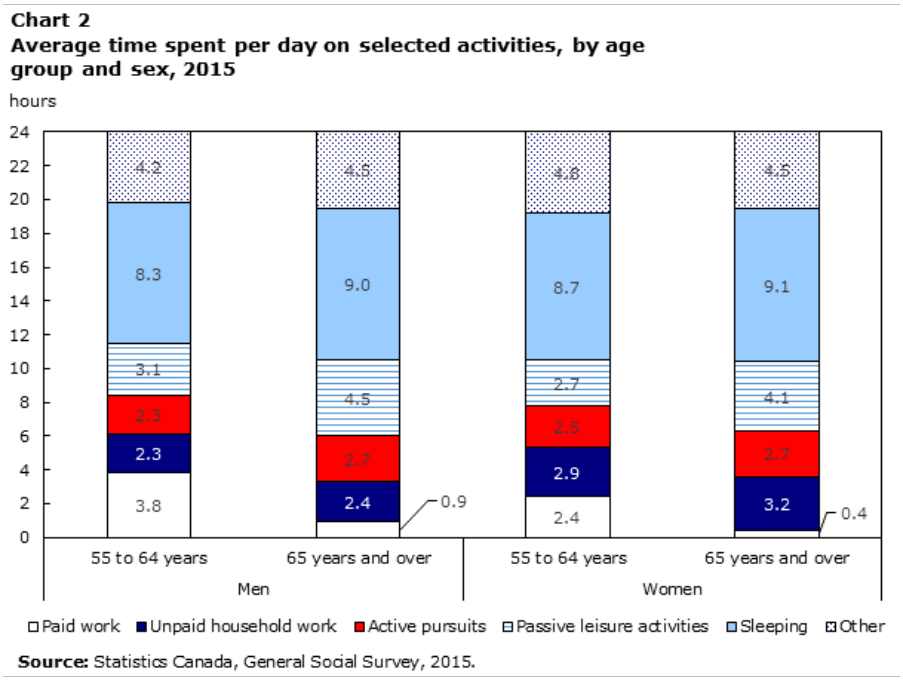



Figure 5 – Chart 2 Average time spent per day on selected activities [Image] (2015) Retrieved from https://www150.statcan.gc.ca/n1/pub/75-006-x/2018001/article/54947-eng.htm

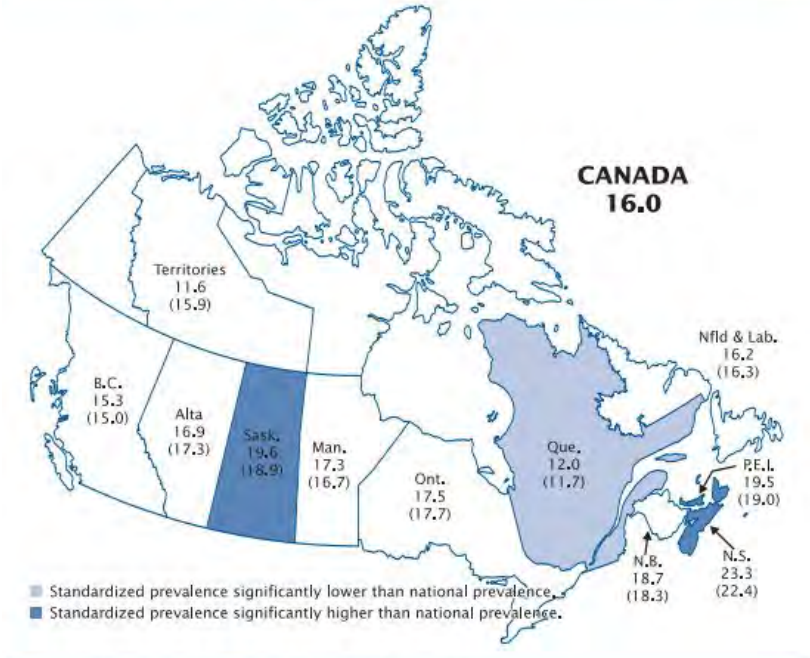
### Social

People suffering from OA may have unstable social lives, as they can find activates more difficult than they used to be and have to stop, for instance maybe this person had a favorite sport that they used to play with their friends but can no longer participate. These small disabilities can have a large social impact on a person's life.

### Lifestyle and personality

Osteoarthritis suffers above the age of 60 spend most their day doing leisurely activates which could range from sitting outside to cooking. People with OA are also inclined to preform exercises to relieve the pains of OA, this could be doing simple at home exercises to hiring a personal trainer. Arthritis can be found just about anywhere in the world, but focusing on Canada, Saskatchewan and Nova Scotia are significantly higher than the national prevalence of arthritis.

**Figure 2-4** **Crude (age-sex standardized) prevalence of arthritis/rheumatism, by province/territory, household population aged 15 years and over, Canada, 2000**




Data source: Canadian Community Health Survey 2000, Statistics Canada

Figure 6 - Crude (age-sex standardized) prevalence of arthritis/rheumatism, by province/territory, household population aged 15 years and over, Canada, 2000 [Image] (2000) Retrieved from https://www.arthritisresearch.ca/wp-content/uploads/Arthritis_in_Canada.pdf

**Preliminary Persona**

**Name:** Betty Smith

**Age:** 67

**Occupation:** Retired Communications specialist

**Income:** $14,109.96

**Education:** Bachelor's Degree - Communications

**Relationship Status:** Married, 1 kid

**Location:** Toronto, Ontario

**Career/ Volunteer:** Retired

**Years of Service:** 30

**Social:** Hangs out with friends and family

**Frequency of Activity:** Leisure activates throughout the day

**Hobbies:** Walking, Tennis, Shuffleboard, cooking

*Figure 7 Woman with a walker [Image] (2016) Retrieved from https://www.pinterest.ca/pin/551550285595738963/*

## Primary User Profile

| **Demographics** | | **User Behavior** | | **Personality** | | **Cognitive Aspects** | |
|---|---|---|---|---|---|---|---|
| Age | 60+ | Frequency of Use | 6hr (mobility Aids) | Go Getter | ↑ | Technical Skill | ↑ |
| Gender | Mixed (60% Female) | Duration | Varies (20 mins to x hrs) | Self-Efficacy | ↑ | Pre-Requisite Knowledge | ↑ |
| Ethnicity | Non-Hispanic White | Social | low-Social | Changeability | ↑ | | |
| Income | Middle Class ($40,000 to $80,000) | Level of Focus | Medium | Uncertainty Avoidance | ↓ | | |
| Education | Degree | Location | Residential – Rural/ Urban | | | | |

### 2.1.3 User Observation – Activity Mapping

In any product development, user observations provide ample amounts of information on the user's personal experience while doing certain tasks. These types of studies open new directions for critical design thinking that may not have been thought about beforehand.

**Objectives**

- Determine pain points
- Find new areas of thinking
- Journey map / empathy map
- Users daily activities

**Methods**

In order to gain data from the users themselves, one-on-one interviews had been done. These interviews involved the user to perform some everyday tasks that they find hard to do with arthritis. While the user performs these tasks, it is crucial to ask questions that will give the opportunity for further inspiration and development. Data collection had been done by manual note taking for later review.

**User of Study**

- Senior with arthritis
- 88 years old
- Female
- Lives independently on large property

### Users Daily Routine

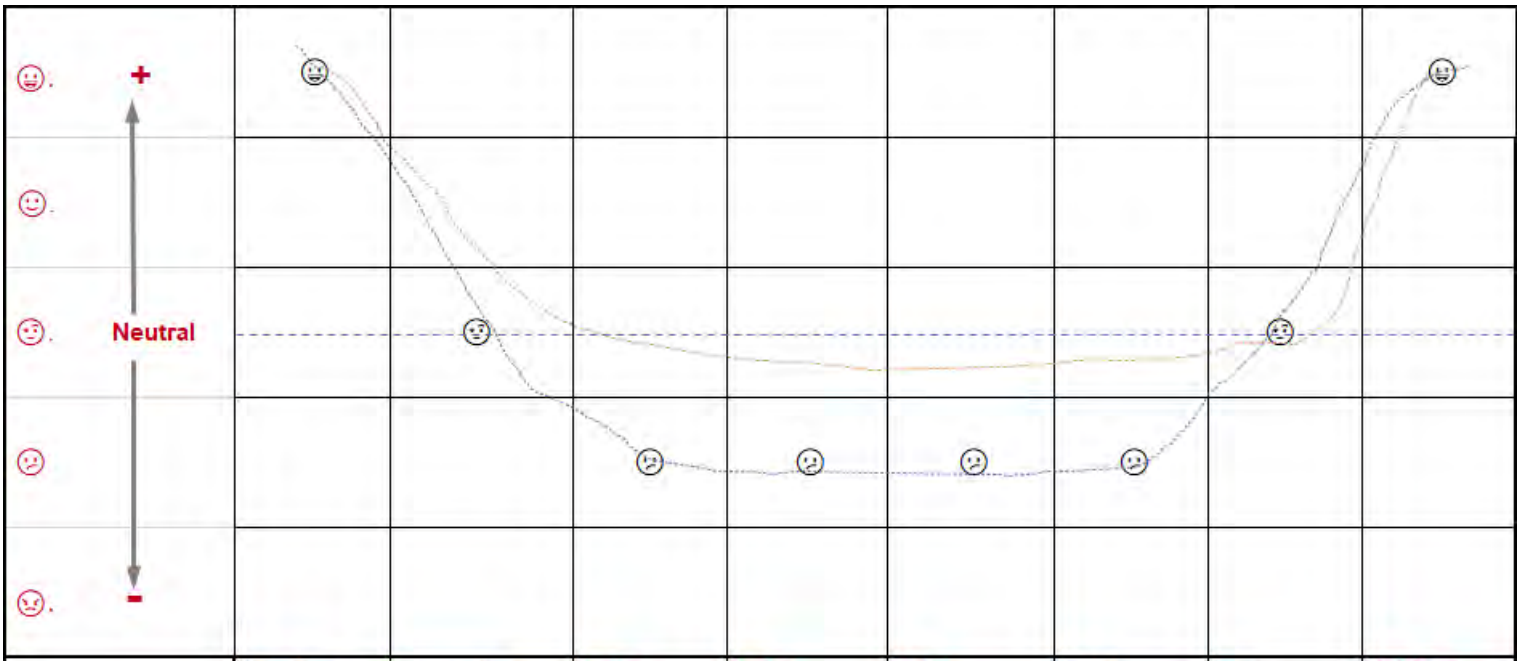
| Time of Day | Task | Pain-points |
|---|---|---|
| Morning | ▪ Wake up, turn on furnace<br>▪ Make the bed<br>▪ put on makeup “paint the barn”<br>▪ Makes tea and takes medication<br>▪ Feed the birds<br>▪ Take the garbage out<br>▪ Check Facebook<br>▪ Have a bowl of cereal | ▪ Bending down to make the bed<br>▪ Walking down the stairs/filling the feeder (heavy) |
| Afternoon | ▪ Do laundry<br>▪ Check the mail<br>▪ Clean around the house<br>▪ Yardwork<br>▪ Clean out fireplace<br>▪ Take food out for dinner<br>▪ Drive into town for grocery’s and medication | ▪ Long steep driveway to get to mailbox<br>▪ Cannot move heavy furniture<br>▪ Hard to move around house with walker<br>▪ Heavy mobility aids (Portability)<br>▪ Heavy groceries |
| Evening | ▪ Plays card games on computer<br>▪ Feeding logs into the fire<br>▪ Making dinner<br>▪ Watches late night news<br>▪ Shower<br>▪ Go to bed | ▪ Logs are hard to lift (gripping)<br>▪ Using small utensils<br>▪ Slippery shower / getting in and out of the shower |

## Focused Task

- Getting the mail

| | Planning | Preparation | Task 1 | Task 2 | Task 3 | Task 4 | Goal | Completion |
|---|---|---|---|---|---|---|---|---|
| User Goals | Getting the mail | Perparing to go outside | Going outside | Use the walker | walking down long driveway | Get mail and walk back | Get back to the house with the mail | Reading mail |
| User Actions | Checking the weather outside | Put jacket on | opening door | grab the walker with | slowly walk down the | Grab mail | slowly walk back up | sit down at the table |
| | seeing if there is mail | sit down and put shoes on | walking down steps | release the breaks | | Stand at a safe distance from the road | walk up the steps using the railing | Going through the mail |
| | | | | slowly begin walking | | | Untie shoes | |
| | | | | | | | | |
| User Thoughts | Favourite part of the morning | decided wether or not to | make sure to use railing | making sure to have a steady footing | making sure to watch | Watching out for ca | making sure the walker is put away | Reading the mail |
| | | | go slow | | | checking the mail bo | ankles slightly sore | |
| | | | | | | | | |

## Journey Map




| | Planning | Preparation | Task 1 | Task 2 | Task 3 | Task 4 | Goal | Finish up |
|---|---|---|---|---|---|---|---|---|
| User Goals | Getting the mail | Perparing to go outside | Going outside | Use the walker | walking down long driveway | Get mail and walk back | Get back to the house with the mail | Reading mail |

**Results**

A person diagnosed with arthritis, has the same day as the average individual, but someone that has arthritis may have some difficulties doing tasks that others may have never thought about. Something that comes easy for the average person may be extremely difficult for someone suffering from joint pain, for instance going and getting the mail doesn't require the average person to plan out their actions before performing the task to limit injury and stay safe.

### 2.1.4 Human Factors – Research of Existing Products

Ergonomics are an essential aspect when it comes to mobility aid development, as users may use these aids for a large period of their day. Mobility aids coming various forms from walkers to braces, all these aids must take into consideration how the users will use the product, where the touch points are, the scale of the product, etc. Utilizing the current products on the market will give a clearer understanding of the ergonomic factors other companies had taken into consideration.

**Objectives**

- Compare and contrast existing ergonomic considerations
- Identify gaps in the market

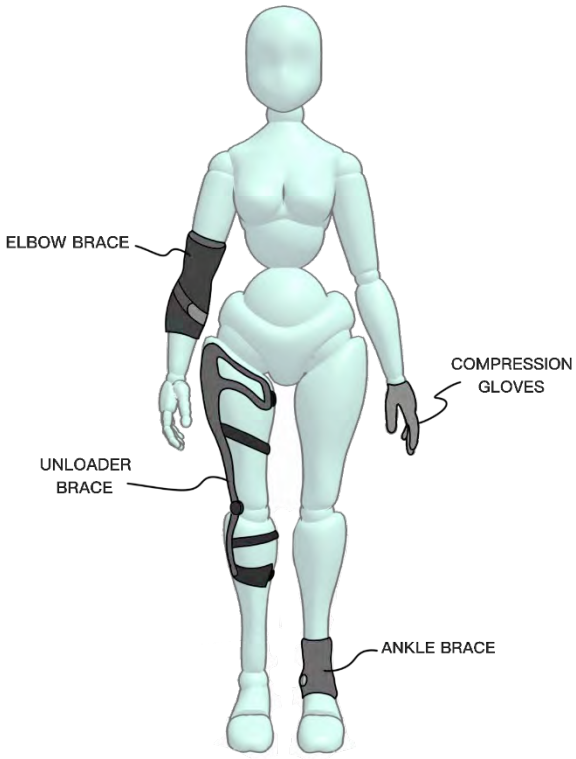
**Methods**

By utilizing the internet, a collection of products pertaining to the proposed design direction have been outlined and documented. Along with identifying similar products it is important to look for gaps in the current market that could offer a different design direction.

**Results**

| | Product Image | Description |
|---|---|---|
| 1 |  | **Ossur Unloader One**<br>• Dual Dynamic Force System™ (DFS) straps provide unloading of the knee joint<br>• Moderate to severe unicompartmental knee osteoarthritis<br>• Proprietary Sensil® silicone liners are designed to reduce migration. |
| 2 |  | **Ossur Unloader One X**<br>• Moderate to severe cases of knee osteoarthritis<br>• Entire brace is machine washable<br>• Alignment guide, color-coded touchpoints, and Quick Fit buckles allow for intuitive donning and doffing |
| 3 |  | **Össur Formfit® Pro Knee OA**<br>• Lightweight CoolVent™ knit in popliteal area for added breathability and comfort.<br>• Patella graphics for intuitive placement<br>• Early or mild stages of osteoarthritis |
| 4 |  | **Push med Elbow Brace**<br>• Adjustable with one hand.<br>• excellent fit and silicone strips prevent migration during movement.<br>• Comfortable and lightweight |

| | | |
|---|---|---|
| 5 |  | **Donjoy Performance Trizone Elbow Support**<br>• Anti-migration technology<br>• All-natural carbonized bamboo is thermal regulating<br>• Three zones of compression |
| 6 |  | **MedSpec Motion Manager - Wrist Support**<br>• Ventilated adjustable strap allows adjustment of compression around the carpals<br>• Flip tab allows product to be worn on either right or left hand<br>• Semi-flexible polyethylene stay: controls wrist motion in functional range |
| 7 |  | **Donjoy Velocity ankle brace**<br>• low profile and lightweight<br>• moldable foot plate<br>• R3 technology (rapid-rigid-ratched) in the calf cuff, provides compression to your ankle joint to prevent swelling. |
| 8 |  | **Compression gloves**<br>• non-invasive relief<br>• comfortable and breathable design<br>• 60% Cotton / 33% Polyester / 7% Spandex<br>• easy to clean |




### 2.1.5 Safety and Health – Research of Existing Products

When it comes to mobility, health and safety is a number one priority. Another factor that needs to be considered are the effects of arthritis and how this diagnosis can cause further safety issues. As each user's mobility issues can range from minor to major, there are a lot of areas where health and safety needs to be well thought out.

**Objectives**

- Determine touchpoints
- Identify comfortable materials
- Identify structural supports

- Benchmark current solutions

## Methods

By researching current products and collecting data on the current health and safety considerations.

### Current Health and safety considerations

#### Results

| Type of Brace | |
|---|---|
| Prophylactic Brace | ▪ To protect from injury<br>▪ Worn for sports |
| Functional / Supportive braces | ▪ Support for a previously injured joint |
| Rehabilitative braces | ▪ Limit movement<br>▪ Improve healing time<br>▪ Used after surgery |
| Unloader / offloader braces | ▪ Most used for arthritis<br>▪ Reduce pressure on effected side of joint |

## 2.2 Introduction to Product Research

Conducting research on current products related to the proposed thesis topic will help determine what features and benefits current companies are using to generate sales. This also

gives a unique insight on the wants and needs of the end-user and to identify if there are any gaps in the current market, that customers may be looking for.

**Objectives**

- Identify and benchmark features and benefits currently being offered
- Benchmarking materials and functionality
- Benchmarking Aesthetics and Semantic Profile of current products
- Identify new technology / materials

**Methods**

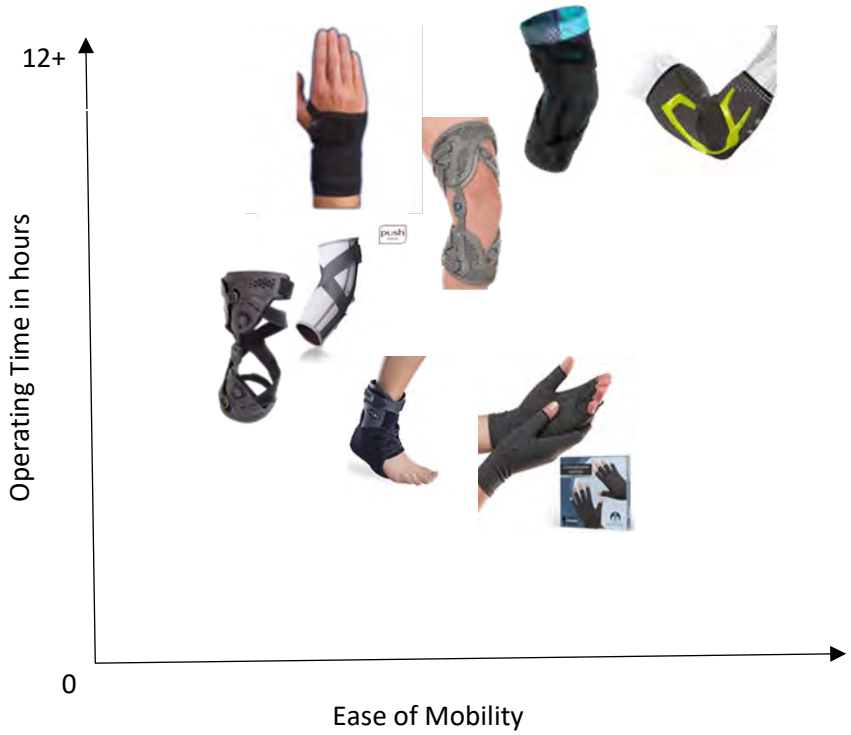
Information was gathered utilizing the online marketplace, where data was collected on current products, materials, benefits, features and user reviews.

### 2.2.1 Benchmarking – Benefits & Features

Utilizing a X-Y graph to compare products on two features of the selected products for each axis of the graph. These two graphs will give a representation of the current products and identify any patterns. The first X-Y graph shows the difference between soft and rigid bodies as well as the location of which the brace would be utilized. In the second X-Y graph the products are compared by the operation time and the ease of mobility for each product.

**X-Y Graph 2.2.1.1**


**X-Y Graph 2.2.1.2**



**Benefits and Features Charts 2.1.1.3**

Furthermore, two separate charts were created to compare the features and benefits between current products.

| BENEFITS | Sort #1 | Sort #2 |
|---|---|---|
| From Promotional Material | DATA [On Menu Bar] → | Groups like categories |
| comfortable | adjusted with one hand | *comfort* 13 |
| lightweight | at work or at home | comfortable |
| low-profile | Color-coded Quick Fit Buckles simplify | comfortable |
| excellent suspension | comfortable | comfortable |
| lightweight | comfortable | comfortable and light |
| easily fine-tuned | comfortable | at work or at home |
| Color-coded Quick Fit Buckles simplify | comfortable and light | enhanced comfort |
| improve comfort | easily fine-tuned | excellent suspension |
| reduce migration | easy to apply and can be washed | extra support |
| reduces pain | easy to put on and take off | extra support |
| infinitely adjustable extension | enhanced comfort | extremely comfortable |
| prevents overstretching | excellent suspension | flexible support |
| adjusted with one hand | extra support | high-quality comfortable material |
| withstanding strong traction forces | extra support | improve comfort |
| comfortable and light | extremely comfortable | *style* 8 |
| easy to put on and take off | flexible support | easily fine-tuned |
| high-quality comfortable material | high-quality comfortable material | easy to apply and can be washed |
| keeps the skin dry | improve comfort | easy to put on and take off |
| easy to apply and can be washed | infinitely adjustable extension | lightweight |
| provide flexible support | injury prevention | Lightweight |
| used on either hand | keeps the skin dry | lightweight |
| comfortable | lightweight | Low Profile |
| enhanced comfort | Lightweight | low-profile |
| flexible support | lightweight | |
| at work or at home | Low Profile | *efficiency* 3 |
| extra support | low-profile | Color-coded Quick Fit Buckles simplify application and removal |
| prevent ankle sprains | prevent a future injury | without bulkiness |
| extremely comfortable | prevent ankle sprains | withstanding strong traction forces |
| prevent a future injury | prevents overstretching | |
| comfortable | provide flexible support | |
| injury prevention | reduce migration | |
| Low Profile | reduces pain | *ease* 5 |
| Lightweight | used on either hand | adjusted with one hand |
| extra support | without bulkiness | infinitely adjustable extension |
| without bulkiness | withstanding strong traction forces | injury prevention |
| | | keeps the skin dry |
| | | used on either hand |
| | | |
| | | *Safety* 6 |
| | | prevent a future injury |
| | | prevent ankle sprains |
| | | provide flexible support |
| | | reduce migration |
| | | reduces pain |
| | | prevents overstretching |

| FEATURES | | Sort #1 | Sort #2 |
|---|---|---|---|
| From Promotional Material | Re-order: NOUN first | DATA [On Menu Bar] → | Group like categories |
| microfibres | Adjustability: adjustable wrist compression | Adjustability: adjustable wrist compression | Base Frame 8 |
| 3-Points of Leverage | Adjustability: anatomical fit | Adjustability: anatomical fit | Base Frame: lightweight |
| adjustable wrist compression | Adjustability: Dynamic Force Control System | Adjustability: Dynamic Force Control System | Base Frame: Anatomically Designed Bilateral Hinges |
| anatomical fit | Base Frame: lightweight | Base Frame: lightweight | Base Frame: Breathable liners |
| Anatomically Designed Bilateral Hinges | Base Frame: Anatomically Designed Bilateral Hinges | Base Frame: Anatomically Designed Bilateral Hinges | Base Frame: Flexable shells |
| breathable liners | Base Frame: Breathable liners | Base Frame: Breathable liners | Base Frame: flexible plastic stays |
| Dual Dynamic Force Straps | Base Frame: Flexable shells | Base Frame: Flexable shells | Base Frame: neoprene base |
| Dynamic Force Control System | Base Frame: flexible plastic stays | Base Frame: flexible plastic stays | Base Frame: Rigid Uprights |
| flexible plastic stays | Base Frame: neoprene base | Base Frame: neoprene base | Base Frame: soft |
| flexible shells | Base Frame: Rigid Uprights | Base Frame: Rigid Uprights | |
| lightweight | Base Frame: soft | Base Frame: soft | |
| neoprene base | Materials: Össur Sensil® Silicone | Materials: Össur Sensil® Silicone | |
| Össur Sensil® Silicone | Materials: Microfibers | Materials: Microfibers | Materials: 5 |
| pulled for use as more for its compression features | Materials: silicone application | Materials: silicone application | Materials: Össur Sensil® Silicone |
| Rigid Uprights | Materials: Sympress | Materials: Sympress | Materials: Microfibers |
| silicone application | Materials: zipper | Materials: zipper | Materials: silicone application |
| soft | Straps: 3-points leverage | Straps: 3-points leverage | Materials: Sympress |
| strap system is very functional | Straps: Dual Dynamic Force straps | Straps: Dual Dynamic Force straps | Materials: zipper |
| Sympress | Straps: pulled for use as more for its compression features | Straps: pulled for use as more for its compression features | Straps 4 |
| zipper | Straps: strap system is very functional | Straps: strap system is very functional | Straps: 3-points leverage |
| | | | Straps: Dual Dynamic Force straps |
| | | | Straps: pulled for use as more for its compression features |
| | | | Straps: strap system is very functional |
| | | | |
| | | | Adjustability 3 |
| | | | Adjustability: adjustable wrist compression |
| | | | Adjustability: anatomical fit |
| | | | Adjustability: Dynamic Force Control System |

**Results**

## Benefits Table

| Key Benefits of Comparable Products | |
|---|---|
| ***Keyword*** | ***Frequency*** |
| Comfort | 13 |
| Style | 8 |
| Safety | 6 |
| Efficiency | 5 |
| Ease | 3 |

## Features Table

| Key Features of Comparable Products | |
|---|---|
| ***Keyword*** | ***Frequency*** |
| Base Frame | 8 |
| Materials | 5 |
| Straps | 4 |
| Adjustability | 3 |

### 2.2.2 Benchmarking – Functionality

Functionality is a major aspect in any product, but especially when dealing with a mobility aid product such as a knew brace. The user needs the product to function well for them to be comfortable and make the rehabilitation process work or they may even cause damage the affected area.

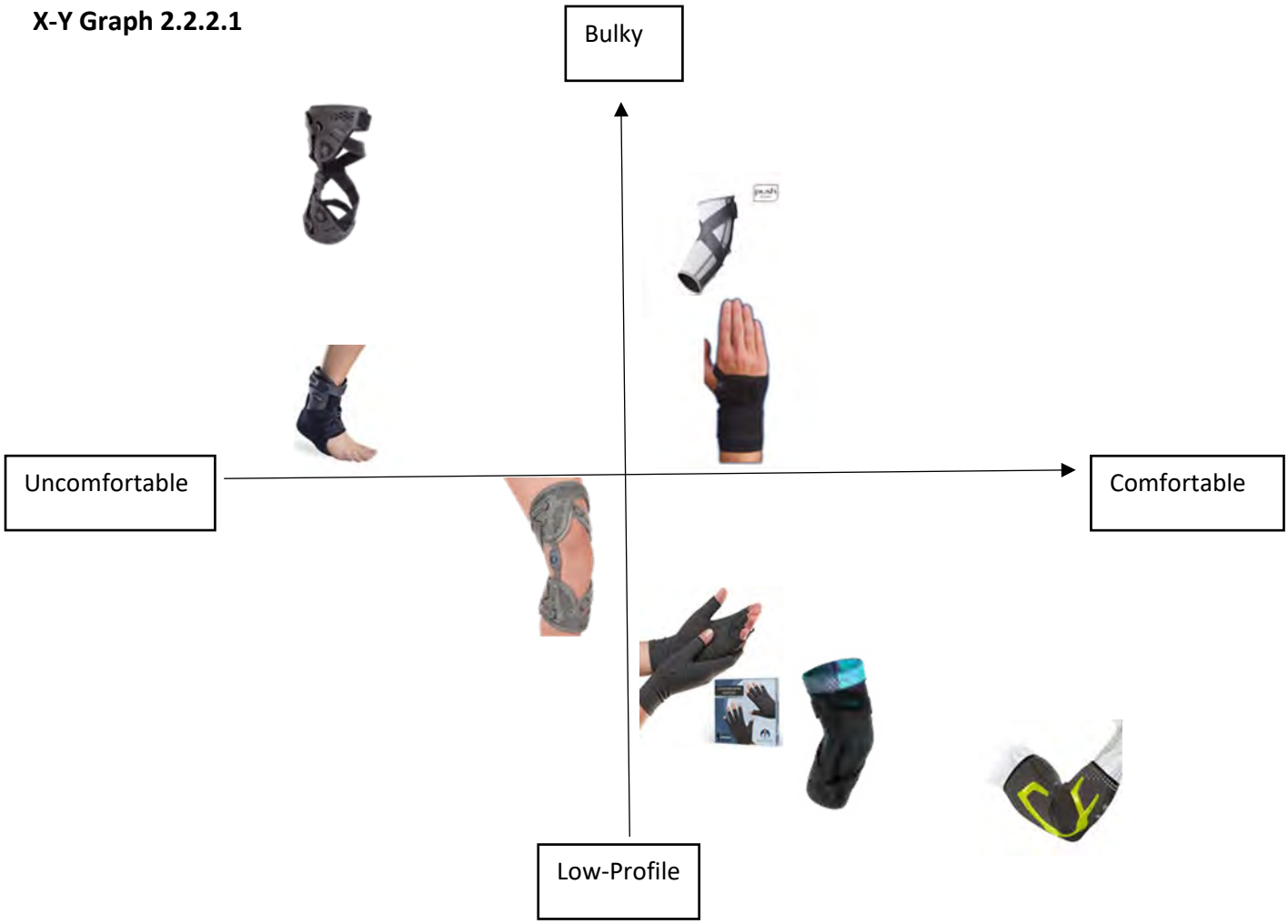
**Objectives**

- Identify different areas of functionality between current products
- Identify current trends

**Methods**

By analyzing current products on the market through online stores and forums. An X-Y graph was created to show the difference in functionality between current mobility aids.

**X-Y Graph 2.2.2.1**




**Results**

As shown in the above graph, there are many mobility aids in the form of braces. These braces range from bulky plastic systems to skin-tight low-profile options. While the low-profile options provide a more comfortable experience, they lack the extra support in some areas and vice versa. The user has to choose between a more comfortable option or a more supported device, this will vary between arthritis patients and the severity of their osteoarthritis.

### 2.2.3 Benchmarking Aesthetics and Semantic Profile

This section of the report will be utilized to benchmark current aesthetics and semantic profiles of existing mobility aids in the category of joint braces.

**Objectives**

- Identify current aesthetic trends
- Identify current product expression / personality

**Methods**

Data and information was collected by using a chart comparing the differences between current braces on the market. This chart focuses on the products colour, size, texture, graphics, finishes etc.

**Results**

| **Aesthetics and Semantic Profile** |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Shape (profile) | Bulky, Large components | Semi-low Profile | Low profile | Bulky Large wrap | Low profile One Component | Semi-low profile | Low profile | Bulky |
| Colour | Neutral dark grey | Light grey | Black, blue accents | Light grey accents White | Neutral dark grey Light green accents | Flat black | Flat dark grey | Two tone grey |
| Pattern | Cut out pattern | Cut out pattern | Minimal accent patterns | Basic line pattern | Support placement | N/A | N/A | N/A |
| Materials | silicone liners plastic | silicone liners plastic | flexible EVA Breathable Fabric | Silicon Plastic stiffeners | Carbonized Bamboo Silicon | Neoprene base nylon/polyester top | soft, breathable cotton | Plastic Breathable material |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Breathable fabric | | | Padded fabric | | plastic stays | | |
| Texture | Smooth plastic Soft touch points | Smooth plastic Soft touch points | Soft | Smooth plastic | Support extrusion | Soft | Soft | Smooth plastic Soft touch points |
| Technology | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Area of use | Knee | Knee | Knee | Elbow | Elbow | Wrist | Wrist / Hands | Ankle |

### 2.2.4 Benchmarking – Materials and Manufacturing

Most braces are mass produced to fit certain human percentiles, these types of braces are usually adjustable soft fabric and or rigid plastics. As there are many different types of braces it is difficult to narrow the manufacturing process down as some use metals, plastics, silicon, compression materials. Most soft bodied braces are stitched fabrics and materials, while braces with plastic would be injection molded. One exception to the manufacturing process are custom braces, these braces are made by scanning the user's limb and the company makes the brace around the 3D model of the user limb.

### 2.2.5 Benchmarking – Sustainability

Sustainability is become ever more present as the years go on. Analyzing existing products on the market that relate to arthritic braces provided some further understanding on how brace companies go about sustainability. For an example the company Mueller Sports Medicine "adopted the bottom-line method to examine the effects of business activities on the economy, social equity, and environment" (Mueller Sports Medicine Sustainability, 2020). As far as materials go brace companies tend to opt for an environmentally friendly option such as

Carbonized Bamboo. Using Mueller Sports as another example, tend to use recycled plastics withing their braces.

### 2.3 Summary

This section of research involves the interviews that were conducted with an expert in the field of the proposed topic. The results from this interview will provide a better understanding of arthritis and mobility from a physiotherapists view.

**Objectives**

- Gain further insight on arthritis and mobility
- Identify rehabilitation aspects of arthritis

**Methods**

By contacting an expert in the field of arthritis and rehabilitation. Data collection through an online survey which was completed by the expert.

**Summary of Results**

- Moderate to major mobility issues are more common than minor
- Age 60+ arthritis becomes more prevalent
- Arthritis mainly effects Back, Hips, knees, and feet
- Osteoarthritis can impact grip strength
- Osteoarthritis is a “wear and tear”
- Reduce joint pain by alternating sitting and standing. Using a walker to offload back, hips, knees.

- Biggest complaint: pain doing everyday tasks and reduced mobility
- Limiting the pain: Prescription and non-prescription (over the counter) and pain clinics
- If joints are severely affected, then surrounding soft tissue could be impacted
- Arthritis effects mental health when a person becomes less independent and suffers functional loss.
- Calcium is the most common food supplement for bone density
- A fracture can result in arthritic pain after the fact. For instance, osteoarthritis

  Congenital birth issues with surgery to correct can result in arthritis later.
- every area of the home can be an issue! Stairs, getting on/off toilet, in/out of bed or shower/tub, getting dressed, meal prep, laundry etc.

# Chapter 3

### 3.1 Analysis

This chapter will utilize the user research and product research from the previous chapter, to analysis the users needs that are not met by current products as well as the latent needs and the categorization of theses needs.

#### 3.1.1 Needs/Benefits Not Met by Current Products

Currently, users have many different options when deciding which mobility aid, they would like to buy and use. This section will aim to analysis the users needs and how current mobility aids meet those needs. From the information gathered there may be opportunities to improve on.

**Objectives**

- Identify user needs
- Identify areas for improvement
- Identify current product solutions

**Method**

This section reflects to some sections in chapter 2 regarding user behaviour, user interviews, features, and benefits and expert interviews. Information from these sections as well as the empathy and journey mapping will be used to identify the unknowns.

**User Needs**

- Low Profile
- Easy to use interface

- Develop breathable/lightweight brace material
- Adjustable braces
- Ease of use

**Areas for improvement**

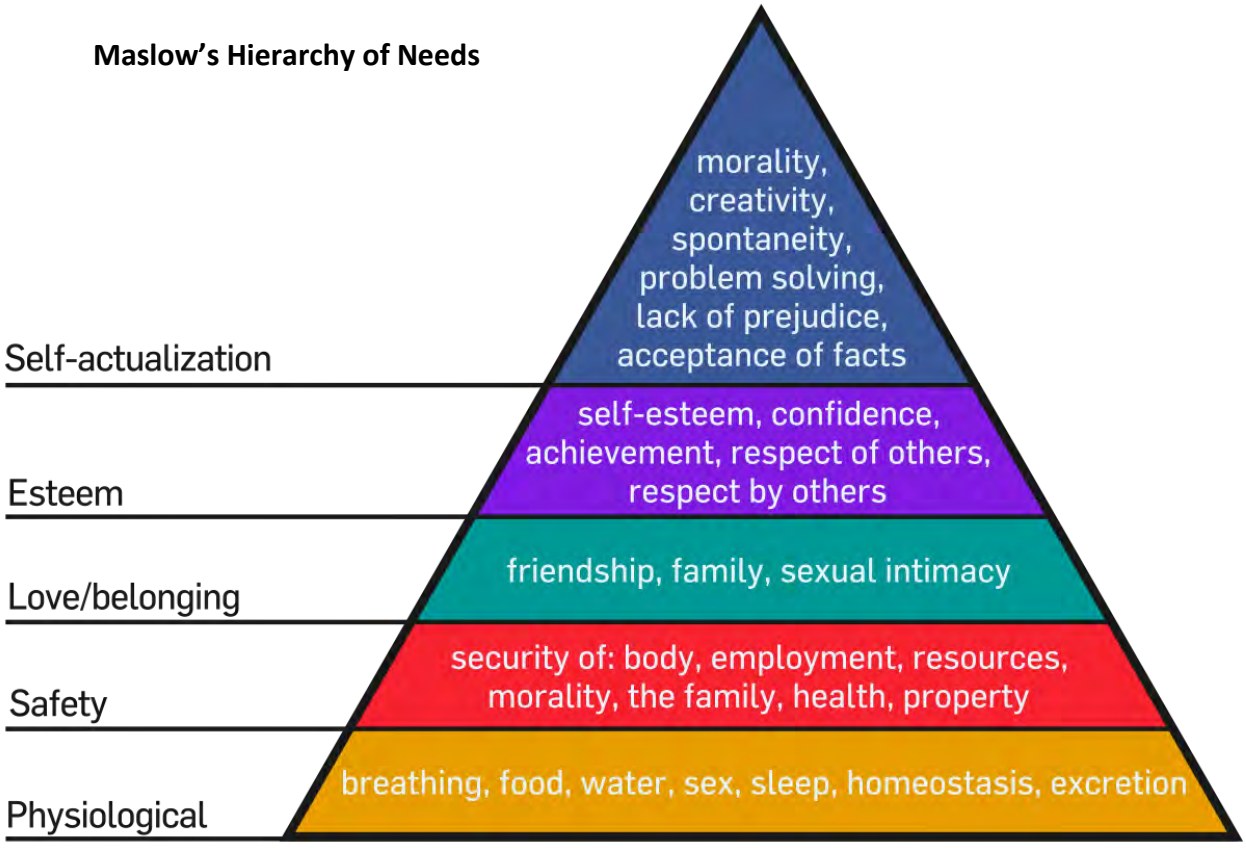
- Improve comfort
- Improve ease of mobility
- Improve on medical devices aesthetics
- Improve wearability
- Improve rehabilitation

**Current product solutions**

- Breathable materials
- Form fitting materials
- Skin friendly materials
- Variability in product sizing and adjustability
- Variability of braces

### 3.1.2 Latent Needs

**Maslow's Hierarchy of Needs**




Eaton, S. E. (2012). Maslow's Hierarchy of Needs [Hierarchy of needs]. Retrieved 2020, from https://drsaraheaton.wordpress.com/2012/08/04/maslows-hierarchy-of-needs/

| | Benefit | Possible Corresponding Fundamental Human Needs (FHN) | Relationship between Benefits and FHN |
|---|---|---|---|
| 1 | Style | Esteem, Respect of others | Moderate |
| 2 | Comfort | Control, Security | Strong |
| 3 | Ease | Accomplishment, protection, security, control, self-esteem | Strong |
| 4 | Efficiency | Accomplishment, protection, control, self-esteem | Strong |
| 5 | Freedom | Leisure, Participation, Belonging, self-esteem | Strong |

### Style

Since this solution will be fitting into a gap in the mobility aid market (style) its very important that the users want to participate in wearing the products and be happy using them anywhere. The look of this product should not be overlooked.

### Comfort

As mobility is the main aspect in the proposed design, its essential that the user can comfortably use the products for long or short periods of time. Bulky unergonomic features will have to be minimized.

### Ease

Users that come into contact with the product should be able to use / interact with the system easily and with out question. From putting the product on to taking it off needs to be an easy and smooth activity for the users.

### Efficiency

Efficiency is an important aspect for the proposed thesis topic, mobility needs to be a quick and efficient activity. If this type of product is not efficient it would simply not sell.

### Freedom

The freedom of the user, Arthritis can take many joys out of the world, people may struggle to get out and do their own thing or go to social events and overall take care of themselves.

### 3.1.3 Categorization of Needs

**Immediate Needs**

- comfortable walking / reaching / bending
- Reduce Joint pains
- Statistical information on joint movements
- Low probability of loss of balance

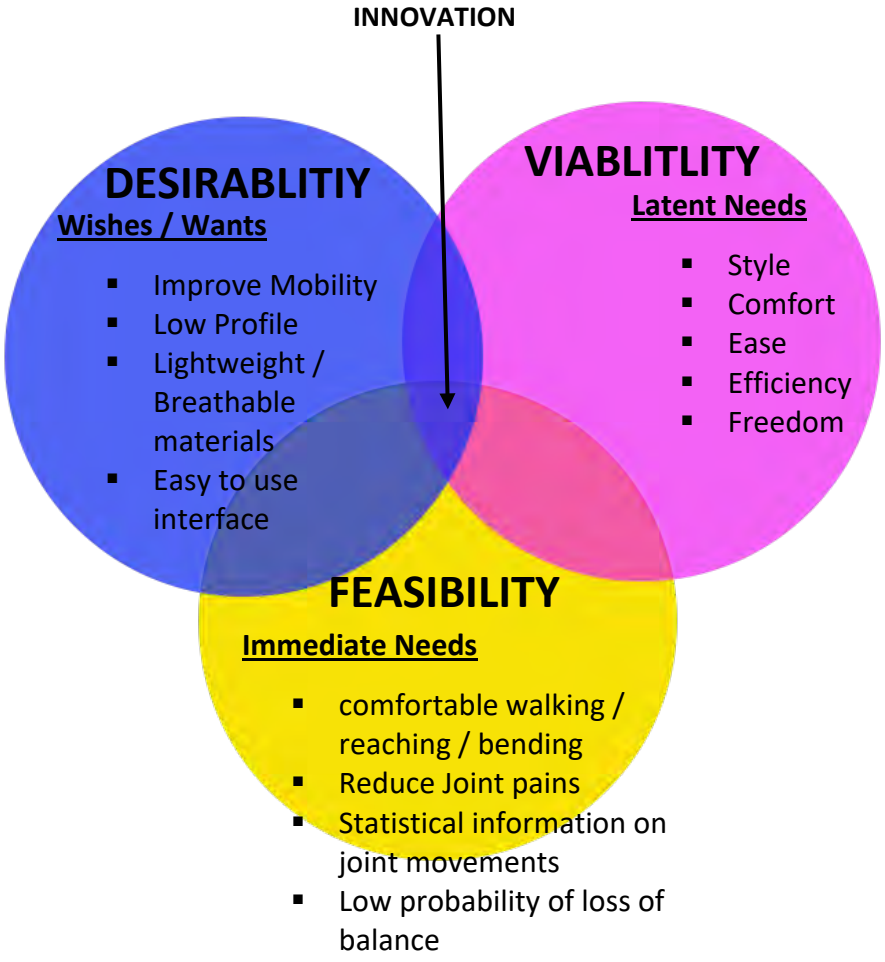
**Wishes / Wants**

- Improve Mobility
- Low Profile
- Lightweight / Breathable materials
- Easy to use interface

**Latent Needs**

- Style
- Comfort
- Ease
- Efficiency
- Freedom

### 3.1.4 Needs Analysis Diagram




## 3.2 Analysis – Usability

### 3.2.1 Activity – Workflow Mapping

Referring back to section 2.1.3, The user observation of an elderly person with arthritis performing a task. The task that she had completed was the process of walking outside and picking up her mail from the mailbox at the end of the driveway. Some of the key aspects from the observation are as follows:

**Interactions with walker**

- Walker is not always at a close enough distance
- Has to use walker over electric scooter when the weather is not clear
- Has a hard time descending the steep dive way (feathering wheel breaks)
- Walker sits outside causing breaks to degrade

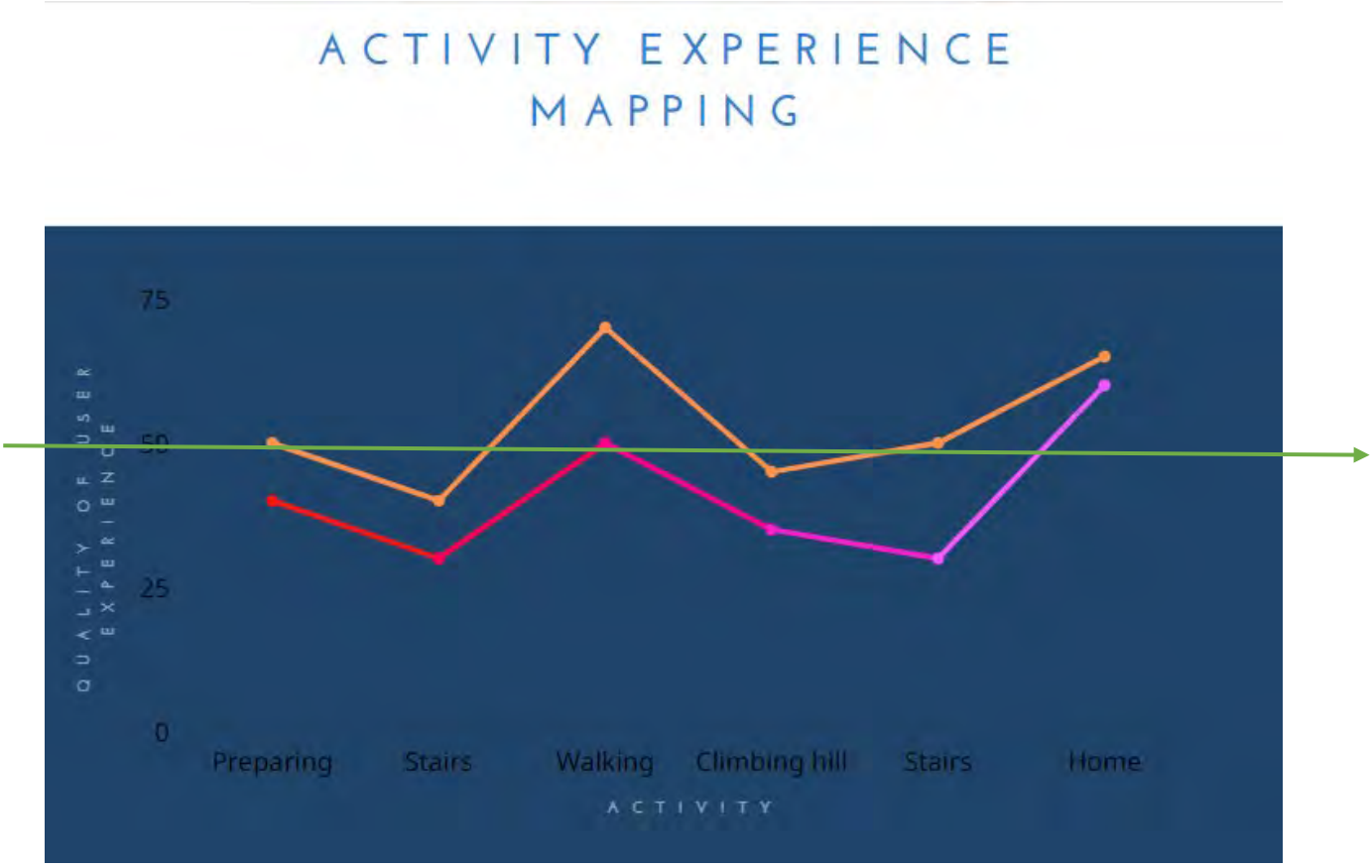
**Ergonomic pain-points**

- Difficulties putting on shoes due to joint pains in her hands
- Bending over while tying shoes cause strain on her back
- Making sure not to slip on the outside staircase
- Knee joints sore from walking up and down the driveway

**Ability to perform task**

- Dangerously close to the road
- Always looking down watching her step
- Completes task
- Slow and thought-out process

### 3.2.2 Activity – Experience Mapping




50 = Neutral, Current User Experience  Potential User Experience

As development continues the direction may change as well, while this user observation provided information to further develop the thesis topic, the proposed topic is now more focused on arthritic braces. To gather more relevant information on the topic, online forums were utilized to gain the perspective of the users that currently use braces for their joint pains. These observations can be summarised as follows:

- Users experienced, excessive heat causing them to sweat in the areas where the brace is used
- Users embraced the ability to adjust their brace quickly by using Velcro straps

- Braces were unutilized at over night and when performing tasks that cause strain on their joints
- Putting on and off a brace may be difficult for people suffering from multiple forms of joint pain
- Users experience a loss in mobility but its better than not using the brace
- Bulky braces can get in the way while preforming tasks
- Braces may be hard to correct placement when misaligned when under clothing

### 3.3 Human Factors

Osteoarthritis is one of the leading causes for seniors over the age of 65 to have mobility issues. When arthritis begins to limit a person's mobility, the person may decide to purchase a mobility aid, to ease everyday tasks. The current mobility aid market offers many different solutions to various issues surrounding arthritis and mobility. When designing a wearable product, ergonomics becomes a very important factor to consider. Critical ergonomic measurements will ensure that an arthritic brace user can wear the mobility aid without any discomfort and minimal restrictions to the users range of motion. Increasing mobility for the user is the upmost priority, as well as providing the user with critical information on their affected joints to further their understanding of their own bodies and how they function with arthritis. This economic report was used to further understand the user's interaction with arthritic braces throughout their day to day lives.

## LITERATURE REVIEW

Throughout this report, anthropometric data was gathered from scholarly sources, mainly data from "The Measure of Man and Women" (Dreyfus & Tilly, 1993). This data was utilized to generate accurate measurements for the 1:1 buck study. Where additional measurements were

required, data was collected from “Anthropometry and Biomechanics” (NASA, 2020). These papers contributed to further the understanding of each percentile ($97^{th}$, $50^{th}$, $5^{th}$) in various positions the user may find themselves in while wearing each brace such as standing, walking, sitting and overall movements. As anthropometrics can vary drastically between user’s its important to adhere to critical ergonomic measurements for each selected body part.

## METHODOLOGY

The ergonomic evaluation and analysis of a family of arthritic braces was conducted with the following considerations:

### Objective(s)

The aim of this process was to evaluate the full-bodied human interaction design and full-bodied ergonomic challenges for a product family of arthritic braces. While *full-bodied* as a term may have several meanings, pertinent to the thesis criteria, this report evaluates only three major body part areas relevant to full-bodied human interaction design (Chong, Zaccolo, Kappen, Thomson, Burke & White, 2020). This ergonomic evaluation report outlines the methods used to evaluate the three major body-part areas (arms, legs, hands) for assessment from human factors, ergonomics and convenience of use challenges.

### Decision(s) to be made

The following interactions were observed to identify any unpleasant or negative interactions while interacting with each brace from the product family. Major body part areas (Chong et al., 2020) were investigated to minimize the negative experiences and maximize the positive experiences of:

1. Taking on and off each brace (hands, arms, legs, foot)
2. Adjustments while wearing each brace (Hands, arms)
3. Range of motion while using each brace (elbow, knee, ankle, wrist)

**Description of Users Targeted by Product**

The following traits for the selected target user were considered while designing the various components of the brace product family.

- The target demographic were individuals who suffered a loss of mobility caused by arthritis.
- The target users age above the age of 65.
- Lives with-in a small city
- Various users were observed interacting with arthritic braces for the purpose of the user observation report.

**Evaluation process**

The evaluation process consisted of designing, building and testing a full scale (1:1) ergonomic buck of the family of braces, which allowed for critical observation of the following:

1. Observing how the user puts on and off each brace. (hands, arms, leg, ankle)
2. Observing how the user moves around their surroundings (full-body interaction)
3. Documenting how often the user may need to adjust each brace (hands, arms)
4. Identifying critical human dimensions affecting product use (arms, legs, feet)
5. Observing different locations for sensors and batteries (arms, wrist, ankle, legs)

**Description of User Observation Environment Used in this Study**

For this study, 1:1 models for the product family of arthritic braces were created at home using various materials such as, repurposed compression clothing, Velcro, foamboard, elastic straps, and sewing materials.

**Location and Timeframe**

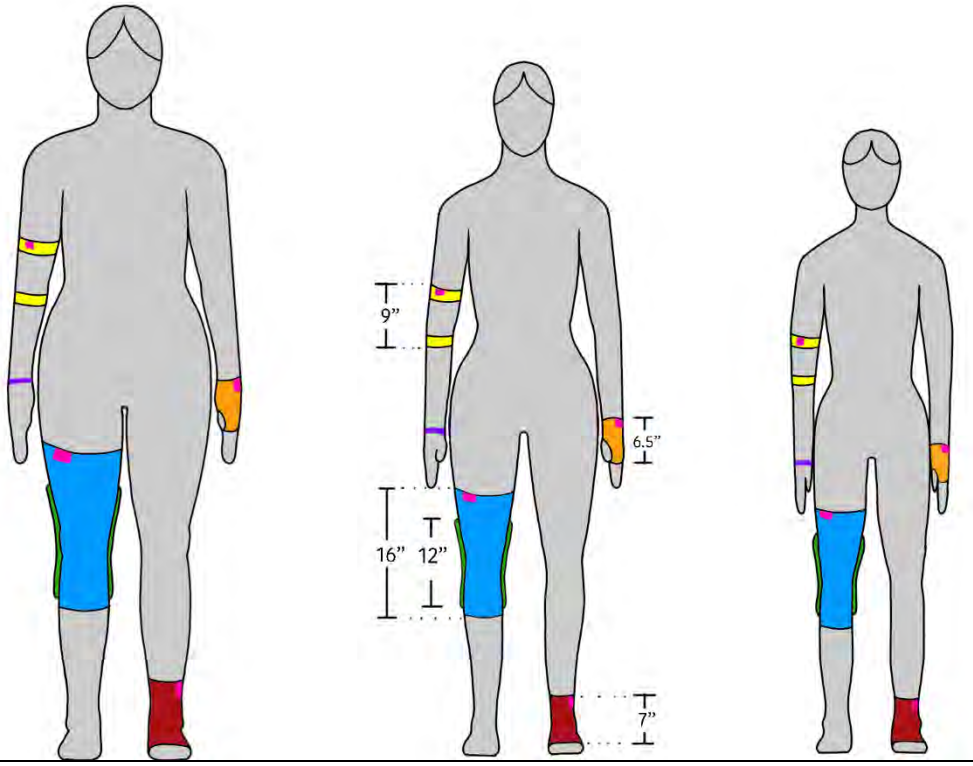
Date of Observation(s): 2021/01/12

Location of Observation(s): Waterloo, Kitchener

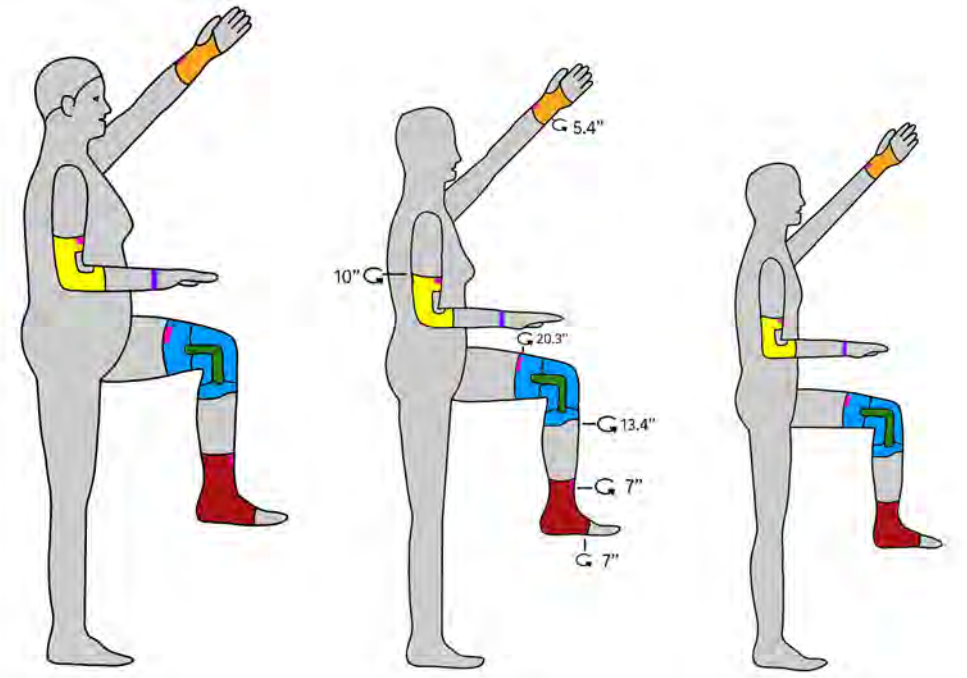
**RESULTS**

The results from the ergonomic study, gathered information on the anthropometric data for each female percentile, left to right ($97^{th}$, $50^{th}$, $5^{th}$). Illustrated below identifies critical dimensions shown on the drawn figures of each percentile pertaining to the selected target users. Dimensions gathered from the 1:1 buck exercise were utilized to refine crucial measurements shown below:

**ANALYSIS**

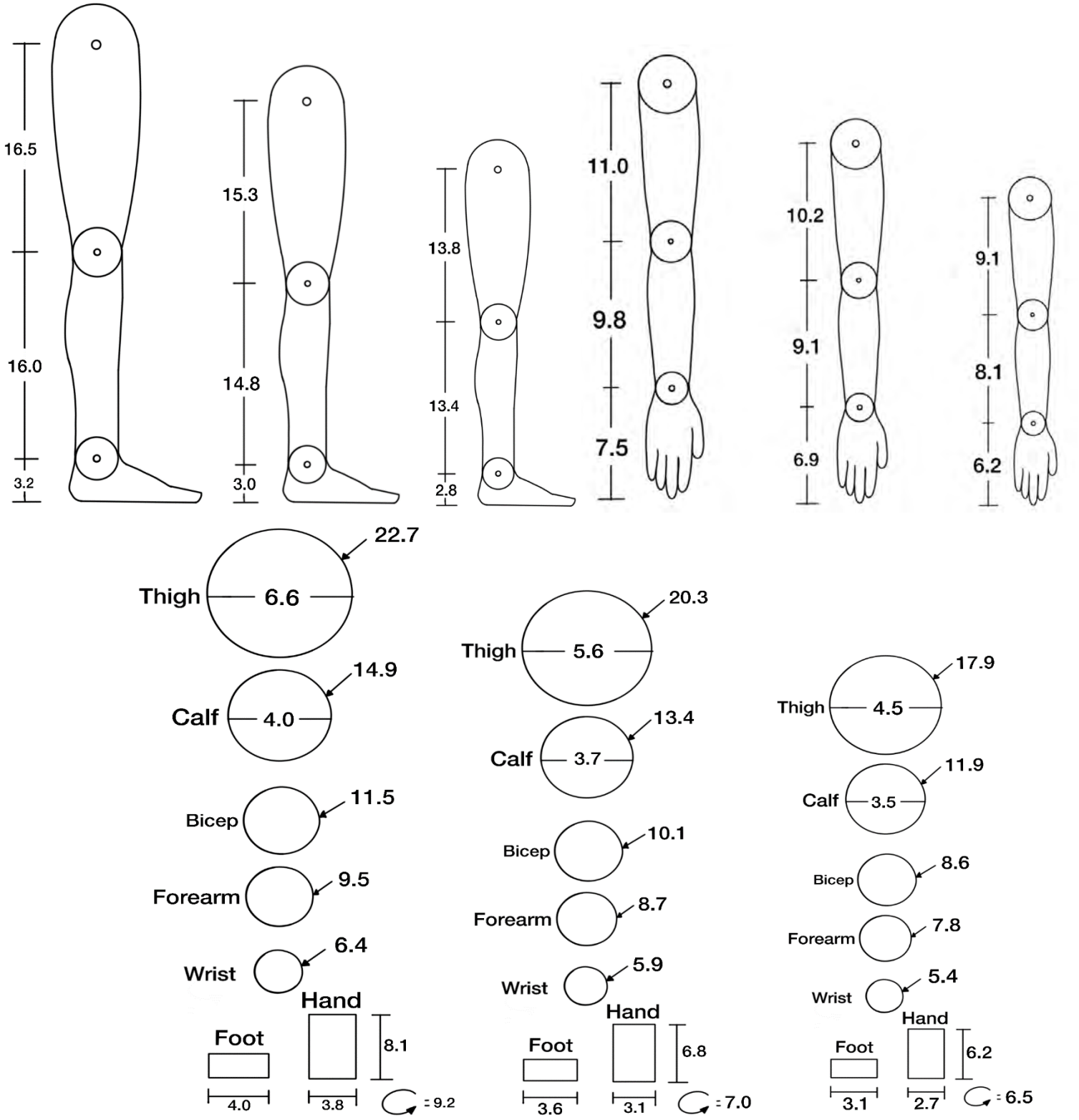



(Figure 1) Overall length of each brace from the product family, represented on 50 percentile women. In this sense, product sizing would come in small, medium, and large sizes.




(Figure 2) Overall Circumference of each brace in the product family, represented on 50 percentile women

***Other relevant measurements as defined by Henry Dreyfus (measurements in inches)***



***Knee Brace***

<table>
<tr><td>  <br>(Figure 3)</td><td>  <br>(Figure 4)</td></tr>
<tr><td>50 Percentile women simulating how the user would be wearing the knee brace in various positions.</td><td>Unworn knee brace layout.</td></tr>
<tr><td colspan="2">This study focuses on ergonomics surrounding the user’s knee. (brace sizing of straps, hinge, compression sleeve) as well as the placement of motions sensor/battery</td></tr>
</table>

***Knee Brace Analysis***

Observing the one-to-one scale knee brace model provided an opportunity to collect relevant data, such as full-scale measurements of main components in the brace. This study allowed for problem detection surrounding the overall build of the brace, in terms of adjustability, fit and material choices. For each of the braces it was important to figure out the battery and motion sensors layout, to ensure they would not restrict motion. The knee brace featured rigid supports, unlike the rest of the product family, extra attention was put toward observing how a ridged support would work with a compression material.

### *Ankle Brace*

<table>
<tr><td>  <br>(Figure 5)</td><td>  <br>(Figure 6)</td></tr>
<tr><td>50th percentile women simulating how the user would be wearing the ankle brace.</td><td>Unworn ankle brace layout.</td></tr>
<tr><td colspan="2">This study focuses on ergonomics surrounding the user's lower calf, foot, and ankle.</td></tr>
</table>

### *Ankle Brace Analysis*

The ankle brace was built to fit a 50th percentile women, measurements taken from the 1:1 model further extended the knowledge of material lengths such as straps and Velcro locations. The batteries and sensor were placed in an unrestricted location on the lower calf to ensure full range of motion and compatibility with various types of clothing. Keeping the low-profit style for the ankle brace, gives the user the opportunity to wear shoes without discomfort and carry out their everyday tasks.

***Elbow Brace***

<table>
<tr><td>  <br>(Figure 7)</td><td>  <br>(Figure 8)</td></tr>
<tr><td>50th percentile women simulating how the user would be wearing the elbow brace in different positions.</td><td>Unworn elbow brace layout.</td></tr>
<tr><td colspan="2">This study focuses on ergonomics surrounding the user's bicep, elbow, forearm as well as the user's comfortability putting on and off the brace.</td></tr>
</table>

***Elbow Brace Analysis***

The one-to-one scale model of the elbow brace provided measurments for the 50th percentile female, in terms of, material length, strap length, and adjustablility range for various sized biceps and forearms of the 50th percentile female. Observing the range of motion while the user wears the brace, provided information on how compression material will act, ensuring that the material would not cause any discomfort for the user. For the braces battery and sensor placement, it was found that the side of the forearm did not restrict range of motion or come in contact with other body parts, while performing various tasks

***Wrist Brace***

<table>
<tr><td>  <br>(Figure 9)</td><td>  <br>(Figure 10)</td></tr>
<tr><td>50th Percentile women simulating how the user would be wearing the Wrist brace.</td><td>Unworn wrist brace layout.</td></tr>
<tr><td colspan="2">This study focuses on ergonomics surrounding the user's forearm, wrist, hand and fingers.</td></tr>
</table>

***Wrist Brace Analysis***

Observing the one-to-one scale model of the wrist brace, offered more information on the range of motion that a wrist brace may restrict. For the wrist brace, it was important for the design to be low profile for the users to wear the brace underneath clothing and not cause any discomfort to the user. Utilizing compression materials keeps the profile low, while not restricting the range of motion in the user's hand. It was also important to figure out how long the adjustable straps would have to be to offer adjustability in terms of overlapping materials.

## LIMITATIONS AND CONCLUSION

Identifying critical human dimensions affecting product use were as follows:

1. Thick fabric and components restrict users when wearing various types of clothing.

2. Fabrics irritating the user's skin (chafing)

3. Critical dimensions of the knee brace hinge and supports

4. Adjustable strap lengths of each percentile

**Some Ergonomic Issues That Are Still Not Yet Resolved**

Some of the user needs that are not met are the sensor and electronic component locations to ensure that these components do not restrict range of motion. Technology has been advancing quickly in terms of wearable motion sensors, to be small and compact as well as providing accurate motion measurements. The sizing of a wearable brace for the selected target user is also a very important ergonomic consideration as anthropometric data for each user can range significantly. "guidelines can be listed as placement, form language, human movement, proxemics, sizing, attachment, containment, weight, accessibility, sensor interaction, thermal aspects, aesthetics and long-term effect" (Aksahin, 2017).

**Alternate possibilities for the future**

Based on the current study, the alternate options that could be explored in future are as follows:

1. Testing various types of fabrics
2. Sizing variations of compression material stretch

2. Testing motion detection devises in context with each brace.

This study helped to identify critical challenges while wearing arthritic braces in terms of product sizing, component layouts, material thicknesses and adjustable strap lengths for each percentile. The study also established the range of motion, and convenience of use aspects of the three-specific major body-part areas, a major thesis requirement. Furthermore, these findings helped to create a design brief for the final design.

### 3.4 Aesthetics & Semantic Profile

"A lot of medical device companies are looking for differentiation ... They want their products stand out from the competition,"(Buntz & Klopping, 2010). “They must thoroughly consider how end users interact with, and emotionally relate to, the end product” (Buntz & Klopping, 2010). Key elements were observed from data collected from benchmarking current products in the pervious sections.

#### Semantics (Tech)

The data collected from the benchmarked products in chapter two revealed that there are various technologies being used to preform the same function, with some working better than others. As technology continues to develop the mobility aid market is seeing advancements in materials from carbon fiber to carbonized bamboo. CPU technology is becoming easier to fit into almost any form of product now that components such as batteries can be shaped and sized to any products needs.

### Symbolism / Aesthetics

Users looking at the current market of mobility aids have limited options when it comes to aesthetics, as many mobility aids are designed for function over symbolic design. While conducting the user observations and interviews with the users, the most common complaint was how these products looked. Users stated that they sometimes feel self confidence while using a form of mobility aid as the products have the medical look and feel.

### Form Development

As per the proposed thesis topic the form development would revolve round the human form. Users can be expected to wear a knee brace, wrist brace etc. for multiple hours at a time, for this reason the form of the final products needs to be comfortable and functional. It is also important to take into consideration that these products will be worn by people of all shapes and sizes.

## 3.5 Sustainability – Safety, Health and Environment

When a user purchases a mobility aid of any sort, they expect the product to be safe and reliable. Looking at arthritic braces, the user's main goal is to improve their mobility. A brace may be improving your ability to walk but also causing skin irritations, making the brace uncomfortable to wear. When designing a wearable product, comfort for the user is one of the utmost priorities. While physical comfort is always important, the users must be comfortable with the way the products materials are sourced and manufactured. Otherwise, the product

would be at a severe disadvantage to its competitors on the market, already providing the users with ease of mind when it comes to sustainability in their products.

## Literature Review

Reporting on sustainability in mobility aids requires in-depth research into various areas of sustainable design. The report investigates current sustainable practices, done by leading brands in mobility braces, as well as navigating the various types of materials that could be utilized to make a sustainable product. The paper, A Study of the Structure and Properties of Novel Fabrics for Knee Braces, discusses the various material options and how these materials would react in different scenarios. The information presented in this report has been responsibly sourced from scholarly papers and articles.

### 1) Sustainability

#### 1.1) Benchmark Sustainable Initiatives

Current sustainability practices in the field of medical mobility aids seem to focus more on supporting sustainable material sourcing and manufacturing. While some companies, like Ossur, are researching and developing more sustainable materials and reducing plastic among there products. While taking into consideration one the main materials used in braces, neoprene, it was important to find out more about this material. “The process of producing neoprene requires lots of energy. Both petroleum and limestone are non-renewable resources; when they run out, there’s no more” (Cortado, 2018). Making the switch from neoprene to a natural fibre that is space-knitted, could drastically reduce the carbon impact that the production of neoprene would produce.

**1.2) Health**

With any mobility aid, health becomes one of the main priorities. The consideration of materials, to the types of knitting styles can have different health effects for the user. A brace will be in contact with the user's skin for long periods of time. Making the choice of a skin friendly fabric is especially important, otherwise the user may be prone to skin irritations or infections. Material choice aside, the overall functionality of the brace needs to support the rehabilitation of the user's health, rather than degrading it.

**1.3) Safety**

A mobility aid can be the difference between taking care of yourself or needing help from others. Someone who needs a mobility aid, expects the product to help assist in mobility, while also keeping them safe while using the product. The safety of a brace ties into the health of the user in several ways. As mentioned above, braces can provide a hotspot for infections. The opportunity to use antimicrobial materials, such as polyester, could be the difference from an unsafe brace to a safe one.

**3) Sustainability Statement for Final Design**

Sustainability has become one of the forefront issues in product design. Any new design must take sustainability into consideration when choosing materials and manufacturing processes. To create a successful product, the design must coincide with what the target user is looking for. In today's market, the sustainability aspect is very important in the user's eyes, as well keeping the planet a safe place to live.

**Conclusion**

With technology always improving, there will constantly be opportunities to improve sustainable design. Designing ahead of the curve, requires research into all possibilities, whether that be new eco friendly materials or how those materials are manufactured. Mobility aids will forever be changing, to become more sustainable and user-friendly.

### 3.6 Feasibility & Viability

The feasibility of the proposed design relies heavily on new developing technologies such as soft strain sensors and sustainably sourced materials. Material cost is on the lower end as most of the materials used in each brace can be purchased in bulk at lower prices. Along with the short list of materials the manufacturing process can be done at one sewing facility.

### 3.7 Design Brief

The goal of this proposed thesis design is to design a mobility aid that will offer the user comfort and rehabilitation for Osteoarthritis. The mobility aid will consider safety, ergonomics, ease of use and comfort along with the following design criteria:

- Improved brace ergonomics
- Improve the interaction between mobility aid and the user
- Sustainable use of materials
- Improve overall mobility/gait of the user
- Improve the safety of the user
- Implement movement tracking for rehabilitation

- Develop a functional family of smart braces
- Aesthetically pleasing product for the user
- Reduce strain on the user's joints
- Improve the relationship between patient and physiotherapist
- Provide real time data for the user
- Improve comfort for daily use

**Chapter 4**

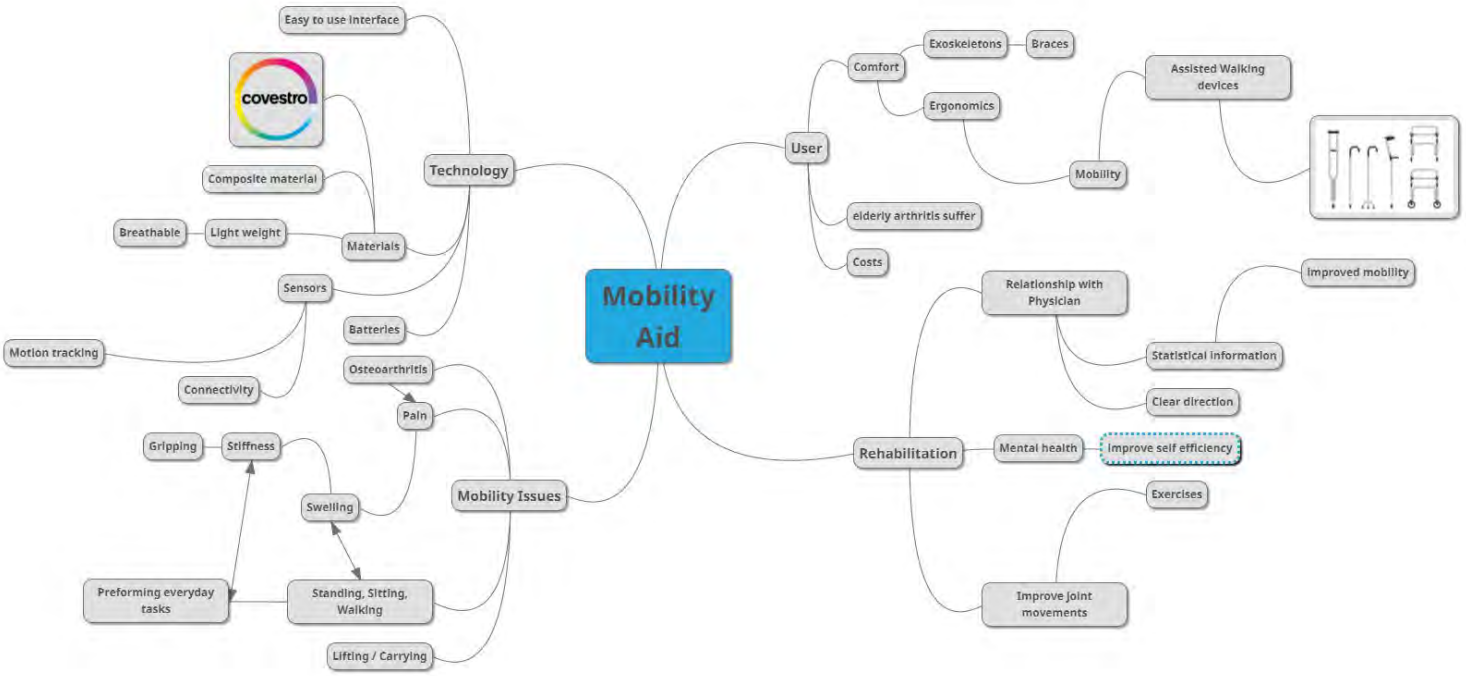
## 4.1 Idea Generation

This chapter focuses on the design of the proposed thesis topic from initial concept ideation through the stages of concept development and refinement, to the final model. **4.1.1 Aesthetics Approach**

Various outlets including google images and Pinterest were used to compile different aesthetics that, will help guide the final designs aesthetic approach. Inspiration boards similar to the one below was utilized.

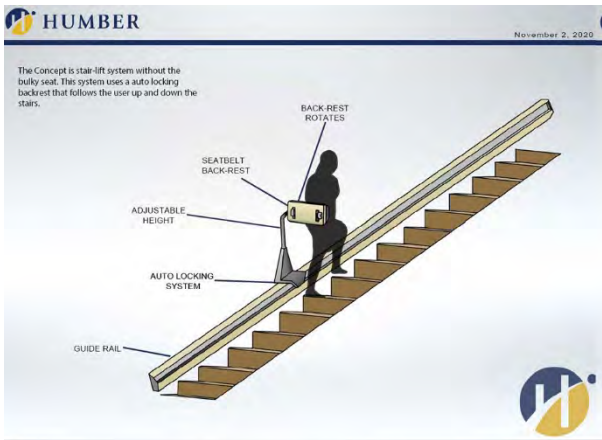
### 4.1.2 Mind Mapping

Mind mapping is a key part of flushing out all areas that may offer new design. Below is an example of a mind map used to further the understanding of the problem area.

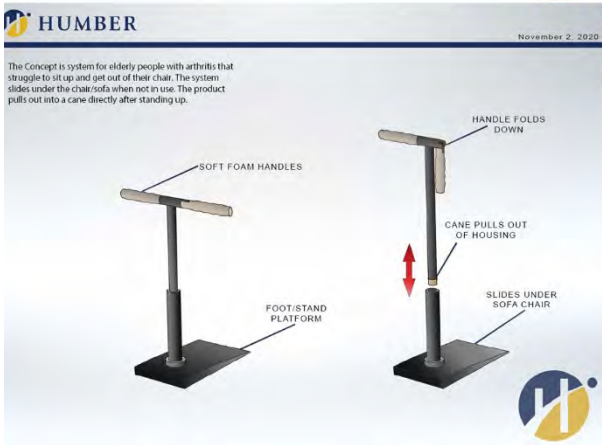


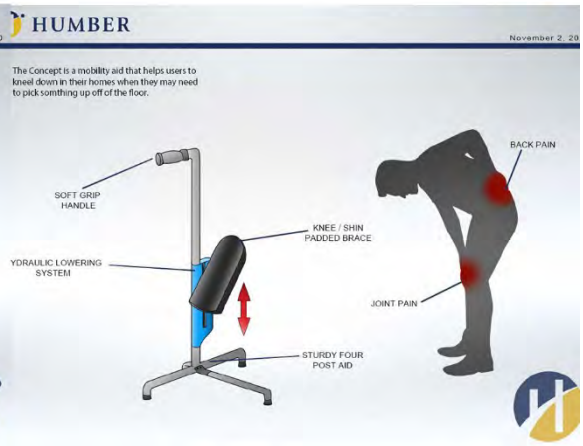

### 4.1.3 Ideation Sketches

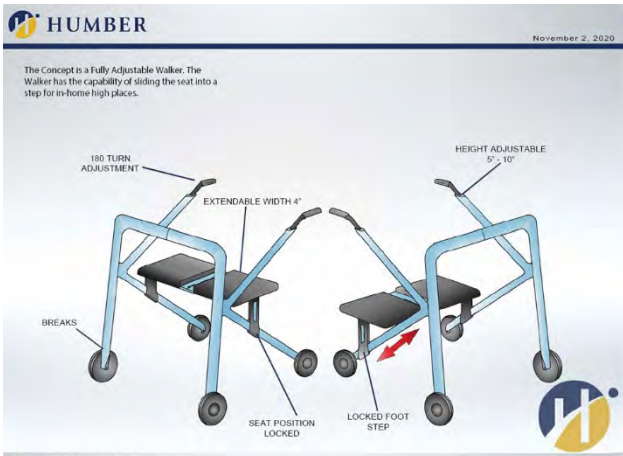
Initial ideation sketches sought to investigate as many areas of design pertaining to increasing mobility among arthritic suffers. These sketches helped further narrow down the design direction.


HUMBER
November 2, 2020
The Concept is stair-lift system without the bulky seat. This system uses a auto locking backrest that follows the user up and down the stairs.
BACK-REST ROTATES
SEATBELT BACK-REST
ADJUSTABLE HEIGHT
AUTO LOCKING SYSTEM
GUIDE RAIL

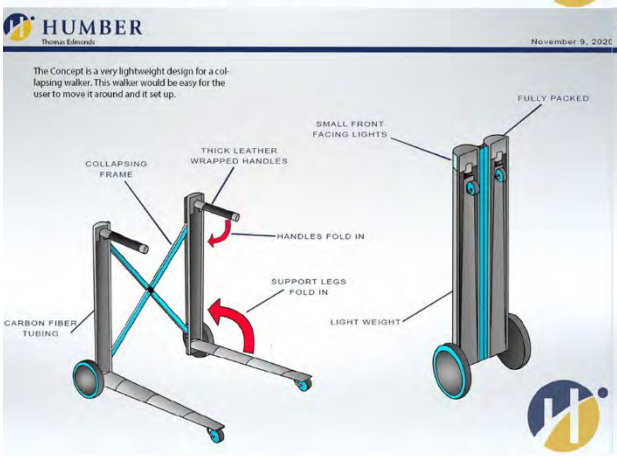

HUMBER
November 2, 2020
The Concept is a walker that doubles as a shopping cart to ease the users shopping experiences. The walker has a telescopic basket, which will hold the users grocery's. For easy transport the walker folds up.
LARGE HANDLE GRIPS
BREAKS
LIGHTWEIGHT ALUMINUM TUBING
WALKER BASKET
TRANSFORMS INTO SHOPPING CART
TELESCOPIC BASKET

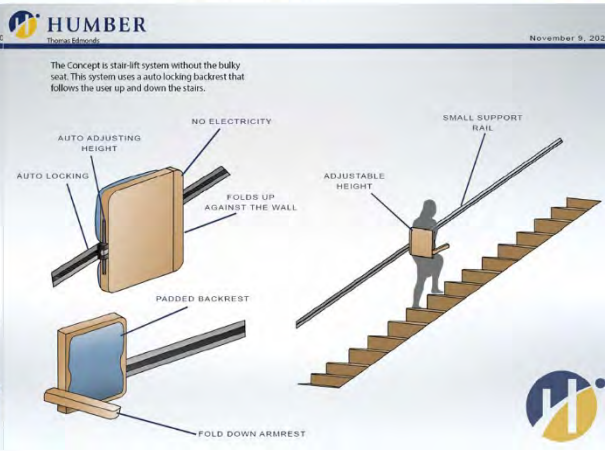

HUMBER
November 2, 2020
The Concept is system for elderly people with arthritis that struggle to sit up and get out of their chair. The system slides under the chair/sofa when not in use. The product pulls out into a cane directly after standing up.
HANDLE FOLDS DOWN
SOFT FOAM HANDLES
CANE PULLS OUT OF HOUSING
SLIDES UNDER SOFA CHAIR
FOOT/STAND PLATFORM


HUMBER
The Concept is a mobility aid that helps users to kneel down in their homes when they may need to pick somthing up off of the floor.
BACK PAIN
SOFT GRIP HANDLE
KNEE / SHIN PADDED BRACE
YDRAULIC LOWERING SYSTEM
JOINT PAIN
STURDY FOUR POST AID


HUMBER
November 2, 2020
The Concept is a Fully Adjustable Walker. The Walker has the capability of sliding the seat into a step for in-home high places.
180 TURN ADJUSTMENT
EXTENDABLE WIDTH 4"
HEIGHT ADJUSTABLE 5" - 10"
BREAKS
SEAT POSITION LOCKED
LOCKED FOOT STEP


HUMBER
Thomas Edmonds
The Concept is a walker designed for use in the winter months. The walker features powered rear wheels to help the user get through the toughest of conditions.
HEADLIGHTS
CLEAR PLASTIC
PADDED SEATING
WIND GUARD
BATTERY POWERED BACK WHEELS
WINTER TERRAIN TIRES


HUMBER
Thomas Edmonds
November 9, 2020
The Concept is a very lightweight design for a collapsing walker. This walker would be easy for the user to move it around and it set up.
FULLY PACKED
SMALL FRONT FACING LIGHTS
THICK LEATHER WRAPPED HANDLES
COLLAPSING FRAME
HANDLES FOLD IN
SUPPORT LEGS FOLD IN
CARBON FIBER TUBING
LIGHT WEIGHT

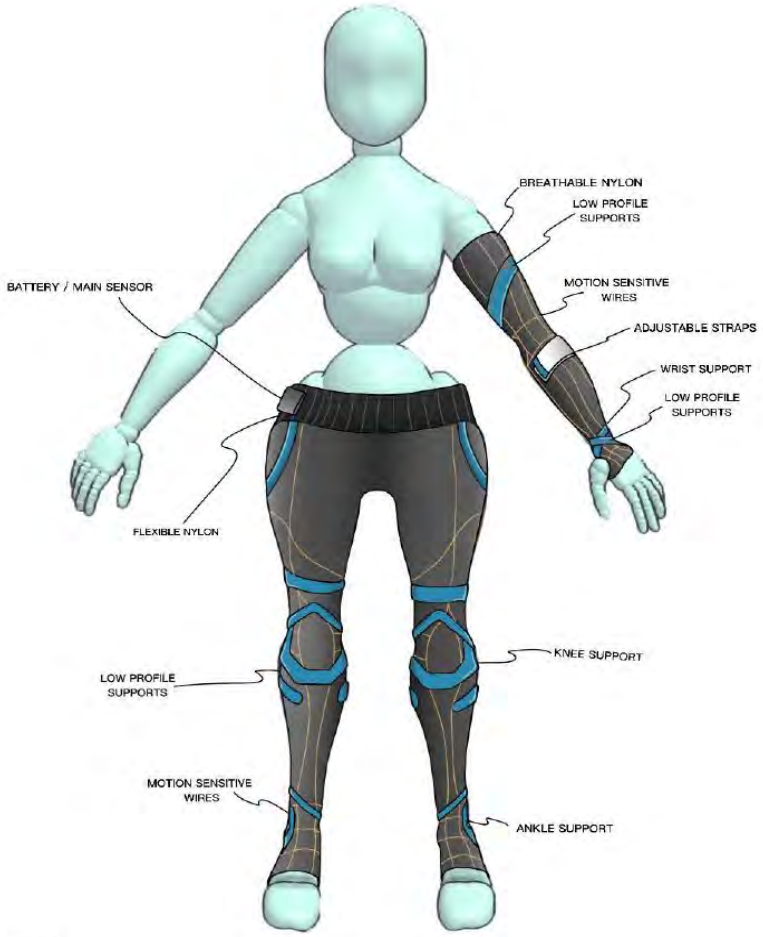

HUMBER
Thomas Edmonds
The Concept is stair-lift system without the bulky seat. This system uses a auto locking backrest that follows the user up and down the stairs.
NO ELECTRICITY
AUTO ADJUSTING HEIGHT
AUTO LOCKING
FOLDS UP AGAINST THE WALL
SMALL SUPPORT RAIL
ADJUSTABLE HEIGHT
PADDED BACKREST
FOLD DOWN ARMREST

### 4.2 Preliminary Concept Explorations

The concept ideation stages brought many different areas of opportunity. Moving forward, one topic/concept was chosen to further explore and refine. The chosen concept was an unloader brace that had smart capabilities, allowing the user to track their joint movements.


### 4.3 Concept Strategy

From the chosen concept direction, two new concept possibilities were created. Both concepts created a product family of braces, the first being a two-brace system that would support the knee, ankle, wrist, and elbow, in the form of pants and an arm sleeve. The second direction created a family of the four specific braces, which can work in unison or by themselves to provide the users with support and statistical data.


BREATHABLE NYLON
LOW PROFILE SUPPORTS
MOTION SENSITIVE WIRES
ADJUSTABLE STRAPS
WRIST SUPPORT
LOW PROFILE SUPPORTS
BATTERY / MAIN SENSOR
FLEXIBLE NYLON
KNEE SUPPORT
LOW PROFILE SUPPORTS
MOTION SENSITIVE WIRES
ANKLE SUPPORT

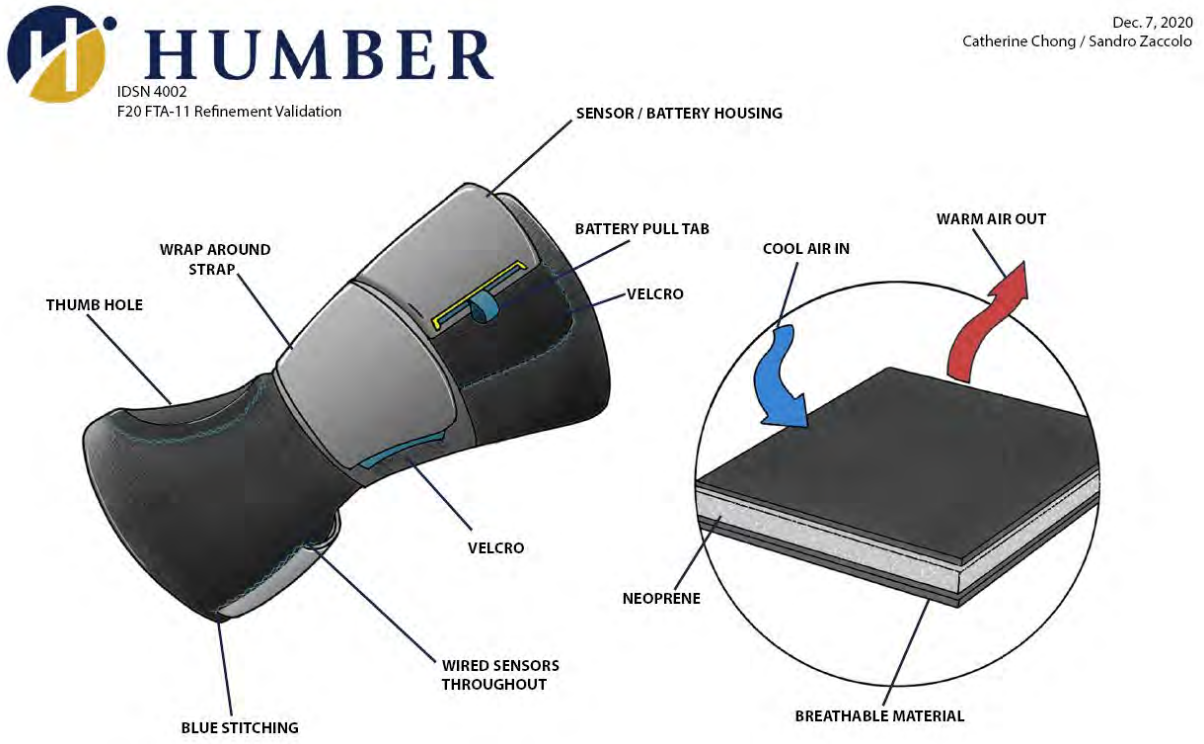

PRODUCT CONCEPTS
BREATHABLE NYLON
MOTION SENSITIVE WIRES
ADJUSTABLE STRAP
BATTERY / SENSOR / PRESSURE
RIGID PLASTIC SUPPORTS
MOTION SENSITIVE WIRES
ADJUSTABLE STRAP
ADJUSTABLE STRAP
SENSOR
BREATHABLE NYLON
LOW PROFILE SUPPORTS
VELCRO
ADJUSTABLE STRAP
MOTION SENSITIVE WIRES
INNER SUPPORT
MOTION SENSITIVE WIRES
BREATHABLE NYLON

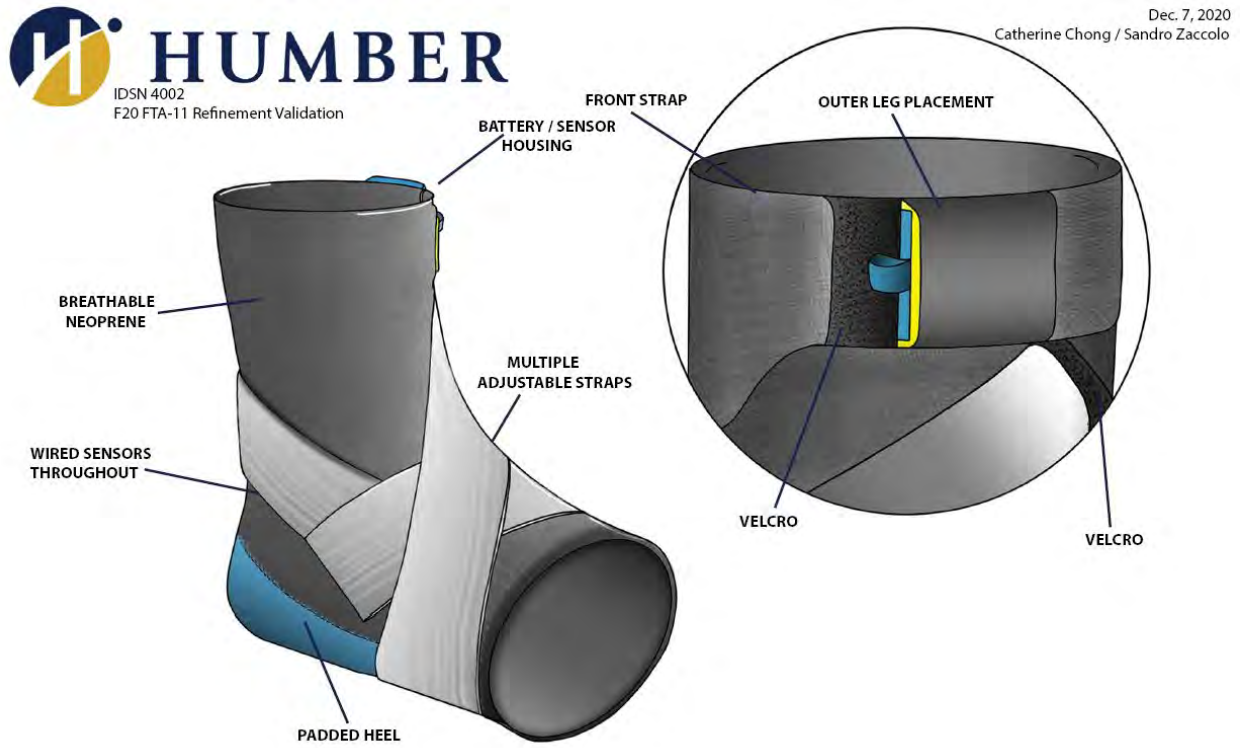
**Results**

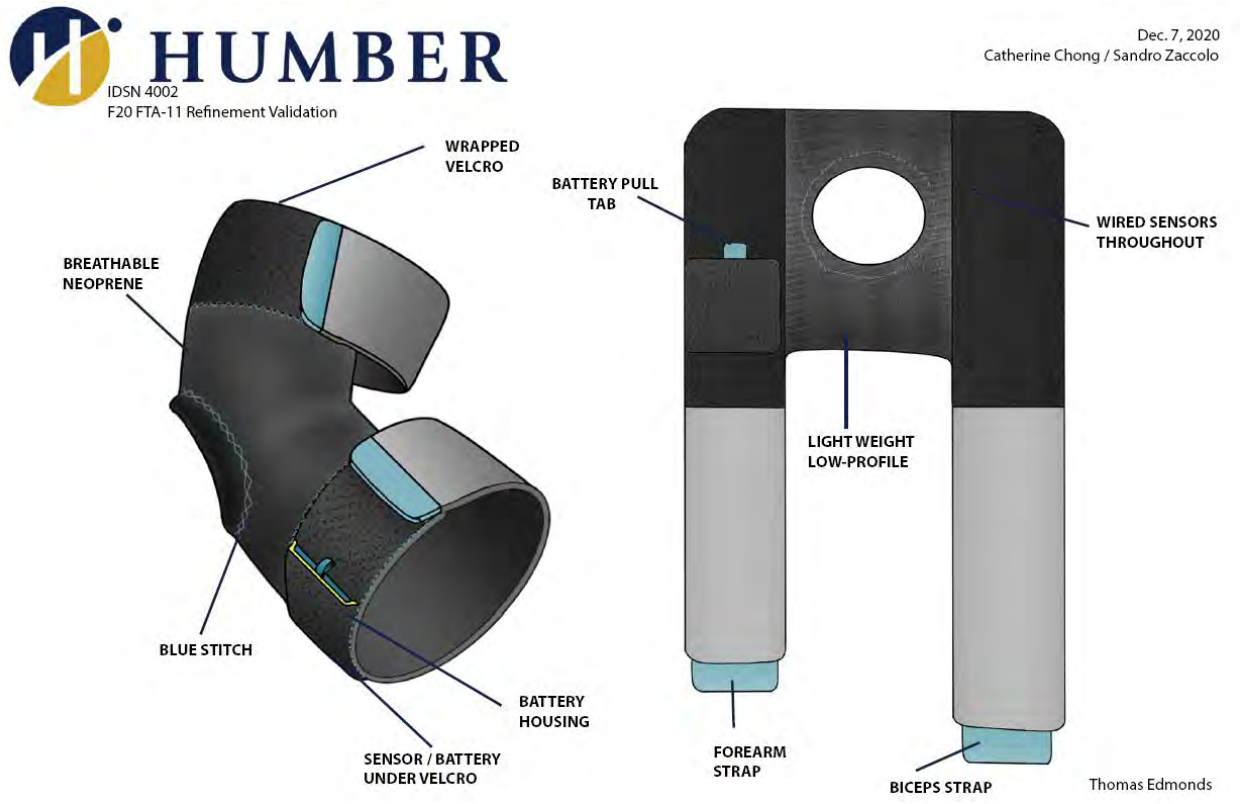
The product family of four braces including a knee brace, wrist brace, ankle brace and an elbow brace, was chosen to further refine.

### 4.4 Concept Refinement

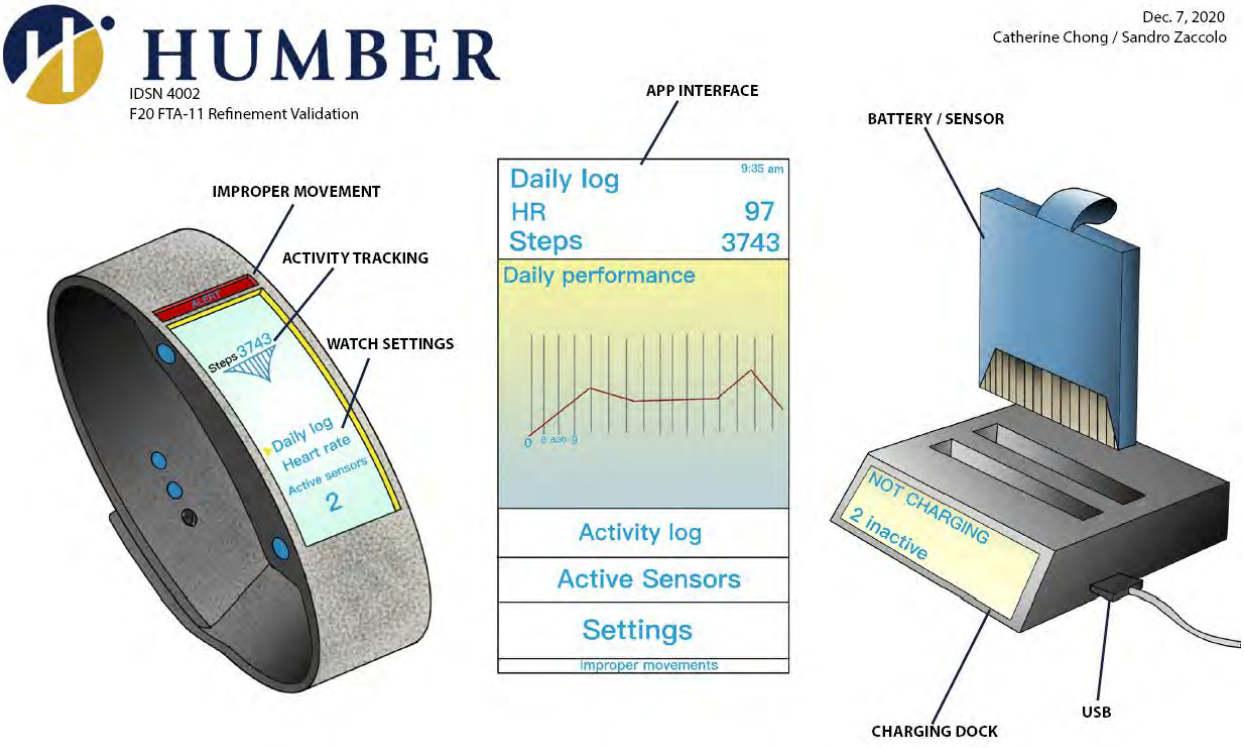
The concept direction was taken to further refine each arthritic brace, understanding how the product will support each arthritic problem area. Refinement of materials, functionality, sensor placement and overall design of the products.




HUMBER
IDSN 4002
F20 FTA-11 Refinement Validation
Dec. 7, 2020
Catherine Chong / Sandro Zaccolo
FRONT STRAP
BATTERY / SENSOR HOUSING
OUTER LEG PLACEMENT
BREATHABLE NEOPRENE
MULTIPLE ADJUSTABLE STRAPS
WIRED SENSORS THROUGHOUT
VELCRO
VELCRO
PADDED HEEL


HUMBER
IDSN 4002
F20 FTA-11 Refinement Validation
Dec. 7, 2020
Catherine Chong / Sandro Zaccolo
WRAPPED VELCRO
BREATHABLE NEOPRENE
BLUE STITCH
BATTERY HOUSING
SENSOR / BATTERY UNDER VELCRO
BATTERY PULL TAB
WIRED SENSORS THROUGHOUT
LIGHT WEIGHT LOW-PROFILE
FOREARM STRAP
BICEPS STRAP
Thomas Edmonds

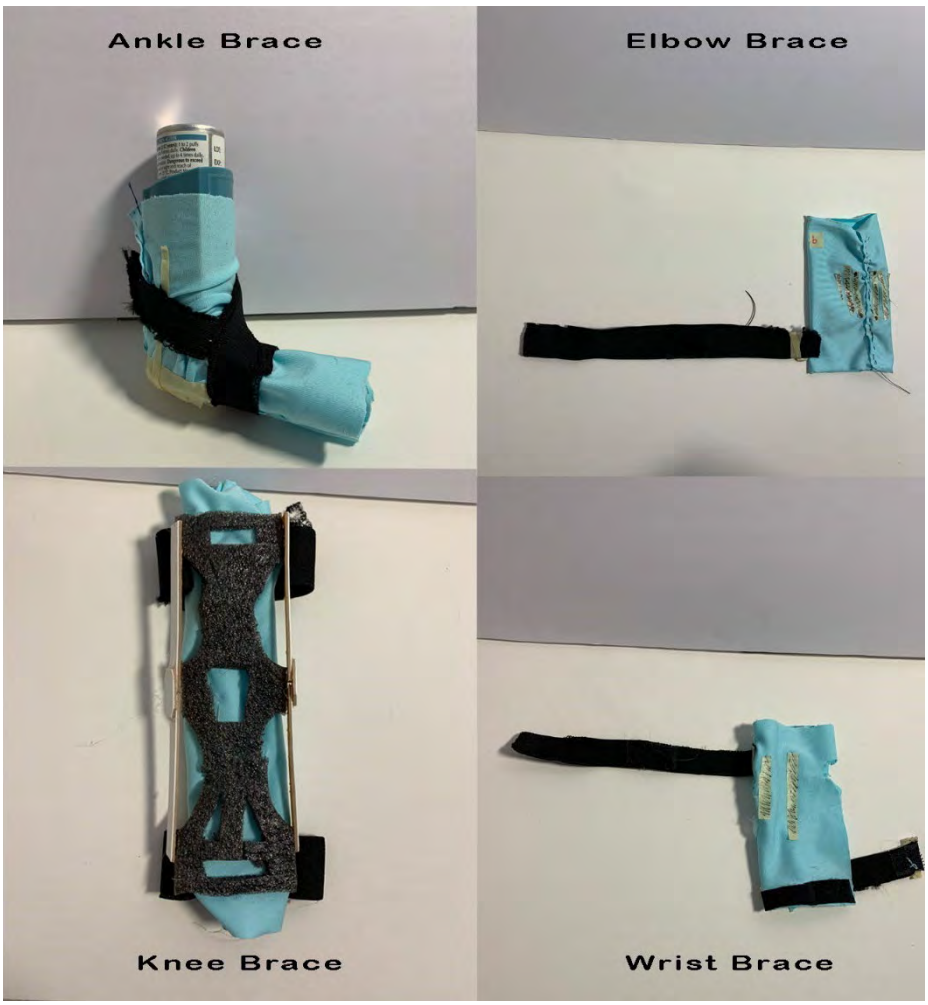

HUMBER
IDSN 4002
F20 FTA-11 Refinement Validation
Dec. 7, 2020
Catherine Chong / Sandro Zaccolo
BATTERY / SENSOR HOUSING
ADJUSTABLE STRAPS
BREATHABLE NEOPRENE
SUPPORTS IN-BETWEEN NEOPRENE
OFF LOADING HINGE
WIRED SENSORS THROUGHOUT
CARBON FIBER SUPPORTS
VELCRO STRAPS
INDICATOR LIGHT
BATTERY / SENSOR
HOUSING IN-LAY
HINGE PIVOT


HUMBER
IDSN 4002
F20 FTA-11 Refinement Validation
Dec. 7, 2020
Catherine Chong / Sandro Zaccolo
APP INTERFACE
IMPROPER MOVEMENT
ACTIVITY TRACKING
WATCH SETTINGS
Alert
Steps 3743
Daily log
Heart rate
Active sensors
2
Daily log
9:35 am
HR 97
Steps 3743
Daily performance
Activity log
Active Sensors
Settings
Improper movements
BATTERY / SENSOR
NOT CHARGING
2 inactive
USB
CHARGING DOCK

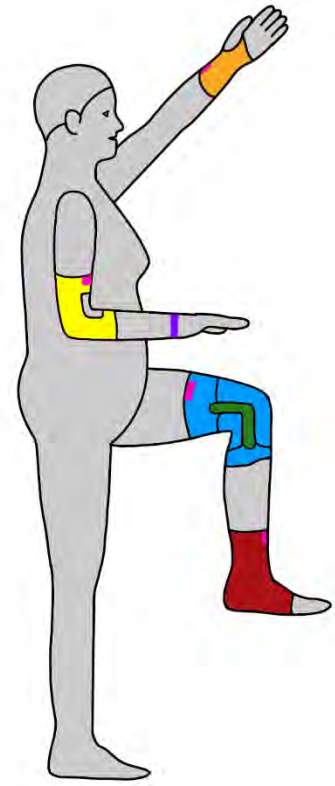
## 4.5 Design Realization

### 4.5.1 Physical Study Models

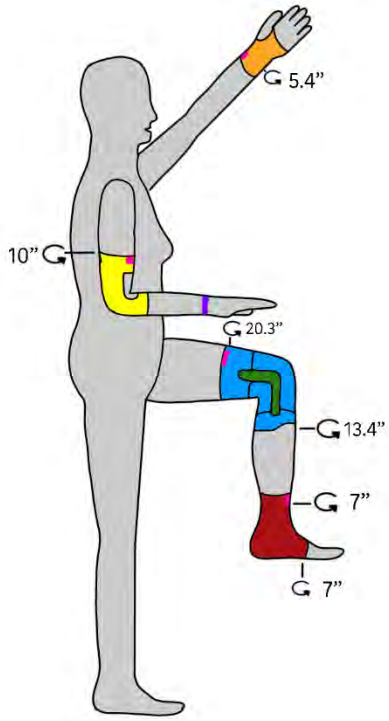
Sketch models were created to help aid in the final design of each brace. This process helped further the understanding of critical dimensions such as strap lengths, material stretch, Sensor placement and overall dimensioning of components.



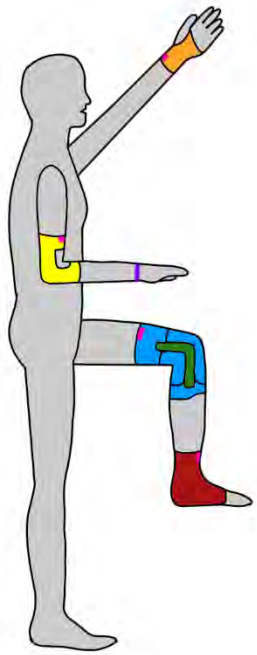
### 4.5.2 Product Schematic



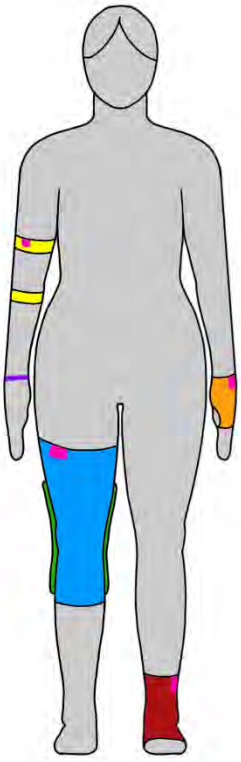
95th

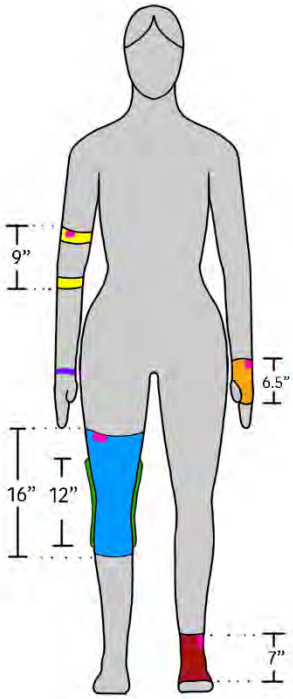



50th



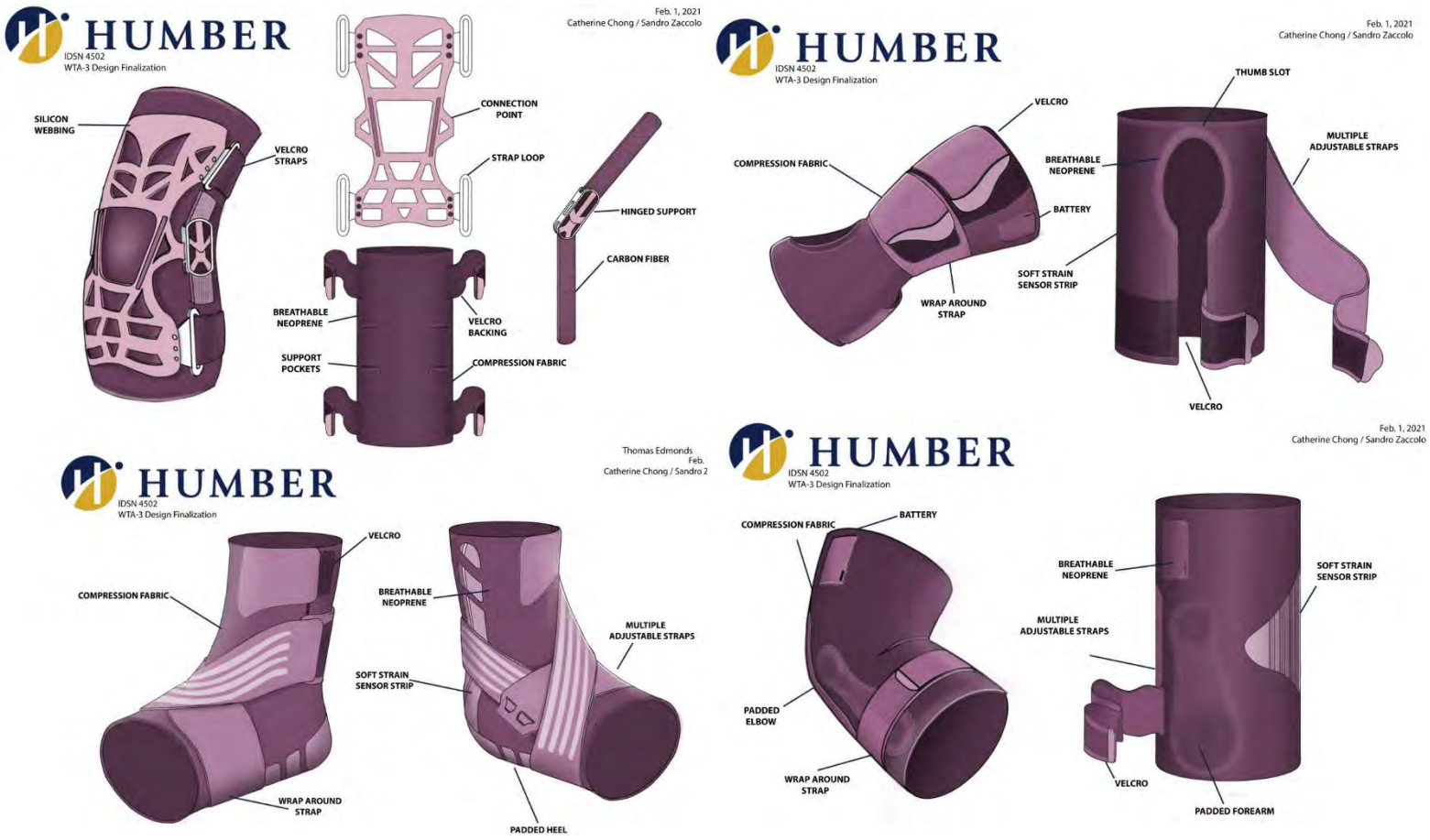
5th



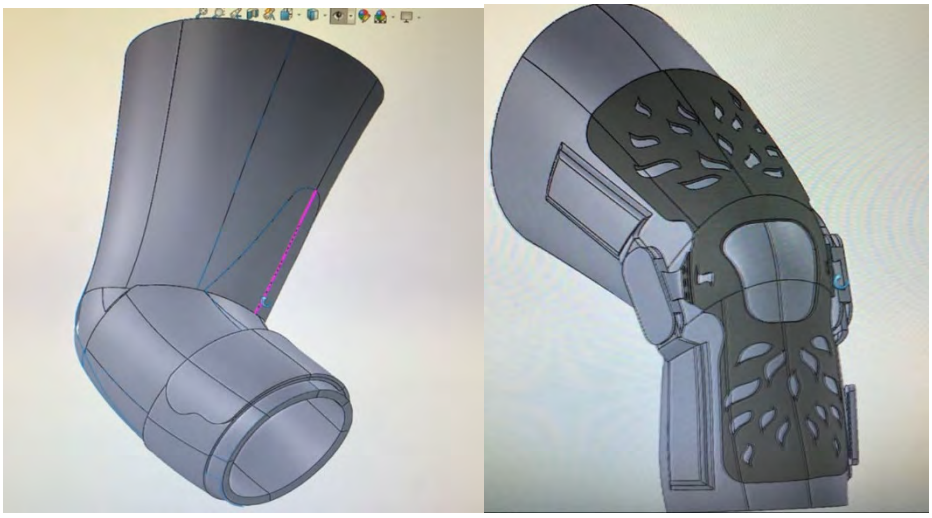


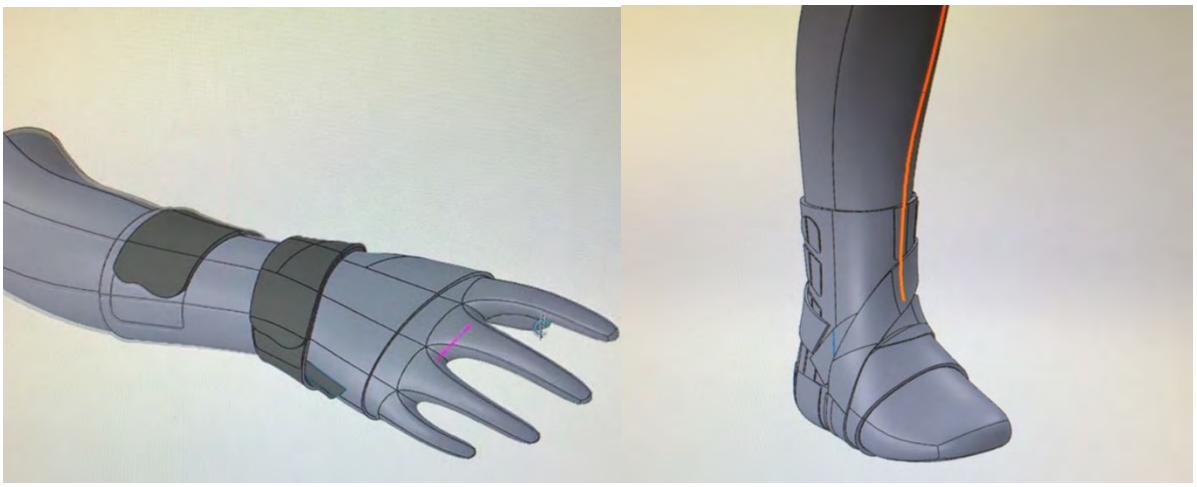

## 4.6 Final Design

The final design consists of four arthritic braces a knee brace, ankle brace, wrist brace and an elbow brace. This is a product family of smart braces, each brace features their own set of soft strain sensors that will transmit and log the user's joint movements to aid in the user rehabilitation, by providing statistical data to the user and their physician.

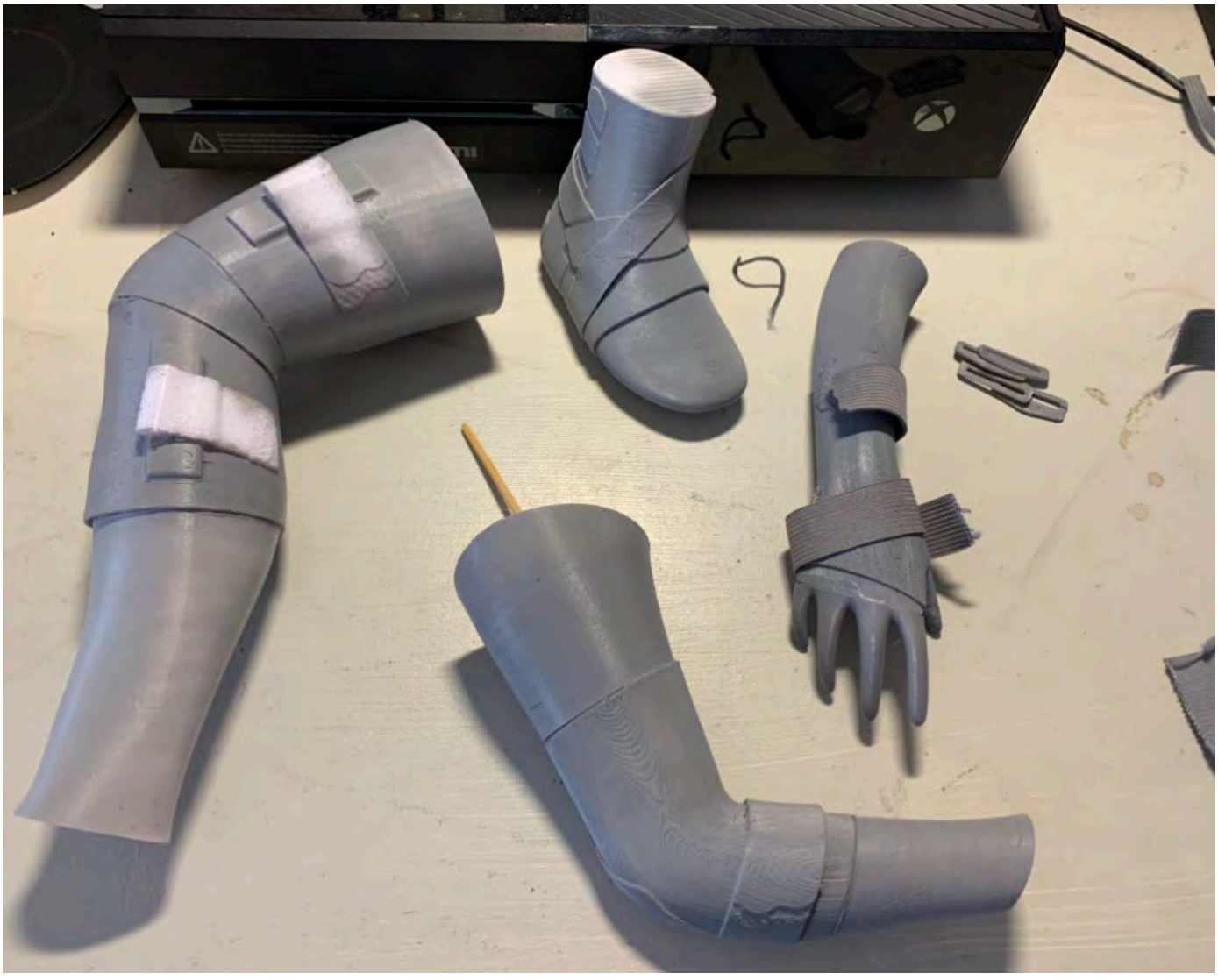



## 4.7 CAD Development





## 4.8 Physical Model Fabrication



**Chapter 5**

## 5.1 Summary

### 5.1.1 Description

Float is a product family of smart arthritic braces, this family of products aid in the rehabilitation process of osteoarthritis. Each brace has the capabilities of tracking the users' joint movements and relaying them back to the user in real time.

### 5.1.2 explanation

Arthritic braces are used everyday by the masses for long periods of time to alleviate joint pain. There is opportunity to provide the users with a product that alleviates joint pain while also aiding in the rehabilitation process. Technology is constantly changing and improving, allowing for technologically innovative products. Float utilizes some of these technological advances to provide the user with a better experience while wearing arthritic braces. Implementing soft strain sensors within the space knitted cotton allows for data collection of joint moment. These sensors stretch and tighten with the user's joint movements, to gather data on improper movements, type of strain on each joint and how each joint reacts to movement. This data can be used to further understand the users Osteoarthritis and help aid in rehabilitation.

### 5.1.3 Benefits statement

With the use of battery free, ultra-thin, soft strain sensors, float braces give the users an opportunity to track a log statistical data on their joint movements. Collecting this data can provide the users with critical information on the way their joints are being used and how they can notice the improper movements that can cause further damage to the affected joints. Not

only does this benefit the user, but it also benefits their physician, allowing them to understand the users' specific problems. In-turn the physician can provide proper feedback, that may speed up the rehabilitation process.

## 5.2 Design Criteria Met

### 5.2.1 Full Bodied Interaction Design

Ergonomics are extremely important to the design of Arthritic braces. A product that will be spending upwards of eight hours on a person's body needs to be comfortable. Many ergonomic requirements and anthropometric measurements were taken into consideration while designing this product family of arthritic braces. Each brace has its own set of ergonomic requirements, as Osteoarthritis affects millions of people every year, it is impossible to have one size fits all. The braces would come in small, medium, and large, while also providing the user with the option to adjust overall fit using the adjustable Velcro straps. The use of compression fabric allows for a more versatile fit allowing for seamless movement through brace sizing. The importance of improving movement for the user required each brace to be low profile to avoid any obstructions while the user goes throughout their day. The wrist brace was designed to allow the user to use their hands freely as if the brace were not there. The same goes for the rest, support features and straps are kept low profile so the user can comfortably wear clothing over top of each brace. The product family needed to be easy to put on and take off as some users may have underlying issues. Each brace has a two step process; sliding the compression sleeve over the specific joint (knee, wrist, elbow, ankle) and then simply Velcro the adjustable straps to the correct fit.

### 5.2.2. Materials, Processes and Technology

Material choice for a medical wearable, such as a brace requires a lot of consideration. These materials are going to be in contact with the user's skin for long periods of time, the fabric must be comfortable, breathable and minimis skin irritation while also providing support to the affected joint. When looking at the current market, medical braces tend to use Neoprene as the main fabric as it is cheap to manufacture and provides the main characteristics such as elasticity and thermal insulation. Neoprene may be used in the masses but when further investigated, "it lacks breathability and restricts the movement of water vapor, moisture as well as the evaporative heat from the skin to the ambient environment" (Pereria et al. 2007, Pg 6). With the limitations of Neoprene, spaced - knitted Fabrics offered limitless construction of various materials to best suit the overall end fabric when it comes to, elasticity, breathability, comfort etc. Customizability of the fabric plays an important part in the proposed design, as soft strain sensors must be knitted within the fabric.

Materials used for the various components of the brace family such as, Straps, connection points, and supports, play a large part of the overall design and sustainability of the product. Brace Straps are essential to an arthritic brace as they provide the compression and support, while there are many material options, the proposed design will utilize an elastic strap, made of 73% polyester and 27% latex rubber. The straps will have Velcro, knitted to the corresponding hook or loop connection point on each brace. With the knee brace requiring a rigid support, market research has shown the use of aluminum as the main material used because of its lightweight properties and strength. Improving on the current market's materials carbon fibre was chosen to create the hinged supports, "a material that offers stiffness and

strength at low density– which is lighter than aluminium and steel, that provides many practical benefits" (Dexcraft, 2015).

#### 5.2.2.1 Manufacturing

When it comes to manufacturing these materials needed for the family of arthritic braces, it is important to source responsible manufactures that adhere to environmental standards and strive to improve their environmental footprint. Components such as Velcro, silicone and carbon fibre must be sourced from responsible manufactures. For an example, Sigmatex (Carbon fibre) holds themselves to 100% zero waste in the production of carbon fibre. The overall manufacturing of these braces would be done by mass sewing/assembling factories.

### 5.2.3 Implementation – Feasibility & Viability

| | | A Class | |
|---|---|---|---|
| Parts | Material | Description | Price |
| Rigid Knee supports | Carbon Fiber | Knee brace supports | (6" x 6" x 1/8")<br><br>$35 |
| Aero Space 2<br>Space knitted fabric | Cotton | Main compression sleeves | $3 / meter |
| Soft Strain Sensors | phenolphthalein-Oxygen | Joint tracking sensors | $2.50 per |
| Elastic Straps | Polyester<br>Rubber | Adjustable Straps | $19 /10 yards |

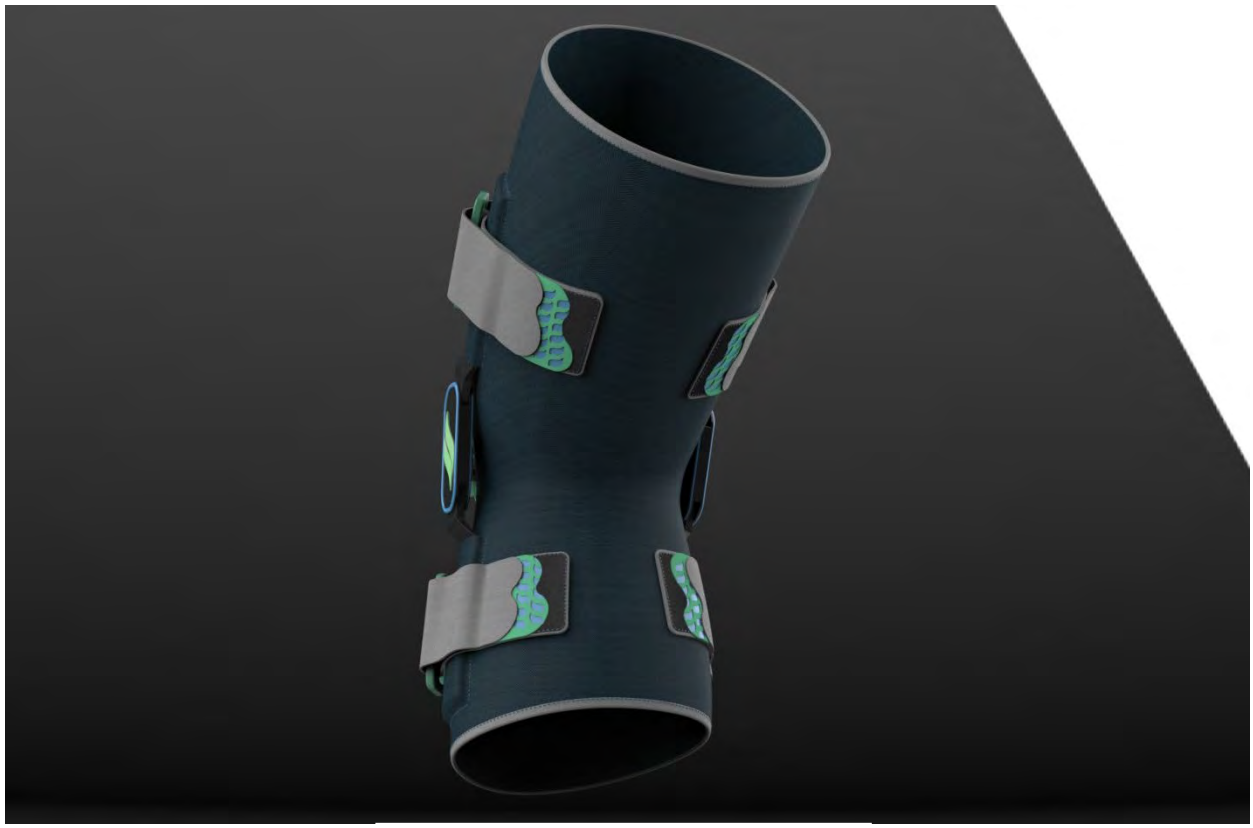
| | | B Class | |
|---|---|---|---|
| Parts | Material | Description | Price |
| Webbing | Silicone Rubber | Main knee support webbing | $3.30 / meter |
| Sew on loop lock | Polyoxymethylene | Anchor points for knee brace webbing | $2 /per 20 |

| | | C Class | |
|---|---|---|---|
| Parts | Material | Description | Price |
| Velcro hook and loop | Nylon<br><br>Polyester | Strap connection points | $15 / per 16ft |

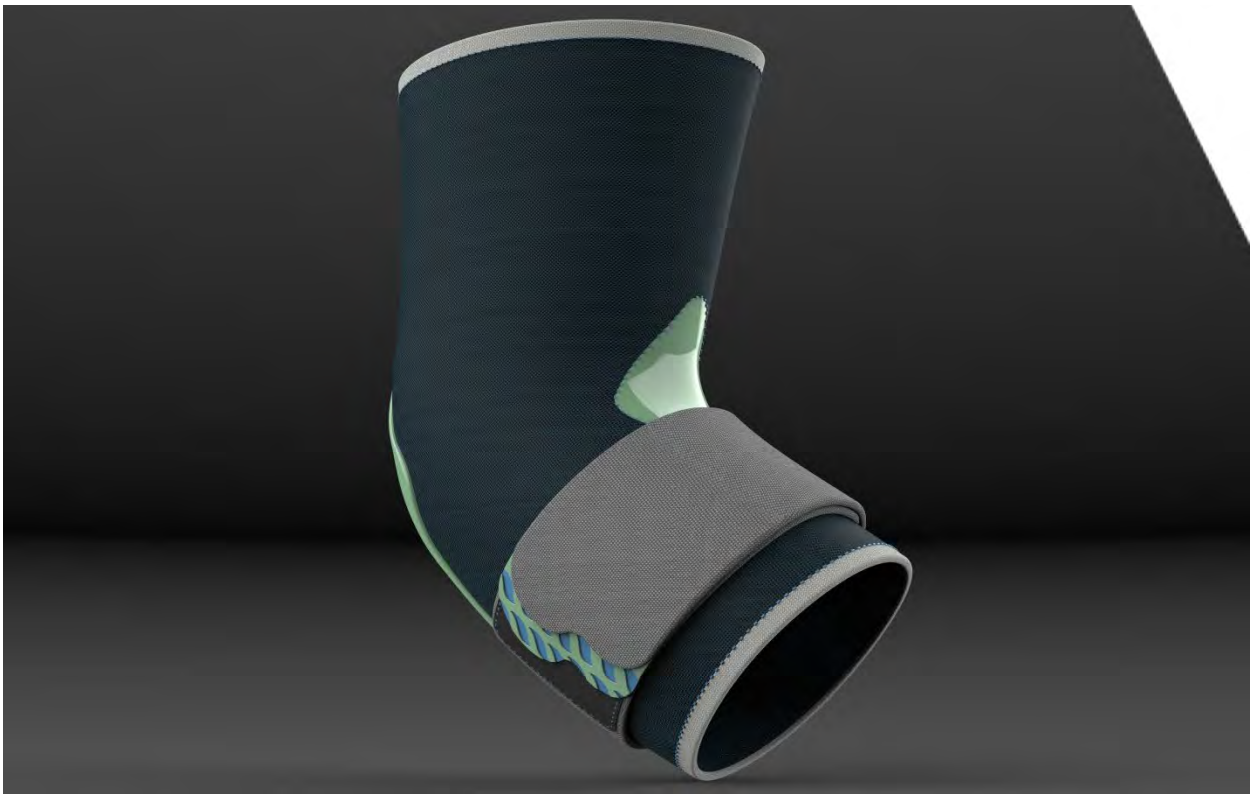
Unit prices are based on current material prices found on today market; these prices are subject to change with manufacturing.

## 5.3 Final CAD Rendering

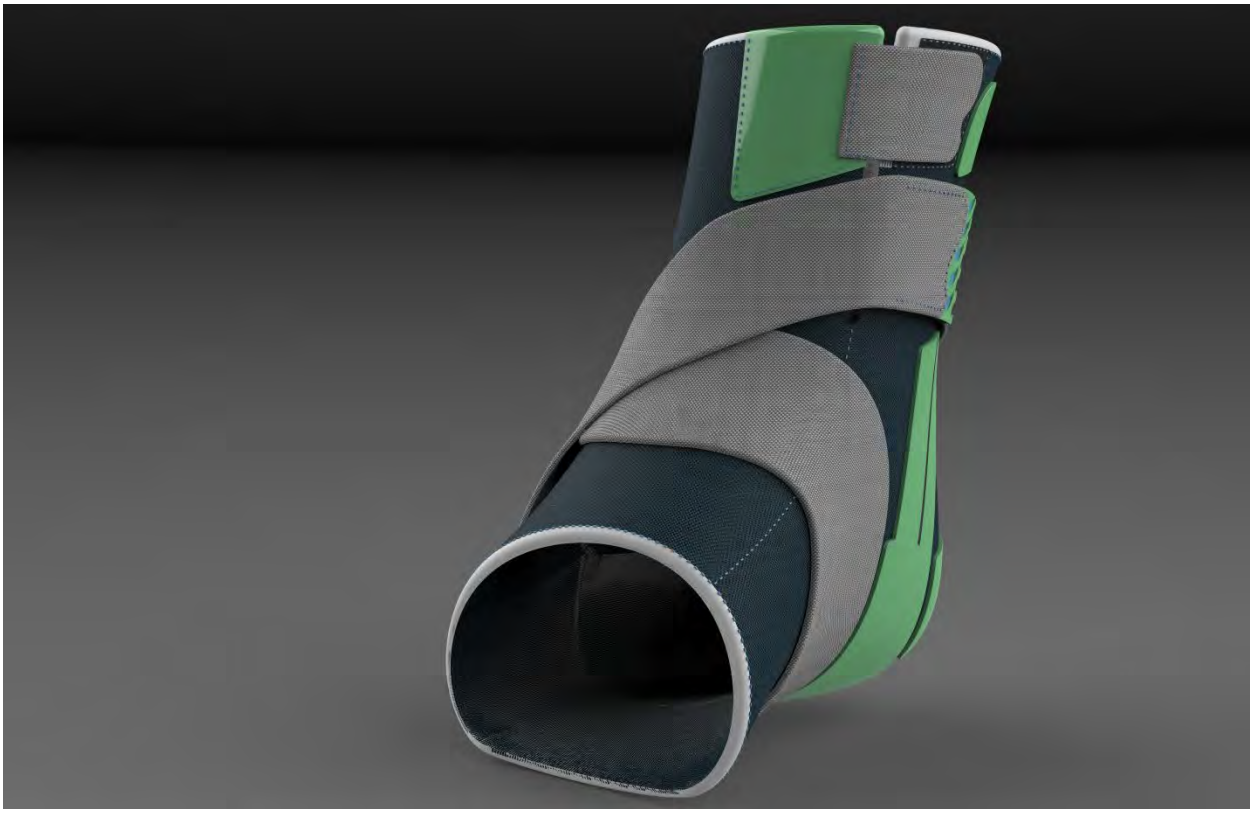
**Knee Brace Final Renders**

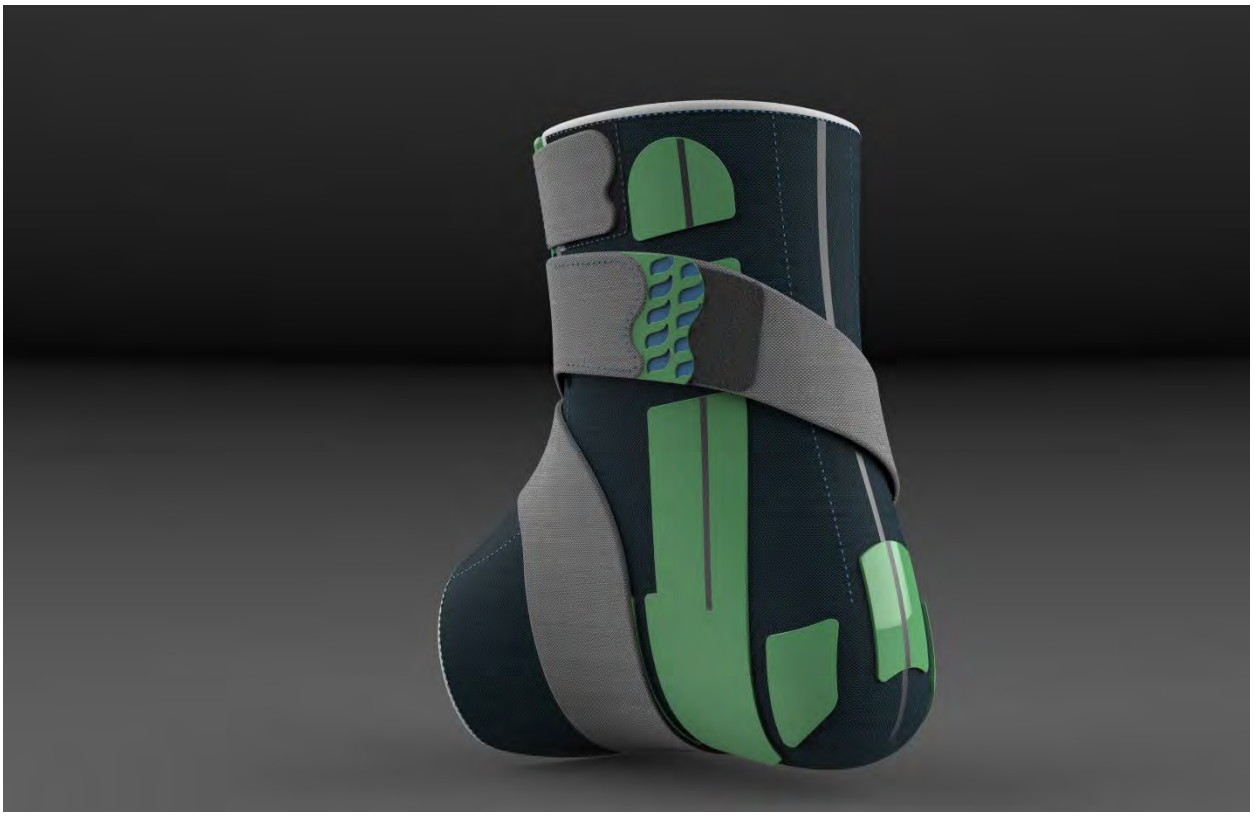


**Elbow Brace Final Renders**

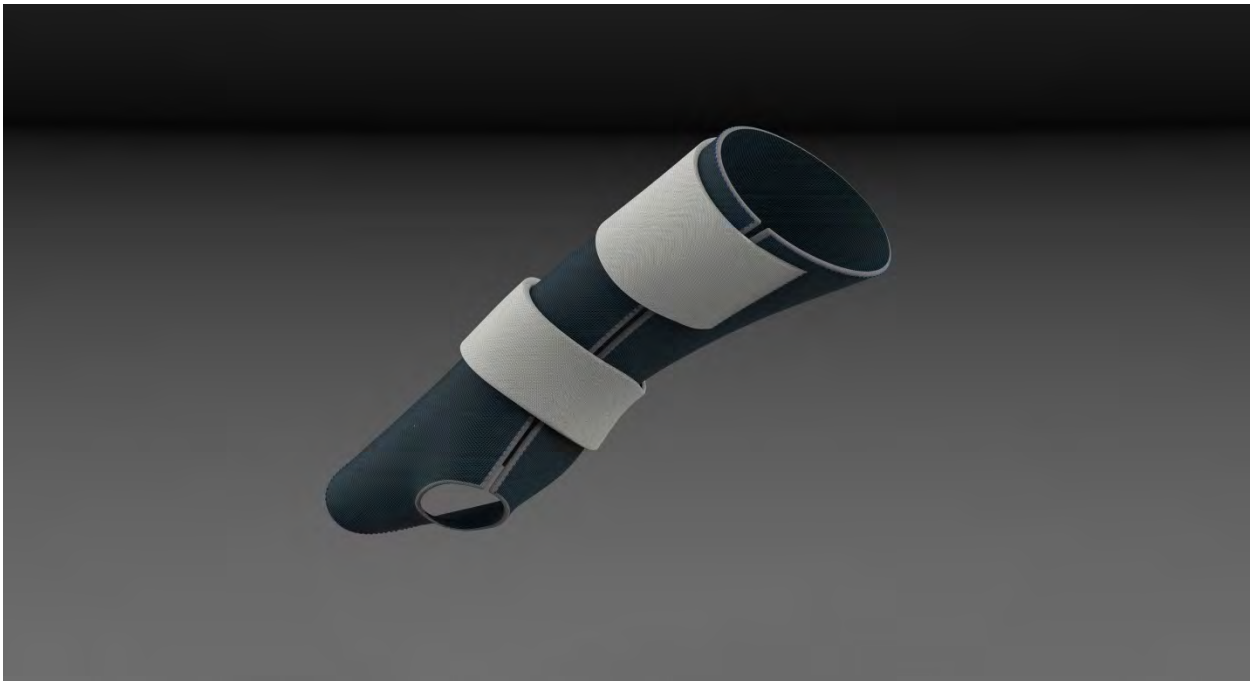


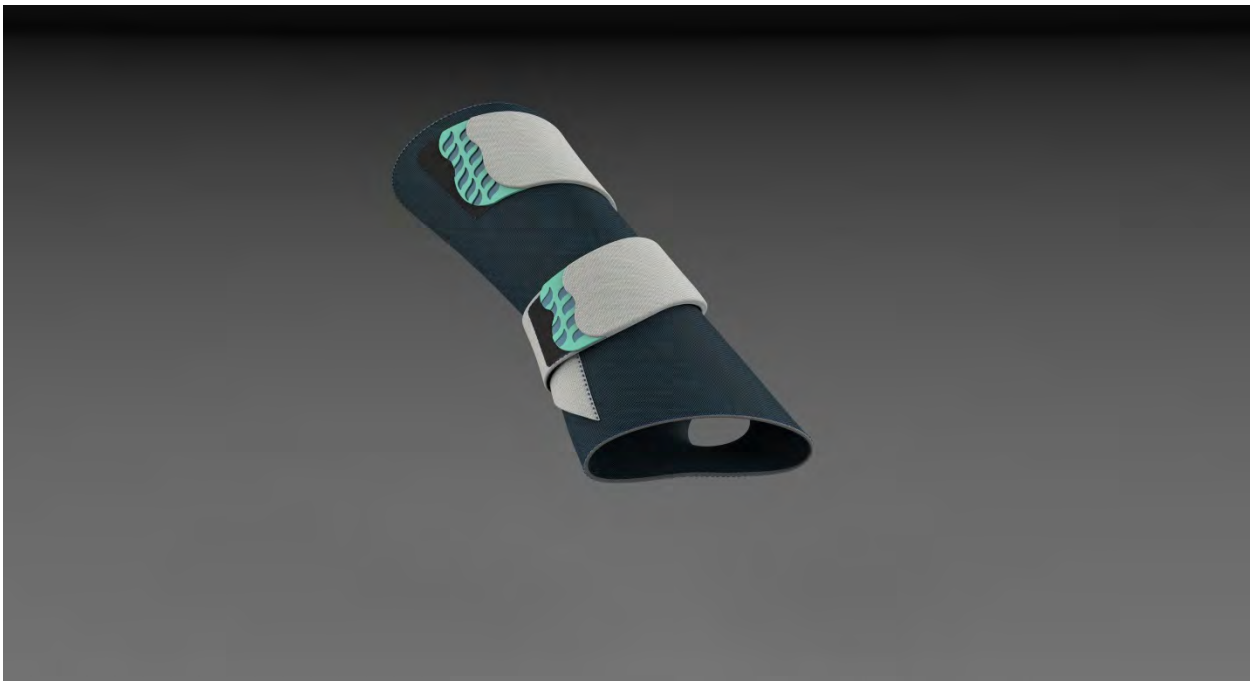
**Ankle Brace Final Renders**



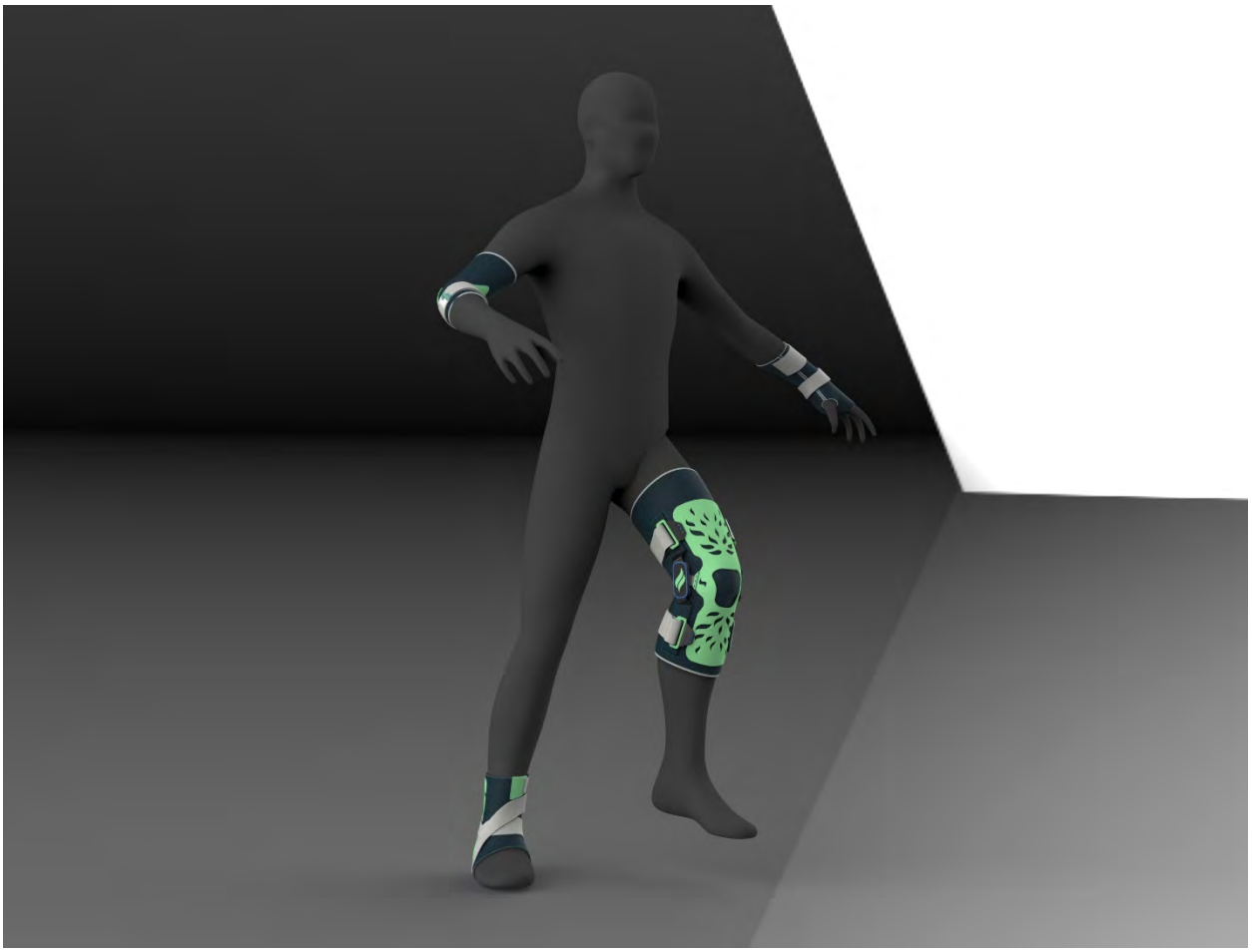


**Wrist Brace Final Renders**





**Product Family Final Render**



## 5.4 Physical Model

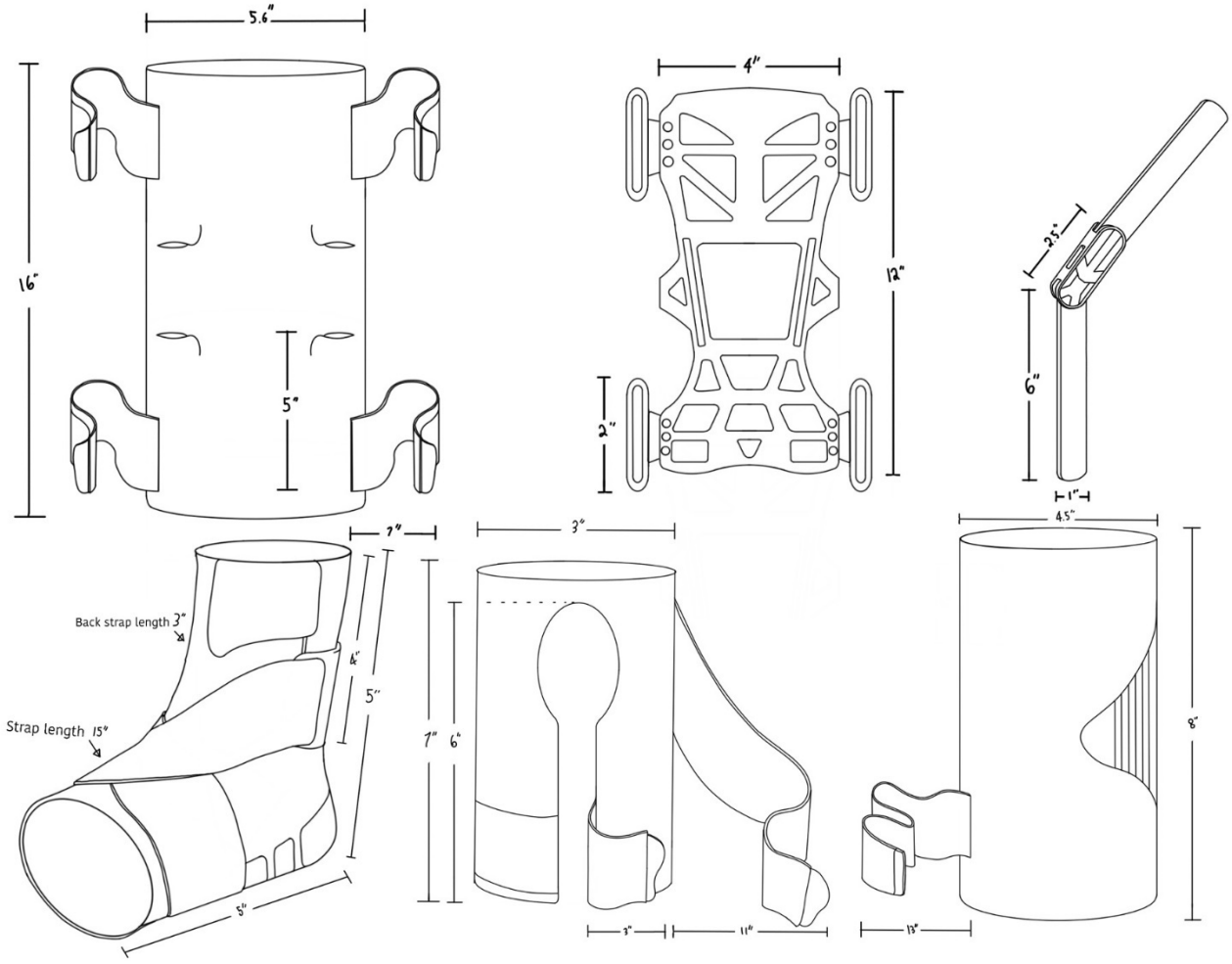
### Knee Brace

**Elbow Brace**

**Ankle Brace**

**Wrist Brace**

## 5.5 Technical Drawings




## 5.6 Sustainability

Float incorporates sustainability into all aspects of the product families design, from sustainable material use and manufacturing to health and safety. Float braces were designed to comfortably fit each and every user, mitigating any uncomfortable skin reactions or side affects. The same consideration was put into material choice, by utilizing space knitted cotton, Float avoids the use of Neoprene, which causes environmental issues as well as releasing toxic particles when manufactured. The products life cycle also becomes an especially important part

of the products sustainability, Float braces are designed using quality materials that are meant to endure hours of daily use to give the user a long-lasting product that they can trust. Float braces aid in rehabilitation hopefully allowing the user to quit using any arthritic braces.

## CHAPTER 6 – CONCLUSION

In conclusion, this report reflects the research and physical design process for a product family of Arthritic braces. The research and physical design found in this report is a direct reflection of Float. The product family aims to improve rehabilitation and mobility for the elderly suffering from arthritis. Float provides users with real time joint tracking data that can be used to further understand their own joints, while also providing their physician with accurate information, that they can use to provide a more personal rehabilitation experience.

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# Chapter 8

# Appendix

## A Discovery

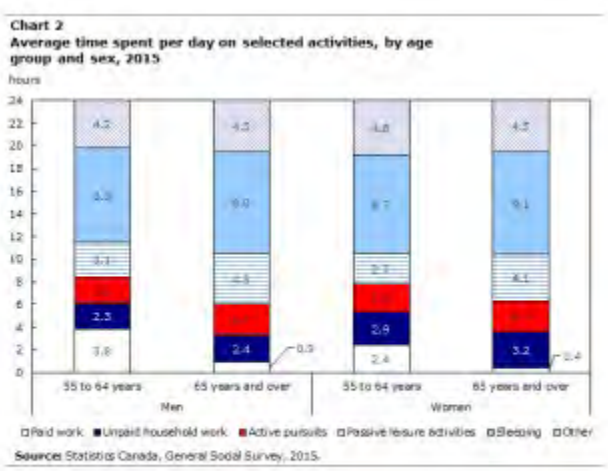



*Figure 13 – Chart 2 Average time spent per day on selected activities [Image] (2015) Retrieved from https://www150.statcan.gc.ca/n1/pub/75-006-x/2018001/article/54947-eng.htm*

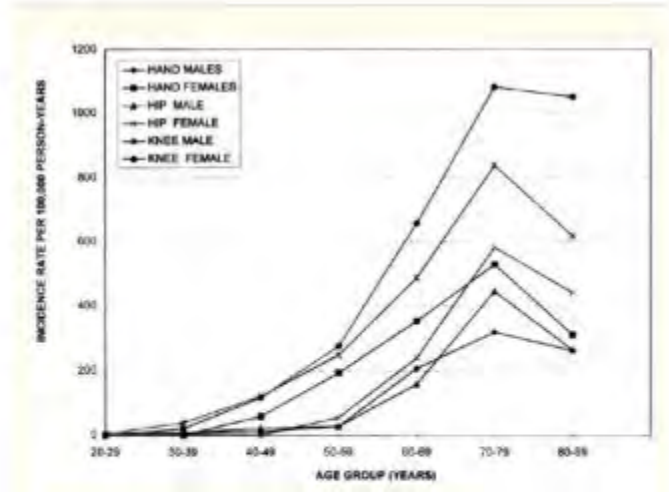



*Figure 7- Zhang, Y., & Jordan, J. (2010, August). Epidemiology of osteoarthritis. Retrieved October 14, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2920533/*

***Race and Ethnicity.*** 78% of individuals with OA (Osteoarthritis) are non-Hispanic whites. However, within their own race/ethnic groups, non-Hispanic black and Hispanic populations have higher rates of OA than non-Hispanic whites.

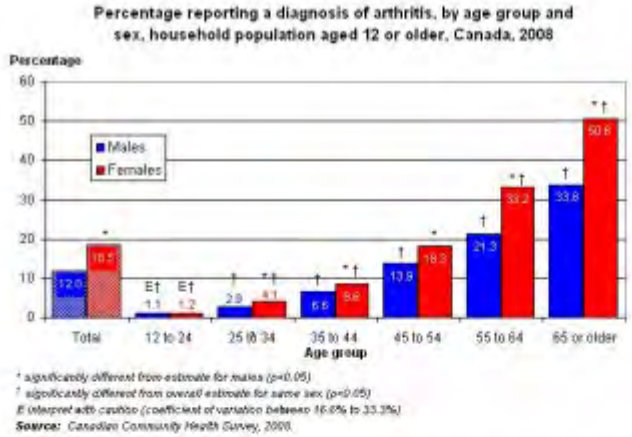



*Figure 5 - Age group and sex [Photograph found in Statistics Canada]. (n.d.). Retrieved from https://www150.statcan.gc.ca/n1/pub/82-229-x/2009001/status/arr-eng.htm (Originally photographed 2008)*

***Age.*** Age as seen in the image search was mostly elderly people from the ages 60 and up. In the below figure it shows the extent of mobility issues of people suffering from arthritis as well as the age groups for each extent of mobility issues.

Causes Reported (%) for at Least 1% of All Persons by Extent of Mobility Difficulties and Age Range* (in Years)

| Causes | Extent of Mobility Difficulties and Age Range (Estimated *N* in Millions) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Minor | | | Moderate | | | Major | | |
| | 18–49 (2.45) | 50–69 (2.72) | ≥70 (2.76) | 18–49 (1.48) | 50–69 (1.91) | ≥70 (1.84) | 18–49 (0.98) | 50–69 (1.96) | ≥70 (2.88) |
| Arthritis and musculoskeletal | 18.1 | 26.0 | 30.1 | 18.6 | 26.4 | 32.5 | 15.0 | 21.7 | 29.6 |

*Figure 6 - Iezzoni, L., McCarthy, E., Davis, R., & Siebens, H. (2001, April). Mobility difficulties are not only a problem of old age. Retrieved October 14, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1495195/*

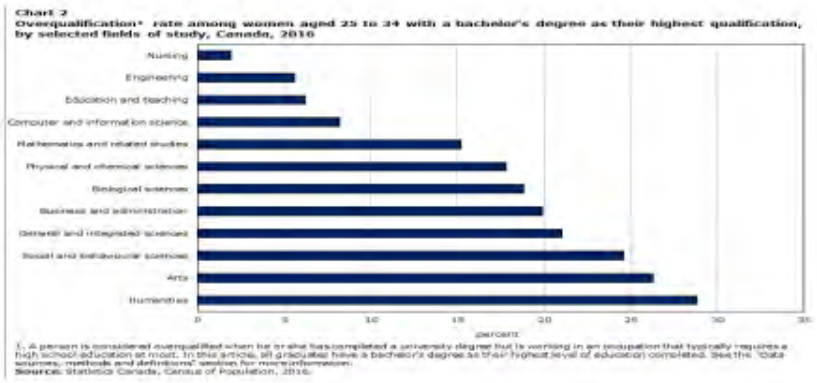



*Figure 9 This Census in Brief article examines the jobs of young bachelor's degree holders. (2017, November 29). Retrieved October 13, 2020, from https://www12.statcan.gc.ca/census-recensement/2016/as-sa/98-200-x/2016025/98-200-x2016025-eng.cfm*

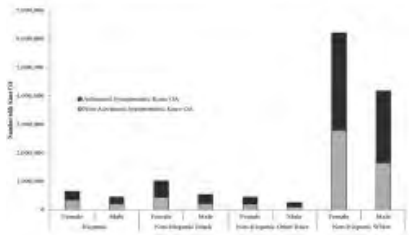
**Income.** As mentioned above arthritis affect many different people and it is difficult to determine the income of arthritis suffers. Focusing on the cost of Osteoarthritis in 2013 (USA), the national arthritis-attributable medical costs were $140 billion. Which is $2,117 in extra medical costs per adult with arthritis.


*Figure 10 -The High Cost of Arthritis. [Image] (2013) Retrieved from https://www.cdc.gov/arthritis/data_statistics/cost.htm*

Proportion of Adults With Arthritis[a] Who Have Arthritis-Attributable Activity Limitation, Severe Joint Pain, or Arthritis-Attributable Work Limitation, by Race/Ethnicity, National Health Interview Survey, United States, 2002, 2003, and 2006

| Characteristic | Total, % (95% CI) N = 85,784 | White[b], % (95% CI) n = 54,193 | Black[b], % (95% CI) n = 12,063 | Hispanic, % (95% CI) n = 11,880 | AI/AN, % (95% CI) n = 301 | API, % (95% CI) n = 3,009 | MRO[c], % (95% CI) n = 948 |
|---|---|---|---|---|---|---|---|
| **Activity limitation[d]** | | | | | | | |
| Unadjusted | 37.7 (36.9-38.6) | 36.2 (35.2-37.3) | 44.6 (42.6-46.7) | 43.2 (40.2-46.3) | 39.1 (29.0-50.2) | 38.2 (31.8-45.1) | 49.5 (41.8-57.2) |
| Adjusted[e] | 35.8 (34.8-36.9) | 34.3 (33.0-35.6) | 43.3 (40.4-46.2) | 41.7 (37.9-45.5) | 31.6 (24.1-40.2) | 32.2 (24.7-40.8) | 47.6 (39.1-56.1) |
| **Severe joint pain[f]** | | | | | | | |
| Unadjusted | 25.6 (24.9-26.4) | 23.1 (22.3-24.0) | 38.3 (36.0-40.5) | 36.4 (33.8-39.1) | 28.7 (21.9-36.6) | 18.5 (13.4-25.0) | 36.6 (29.7-44.1) |
| Adjusted | 25.4 (24.3-26.5) | 23.0 (21.8-24.3) | 38.7 (33.8-39.8) | 35.5 (32.1-39.0) | 26.5 (20.0-34.2) | 17.8 (12.3-25.0) | 33.7 (26.5-41.8) |
| **Work limitation[g]** | | | | | | | |
| Unadjusted | 31.2 (30.2-32.3) | 28.8 (27.6-30.0) | 41.6 (38.9-44.4) | 39.7 (36.4-43.1) | 37.7 (27.3-49.4) | 28.2 (19.9-38.2) | 46.4 (37.6-55.4) |
| Adjusted | 30.8 (29.6-32.1) | 28.8 (27.1-30.2) | 40.8 (37.1-44.3) | 38.7 (34.9-42.7) | 30.2 (21.8-40.0) | 27.0 (18.4-37.9) | 42.7 (33.4-52.6) |

*Figure 8- Bolen, J., Schieb, L., Hootman, J., Helmick, C., Theis, K., Murphy, L., & Langmaid, G. (2010, May). Differences in the prevalence and severity of arthritis among racial/ethnic groups in the United States, National Health Interview Survey, 2002, 2003, and 2006. Retrieved October 15, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2879996/*



*Deshpande, B., Katz, J., Solomon, D., Yelin, E., Hunter, D., Messier, S., . . . Losina, E. (2016, November 03). Number of Persons With Symptomatic Knee Osteoarthritis in the US: Impact of Race and Ethnicity, Age, Sex, and Obesity. Retrieved October 15, 2020, from https://onlinelibrary.wiley.com/doi/full/10.1002/acr.22897*

## B User research

| NEEDS | | DESCRIPTION | COMMENTS BASED ON EVIDENCE & EMPATHY | | | |
|---|---|---|---|---|---|---|
| Category of Fundimental Human Needs (Max-Neef) | Category of Psychological Needs (Maslow) | Interpretation of possible relevance to design problem space | Comments about Needs discovered in topic/problem space (include source from discovery search, if possible) | Level of Relative Importance to design of new product | | |
| | | | | Slight | Moderate | High |
| Basic Needs | | | | | | |
| Subsistence | | | provides comfort and mobility | | | high |
| Protection | | | provides protection while using mobile aids | | | high |
| Affection | | | users may experience a fondness to the ease of mobility | | Moderate | |
| | Physical (the need for air, water, food, rest, health) | | Equipment may provide physical rehabilitation as well as provide relief on joint pain | | | high |
| | Security (the need for safety, shelter, stability) | -control over one's environment<br>-value, in terms of fulfilling a need at lower price and enhancing access, reliability | May provide security from falls and accidents | | | high |
| Social Belonging (Effort/ resources to belong to a 'tribe') | | | | | | |
| Understanding | | | minimal understanding for use | | moderate | |
| Participation | | -convenience, in terms of speed (fast, uses less time)<br>-optimization of limited resources | can provide a quicker way to move around | slight | | |
| Leisure | | | Providing comfortability | | moderate | |
| | Social (the need for being loved, belonging, inclusion) | -fear of abandonment<br>-fear of the enemy<br>-Tribal identity (belongong to the winning team)<br>-Peer Pressure (direct and indirect 'Everybody else has it')<br>-could also consider ease of use that permits participation where participation had been limited | the fear of falling or being unable to complete a task | | moderate | |
| | Ego (the need for self-esteem, power, recognition, presitge) | -social expectation<br>-social status (the elite has it.. I want to be like them)<br>-social recognition<br>-convenience and ease of use that enhances social recognition<br>-gift giving: reciprocal social covenant | expectation to work properly and be able to preform everyday tasks without the help of others. Being able to care for themselves | | moderate | |
| Personal Accomplishment | | | | | | |

The cartilage within a joint begins to break down and the underlying bone begins to change.

OA can cause pain, stiffness, and swelling. In some cases, it also causes reduced function and disability; some people are no longer able to do daily tasks or work.

**2. How many people have OA?**

OA affects over 32.5 million US adults.

**What causes OA?**

OA is caused by damage or breakdown of joint cartilage between bones.

**What are the risk factors for OA?**

Joint injury or overuse—Injury or overuse, such as knee bending and repetitive stress on a joint

3. People who have family members with OA are more likely to develop OA. People who have hand OA are more likely to develop knee OA.
4. There is no cure for OA, so doctors usually treat OA symptoms with a combination of therapies
5. Experts recommend that adults engage in 150 minutes per week of at least moderate physical activity. Every minute of activity counts, and any activity is better than none. Moderate, low impact activities recommended include walking, swimming, or biking. Regular physical activity can also reduce the risk of developing other chronic diseases

| | | |
|---|---|---|
| | Creation | -could consider the convenience aspect of a product (tool) that amplifies human abilities<br>-ease of use |
| | Identity | -could relate to the next generation and be longer term / less immediate. Examples: sexual attractivelness; the health/care/education of children<br>-environmental sustainability |
| | Freedom | -convenience in terms of availability (is it easy to buy) |
| | Self-Actualization (the need for development, creativity) | -includes sensual pleasure, such as: visual, acoustic, tactile, haptic, taste, olfactory<br>-includes aspects of emotional response, such as: empathy, excitement, fun, nostalgia, memory, etc.<br>-could also include compulsive behaviours, such as: buying, gaming, smoking, drinking, sex, adrnaline rush, etc.<br>-aesthetically pleasing<br>-intrinsic pleasure<br>-the ability to prepare for the future in terms of insurance (house, car, medical), pension, investments |

| | | | |
|---|---|---|---|
| Mobility aid improvement could amplifie human abilities and ease of use | | | high |
| the equipment could translate to the next generation to better prepare for use of mobility aids and provide a better look at future mobility problems | | moderate | |
| the equipment should be easy to access for the masses just like todays mobility aids | | | high |
| equipment would provide excitement to users struggling with mobility issues. The product would be aesthetically pleasing and bring back the users confidence and take back their own lives | | moderate | |
| | | | |

**Abstract**

Objective

To compare the 6-minute walking distance (6MWD) in a population-based cohort of patients with osteoarthritis (OA) with that in matched peers from the general population, and to explore the associations between walking ability and risk of cardiovascular disease (CVD) in the OA cohort.

Methods

This cross-sectional study included individuals (ages 40–80 years) who had self-reported OA (n = 500) in a previous population-based study and age- and sex-matched peers from the general population (n = 235). Clinical examinations of the patients with OA included classification according to the American College of Rheumatology criteria, blood sampling, and measuring arterial stiffness (PWV; pulse wave velocity). Group differences in the 6MWD were calculated with t-tests. The association between walking ability and CVD risk in the OA cohort was examined using multivariate regression models.

**Introduction**

The results of recent systematic reviews 1, 2 and population-based cohort studies 3-5 indicate that osteoarthritis (OA) is associated with an increased risk of cardiovascular disease (CVD). Fernandes and Valdes 6 recently reported risk factors shared by both conditions, including age, obesity, chronic inflammation, treatment with nonsteroidal anti-inflammatory drugs (NSAIDs), physical inactivity, and walking disability 6. Patients with hip OA and those with knee OA tend to avoid painful physical activity, resulting in walking disability and physical inactivity 7-9, which in turn result in reduced cardiorespiratory fitness. Because cardiorespiratory fitness is an important independent predictor of CVD 10, 11, OA may be considered to be an indirect cause of CVD 3, 4, 6. The co-existence of OA and CVD reinforces the negative health impact and increases the disease burden 6, 12.

No cure for OA is available; therefore, it is important to identify modifiable factors that can contribute to limiting negative long-term consequences. Even if the underlying mechanisms for the association between OA and CVD are not fully elucidated, it seems clear that OA-related disability increases the risk of CVD beyond what can be explained by common risk factors such as aging and obesity 6. Arterial stiffness is a validated marker of the risk of cardiovascular events and a predictor of mortality 13, 14. An inverse association between the level of physical exercise and arterial stiffness has been observed in healthy individuals as well as in patients with chronic diseases 15, 16, indicating that arterial stiffness can be modified with exercise. The performance-based 6-minute walking distance (6MWD) is known to be a valid measure of walking (dis)ability and cardiorespiratory fitness. The aim of this population-based study was to compare the 6MWD in patients with OA with that in age-matched peers from the general population, as well as to explore the association between walking ability and CVD risk as measured by arterial stiffness.

In total, 630 (60%) of the participants who self-reported OA in the MUST study (n = 1,049) participated in clinical examinations and physical testing (Figure 1). No differences were observed between individuals who participated in the clinical examinations and those who did not (n = 419) with regard to age, sex ratio, self-reported height and weight, and educational status.

**esults**

n the current study, 130 participants were excluded due to inflammatory rheumatic disease (n = 52) nd/or CVD (n = 78); thus, 500 individuals were included in the analyses (Figure 1). The mean ± SD ime gap between the initial self-report of OA and participation in the medical examinations and hysical testing was 8.3 ± 4.0 months. The mean age of the participants was 63 years, and the ajority (72%) were women (Table 1). More than two-thirds of the participants (68%) were classified s being overweight or obese. Approximately 1 of 4 patients reported using NSAIDs on a daily/almost aily basis. Most patients (78%) reported joint pain as ≤5 on the NRS. In total, 347 participants 59%) were classified as having OA in ≥1 joints according to the ACR criteria. Measures of arterial tiffness (PWV) in the OA group ranged from 4.65 to 18.30 meters/second (Table 1). Due to logistic easons, PWV data for 136 patients were missing. There were no statistically significant differences n mean age (P = 0.9) or sex distribution (P = 0.14) between patients with and those without PWV easures, but the mean BMI in patients without PWV measures (1.40 [95% CI 0.45, 2.3], P = 0.004) as higher than that in patients with PWV measures.

**onclusion**

ven at age 40 years, patients with OA had a significantly shorter mean walking distance compared ith their matched peers, underlining the importance of an early clinical approach to OA. urthermore, in the OA group, the 6MWD was significantly associated with arterial stiffness, uggesting that walking ability is important for the CVD risk profile in patients with OA.

**ummary Statements**

1. Exploring the associations between walking ability and risk of cardiovascular disease (CVD) in the OA (Osteoarthritis) cohort. Cohort studies 3-5 indicate that osteoarthritis (OA) is associated with an increased risk of cardiovascular disease.
2. Patients with hip OA and those with knee OA tend to avoid painful physical activity, which can lead to reduced cardiorespiratory fitness.
3. There is currently no cure for OA, it is important to gain further information on the negative impacts that come along with OA.
4. Even at age 40 years, patients with OA had a significantly shorter mean walking distance compared with their matched peers, underlining the importance of an early clinical approach to OA.
5. In the OA group, the 6MWD was significantly associated with arterial stiffness, suggesting that walking ability is important for the CVD risk profile in patients with OA.

**Persona**

**Name:** Betty Smith

**Age:** 67

**Occupation:** Retired Communications specialist

**Income:** $14,109.96

**Education:** Bachelor's Degree - Communications

**Relationship Status:** Married, 1 kid

**Location:** Toronto, Ontario

**Career/ Volunteer:** Retired

**Years of Service:** 30

**Social:** Hangs out with friends and family

**Frequency of Activity:** Leisure activates throughout the day

**Hobbies:** Walking, Tennis, Shuffleboard, cooking

*Figure 12 Betty with a walker [Image] (2016) Retrieved from https://www.pinterest.ca/pin/551550285595738963/*

**Profile**

Betty Smith is a 67 -year-old Caucasian Woman. She attended university to receive her bachelor's degree in communications. She is a retired Communication Specialist and earns a pension of $14,109.96 After working for 30 years. Betty tries to live a self sufficient life to take care of herself and husband.

**User Profile Summary**

| User | Description |
|---|---|
| Primary | Osteoarthritis Suffer |
| Secondary | Physiotherapists |
| Tertiary | Community workers/storefront workers |

**Primary User Profile**

| Demographics | | User Behavior | | Personality | | Cognitive Aspects | |
|---|---|---|---|---|---|---|---|
| Age | 60+ | Frequency of Use | 6hr (mobility Aids) | Go Getter | ↑ | Technical Skill | ↑ |
| Gender | Mixed (60% Female) | Duration | Varies (20 mins to x hrs) | Self-Efficacy | ↑ | Pre-Requisite Knowledge | ↑ |
| Ethnicity | Non-Hispanic White | Social | low-Social | Changeability | ↑ | | |
| Income | Middle Class ($40,000 to $80,000) | Level of Focus | Medium | Uncertainty Avoidance | ↓ | | |
| Education | High School Diploma | Location | Residential – Rural/ Urban | | | | |

Q3 What are the main areas of the body that arthritis affects? What can cause arthritis in these areas?
Essay

| Date | Answers |
|---|---|
| Nov 22 | Back, Hips, knees, feet - osteoarthritis most commonly. Hands - if rheumatoid arthritis the functional deficits tend to be more severe but osteoarthritis can impact grip strength too. Osteoarthritis is a "wear and tear" condition basically. Rheumatoid has a genetic base usually |

Q5 What activities do you recommend to reduce pain among osteoarthritis sufferers?
Essay

| Date | Answers |
|---|---|
| Nov 22 | We often discuss ways to modify how a person completes a task. Alternating sitting and standing. Using a walker to offload back, hips, knees. |

Q6 In your experience what has been the most common complaint from patients with arthritis?
Essay

| Date | Answers |
|---|---|
| Nov 22 | Pain trying to do normal everyday tasks. But lack of or reduced mobility likely most common complaint. |

Q8 Can people with arthritis work labour intensive jobs and at what point do you suggest a medical leave of absence?
Essay

| Date | Answers |
|---|---|
| Nov 22 | This is a very complex question. Yes they can but would need some sort of splint or brace most likely, recognizing that the job may need to be modified. This truly is an individually assessed situation. Many variables to consider. If a client can not safely complete the job then a leave will need to be considered. Hopefully a specialist would have been consulted (ortho, rheumatology) to determine options if conservative therapies not successful. May need therapy - ultrasound etc as part of conservative treatment |

Q10 What are the first signs that someone may have or may develop arthritis?
Essay

| Date | Answers |
|---|---|
| Nov 22 | Family history for RA. Joint pain, red or inflamed joints. Loss of function. |

Q12 Are there surgeries that can reduce arthritis pain?
Essay

| Date | Answers |
|---|---|
| Nov 22 | Yes - joint replacements (shoulders, "knuckles"/MCP, hip, knee). I think some ankle joints have been replaced but less common. Ankles tend to be fused as surgical option. |

Q14 Do injuries increase the likelihood of getting arthritis? If so can you name a couple?
Essay

| Date | Answers |
|---|---|
| Nov 22 | Certainly a fracture can result in arthritic pain after the fact. For instance osteoarthritis Congenital birth issues with surgery to correct can result in arthritis later. An example...I was born with bilateral "club feet". I've had multiple surgeries over the years, mostly Left foot and now I have moderate to severe OA. Surgery was recommended but due to high risk for complications I get injections every 3 months or so. |

Q15 How do the different stages of osteoarthritis differ from one another and what is the pain like at each stage?
Essay

| Date | Answers |
|---|---|
| Nov 22 | Pain is very subjective and each person's pain tolerance varies. Early stages equal less pain one would anticipate but again some people describe severe pain at early stages. I feel the particular joint involved also impacts perception of pain - for example hip and knee arthritis might be more problematic than wrist. Depends upon task person trying to complete, repetition of task etc A person's weight can impact the pain too - if heavier therefore more stress on legs standing and walking |

Q16 Can you explain some problem areas that patients have had while in their home?
Essay

| Date | Answers |
|---|---|
| Nov 22 | Ohh boy - every area of the home can be an issue! Stairs, getting on/off toilet, in/out of bed or shower/tub, getting dressed, meal prep, laundry etc etc. I assess on individual basis and recommend strategies accordingly |

## C Product Research

| | Product Image | Description |
|---|---|---|
| 1 |  | **Ossur Unloader One**<br>• Dual Dynamic Force System™ (DFS) straps provide unloading of the knee joint<br>• Moderate to severe unicompartmental knee osteoarthritis<br>• Proprietary Sensil® silicone liners are designed to reduce migration. |
| 2 |  | **Ossur Unloader One X**<br>• Moderate to severe unicompartmental knee osteoarthritis<br>• Entire brace is machine washable<br>• Alignment guide, color-coded touchpoints, and Quick Fit buckles allow for intuitive donning and doffing |
| 3 |  | **Össur Formfit® Pro Knee OA**<br>• Lightweight Coolvent™ knit in popliteal area for added breathability and comfort.<br>• Patella graphics for intuitive placement<br>• Early or mild unicompartmental osteoarthritis |
| 4 |  | **Push med Elbow Brace**<br>• Adjustable with one hand.<br>• excellent fit and silicone strips prevent migration during movement.<br>• Comfortable and lightweight |

| | | |
|---|---|---|
| 5 |  | **Donjoy Performance Trizone Elbow Support**<br>• Anti-migration technology<br>• All-natural carbonized bamboo is thermal regulating<br>• Three zones of compression |
| 6 |  | **MedSpec Motion Manager - Wrist Support**<br>• Ventilated adjustable strap allows adjustment of compression around the carpals<br>• Flip tab allows product to be worn on either right or left hand<br>• Semi-flexible polyethylene stay; controls wrist motion in functional range |
| 7 |  | **Donjoy Velocity ankle brace**<br>• low profile and lightweight<br>• moldable foot plate<br>• R3 technology (rapid-rigid-ratched) in the calf cuff, provides compression to your ankle joint to prevent swelling. |
| 8 |  | **Compression gloves**<br>• non-invasive relief<br>• comfortable and breathable design<br>• 60% Cotton / 33% Polyester / 7% Spandex<br>• easy to clean |

| FEATURES | | Sort #1 | Sort #2 |
|---|---|---|---|
| From Promotional Material | Re-order: NOUN first | DATA [On Menu Bar] → | Group like categories |
| microfibres | Adjustability: adjustable wrist compression | Adjustability: adjustable wrist compression | Base Frame 8 |
| 3-Points of Leverage | Adjustability: anatomical fit | Adjustability: anatomical fit | Base Frame: lightweight |
| adjustable wrist compression | Adjustability: Dynamic Force Control System | Adjustability: Dynamic Force Control System | Base Frame: Anatomically Designed Bilateral Hinges |
| anatomical fit | Base Frame: lightweight | Base Frame: lightweight | Base Frame: Breathable liners |
| Anatomically Designed Bilateral Hinges | Base Frame: Anatomically Designed Bilateral Hinges | Base Frame: Anatomically Designed Bilateral Hinges | Base Frame: Flexable shells |
| breathable liners | Base Frame: Breathable liners | Base Frame: Breathable liners | Base Frame: flexible plastic stays |
| Dual Dynamic Force Straps | Base Frame: Flexable shells | Base Frame: Flexable shells | Base Frame: neoprene base |
| Dynamic Force Control System | Base Frame: flexible plastic stays | Base Frame: flexible plastic stays | Base Frame: Rigid Uprights |
| flexible plastic stays | Base Frame: neoprene base | Base Frame: neoprene base | Base Frame: soft |
| flexible shells | Base Frame: Rigid Uprights | Base Frame: Rigid Uprights | |
| lightweight | Base Frame: soft | Base Frame: soft | |
| neoprene base | Materials: Össur Sensil® Silicone | Materials: Össur Sensil® Silicone | |
| Össur Sensil® Silicone | Materials: Microfibers | Materials: Microfibers | Materials: 5 |
| pulled for use as more for its compression features | Materials: silicone application | Materials: silicone application | Materials: Össur Sensil® Silicone |
| Rigid Uprights | Materials: Sympress | Materials: Sympress | Materials: Microfibers |
| silicone application | Materials: zipper | Materials: zipper | Materials: silicone application |
| soft | Straps: 3-points leverage | Straps: 3-points leverage | Materials: Sympress |
| strap system is very functional | Straps: Dual Dynamic Force straps | Straps: Dual Dynamic Force straps | Materials: zipper |
| Sympress | Straps: pulled for use as more for its compression features | Straps: pulled for use as more for its compression features | Straps 4 |
| zipper | Straps: strap system is very functional | Straps: strap system is very functional | Straps: 3-points leverage |
| | | | Straps: Dual Dynamic Force straps |
| | | | Straps: pulled for use as more for its compression features |
| | | | Straps: strap system is very functional |
| | | | Adjustability 3 |
| | | | Adjustability: adjustable wrist compression |
| | | | Adjustability: anatomical fit |
| | | | Adjustability: Dynamic Force Control System |

| BENEFITS | Sort #1 | Sort #2 | |
|---|---|---|---|
| From Promotional Material | DATA [On Menu Bar] → | Groups like categories | |
| comfortable | adjusted with one hand | *comfort* | 13 |
| lightweight | at work or at home | comfortable | |
| low-profile | color-coded quick fit buckles simplify | comfortable | |
| excellent suspension | comfortable | comfortable | |
| lightweight | comfortable | comfortable and light | |
| easily fine-tuned | comfortable | at work or at home | |
| color-coded quick fit buckles simplify | comfortable and light | enhanced comfort | |
| improve comfort | easily fine-tuned | excellent suspension | |
| reduce migration | easy to apply and can be washed | extra support | |
| reduces pain | easy to put on and take off | extra support | |
| infinitely adjustable extension | enhanced comfort | extremely comfortable | |
| prevents overstretching | excellent suspension | flexible support | |
| adjusted with one hand | extra support | high-quality comfortable material | |
| withstanding strong traction forces | extra support | improve comfort | |
| comfortable and light | extremely comfortable | *style* | 8 |
| easy to put on and take off | flexible support | easily fine-tuned | |
| high-quality comfortable material | high-quality comfortable material | easy to apply and can be washed | |
| keeps the skin dry | improve comfort | easy to put on and take off | |
| easy to apply and can be washed | infinitely adjustable extension | lightweight | |
| provide flexible support | injury prevention | Lightweight | |
| used on either hand | keeps the skin dry | lightweight | |
| comfortable | lightweight | Low Profile | |
| enhanced comfort | Lightweight | low-profile | |
| flexible support | lightweight | | |
| at work or at home | Low Profile | *efficiency* | 3 |
| extra support | low-profile | Color-coded Quick Fit Buckles simplify application and removal | |
| prevent ankle sprains | prevent a future injury | without bulkiness | |
| extremely comfortable | prevent ankle sprains | withstanding strong traction forces | |
| prevent a future injury | prevents overstretching | | |
| comfortable | provide flexible support | | |
| injury prevention | reduce migration | | |
| Low Profile | reduces pain | *ease* | 5 |
| Lightweight | used on either hand | adjusted with one hand | |
| extra support | without bulkiness | infinitely adjustable extension | |
| without bulkiness | withstanding strong traction forces | injury prevention | |
| | | keeps the skin dry | |
| | | used on either hand | |
| | | *Safety* | 6 |
| | | prevent a future injury | |
| | | prevent ankle sprains | |
| | | provide flexible support | |
| | | reduce migration | |
| | | reduces pain | |
| | | prevents overstretching | |

1 User places knee brace over the knee and begins wrapping the top strap

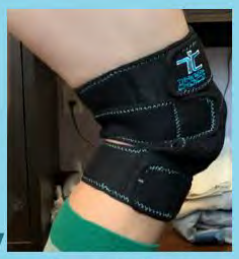
2 Wrapping strap around thigh

3 Placing the top strap into a secure placement over the Velcro

4 Wrapping the middle strap the opposite way

5 Wrapping the bottom strap around the calf

6 Securing the bottom strap onto the Velcro



7 Demonstrating a bent knee

1 User releases straps

2 Attempts to slip into brace without pulling the straps out

3 Staps came out, struggles to line the straps up

4 User pulls straps through the brace and wraps them around to the velcro

5 Wrist brace fully in place

6 User gripping doorknob

7 User demonstrates exercising with a wrist brace

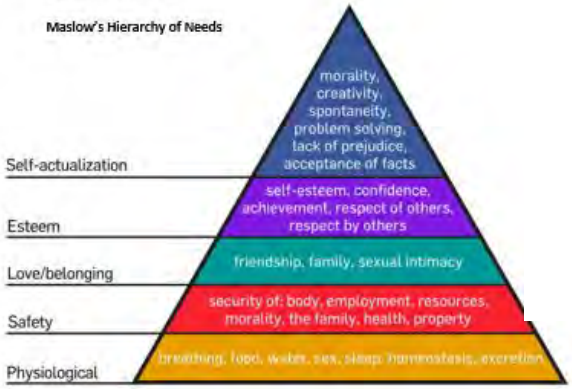
## D Analysis

**Current product solutions**

- Breathable materials
- Form fitting materials
- Skin friendly materials
- Variability in product sizing and adjustability
- Variability of braces

**3.1.2 Latent Needs**

**Maslow's Hierarchy of Needs**




**3.1.4 Needs Analysis Diagram**


Eaton, S. E. (2012). Maslow's Hierarchy of Needs [Hierarchy of needs]. Retrieved 2020, from https://drsaraheaton.wordpress.com/2012/08/04/maslows-hierarchy-of-needs/

| | Benefit | Possible Corresponding Fundamental Human Needs (FHN) | Relationship between Benefits and FHN |
|---|---|---|---|
| 1 | Style | Esteem, Respect of others | Moderate |
| 2 | Comfort | Control, Security | Strong |
| 3 | Ease | Accomplishment, protection, security, control, self-esteem | Strong |
| 4 | Efficiency | Accomplishment, protection, control, self-esteem | Strong |
| 5 | Freedom | Leisure, Participation, Belonging, self-esteem | Strong |

## J Approval Forms

# IDSN 4002
SENIOR LEVEL THESIS ONE

Humber ITAL / Faculty of Applied Sciences & Applied Technology
Bachelor of Industrial Design / FALL 2020
Catherine Chong / Sandro Zaccolo

FTA-4 THESIS TOPIC APPROVAL (TEMPLATE)
This project/assignment constitutes 5% of total mark for the course

Start: Week #4 / Sep-28
Due: Week #5 / Oct-05

**THESIS TOPIC APPROVAL:**

| | |
|---|---|
| **Student Name:** | Thomas / Edmonds |
| **Topic Title:** | How may we improve comfort and mobility for the elderly suffering from arthritis? |

**Abstract**

One of the main health concerns faced by people above the age of forty is arthritis, which can be very painful and difficult to treat. Arthritis is the swelling of one or more joints in the body, the most common types of arthritis are Osteoarthritis and Rheumatoid. Osteoarthritis affects millions of people worldwide, this form of arthritis occurs by the deterioration of the protective cartilage at the end of bones, over time. In most cases Osteoarthritis effects, the joints in the hands, hips, spine, and knees. People suffering from moderate to major damage to these joints, tend to have mobility issues that can cause significant strain on people's everyday lives. Elderly people often struggle with impairing joint pain, which can lead to them needing more support from others, to complete everyday tasks. User research into products on the market and observational research on people with arthritis to gain further understanding on how people go about their day to day tasks, by contacting primary and secondary users. Discovering user pain points from all areas of the users life (home, stores, out-doors) to find the best suited area to focus on and that will demand considerations for full-body human interaction design. The aim of this thesis project is to develop a product that will improve on the mobility of elderly people suffering from Osteoarthritis and to help them be more self-sufficient.

**Student Signature(s):**
Thomas Edmonds

**Date:** 04 / 10 / 2020

**Instructor Signature(s):**
Catherine Chong Sandro Zaccolo

**Date:** 28 / 10 / 2020

Chong, Kappen, Thomson, Zaccolo

# IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2021
Catherine Chong / Sandro Zaccolo

## CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

| | |
|---|---|
| **Student Name:** | **Thomas Edmonds** |
| **Topic / Thesis Title:** | **Arthritic Braces for Rehabilitation** |

### THESIS DESIGN APPROVAL FORM

| | |
|---|---|
| **Thesis design is approved to proceed for the following:** | [X] **CAD Design and Development Phase** |
| **Comment:** | Initial CAD progress well as of week #7/March 1st, continue with detailing and refinement. |

| | |
|---|---|
| **Thesis design is approved to proceed for the following:** | [X] **Model Fabrication Including Rapid Prototyping and Model Building Phase** |
| **Comment:** | Design development progress well as of week #7/March 1st, once CAD is completed, can move forward to model fabrication from week #9 onward. |

| | |
|---|---|
| **Instructor Signature(s):** | Catherine Chong  Sandro Zaccolo |
| **Date:** | 10th March 2021 |

PANEL ON RESEARCH ETHICS
*Navigating the ethics of human research*

**TCPS 2: CORE**

# *Certificate of Completion*

*This document certifies that*

**Thomas Edmonds**

*has completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE)*

Date of Issue: **4 October, 2020**