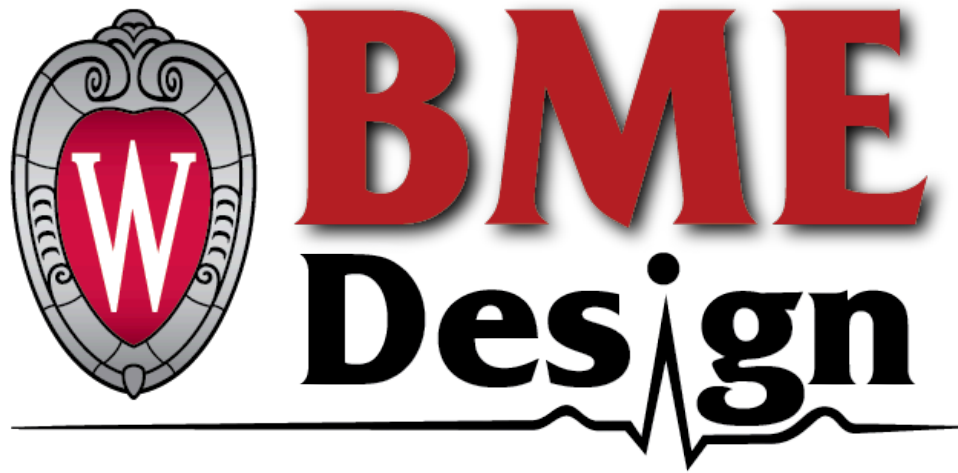




## **Knee Crutch**

*Preliminary Report*

**BME 200/300**

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## ***Abstract***

Non-weight-bearing restrictions following lower-limb injuries and conditions can significantly limit a patient's ability to safely navigate stairs during recovery. Conditions such as Charcot foot and lower-limb amputation can require prolonged offloading and may increase difficulty with stair negotiation due to altered biomechanics [1,2]. Conventional mobility aids, including axillary crutches and canes, require substantial strength, balance, and coordination, while many existing devices are designed primarily for level-ground ambulation [3]. Hands-free crutches, such as the iWALK, can reduce some of these demands but are not specifically designed for the height, stability, compactness, and repositioning requirements of navigating stairs [3,4].

To address this need, a Knee Crutch was developed to support the user's lower leg while maintaining clearance of the injured area and providing a stable platform for stair navigation. The design incorporates a height-adjustable aluminum frame, padded and laterally supportive knee rest, repositioning handle, and rubberized base for improved traction. The device accommodates users approximately 5'0"–6'0", supports loads of at least 180 kg, weighs approximately 4 lb or less, and can be used with either limb. The design also considers sanitation requirements for healthcare environments, mechanical safety, and resistance to tipping during stair navigation and transfers. Through iterative design and evaluation against client requirements, the Knee Crutch aims to provide a lightweight, stable mobility solution for non-weight-bearing patients transitioning from rehabilitation facilities to their homes.

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## ***Introduction***

### A. Motivation

The new Knee Crutch design is impactful because it addresses the difficulty non-weight-bearing patients can experience when navigating stairs during recovery. Patients with lower-limb injuries or conditions such as Charcot foot may be required to keep weight off the affected limb, making traditional mobility aids such as crutches or canes difficult to use safely, particularly for individuals with limited strength, balance, or stability [2], [4]. Many existing mobility devices are designed primarily for level-ground movement and may not provide the height, stability, compactness, or ease of repositioning needed for stair navigation [1]. Hands-free crutches, such as the iWALK, provide an alternative to traditional crutches and can reduce some of the physical demands associated with conventional crutch use [5]. However, existing devices do not address all of the requirements identified by the client, creating an opportunity for a mobility aid specifically designed for short-term stair use.

The Knee Crutch is intended to support non-weight-bearing patients as they transition from a rehabilitation facility to their home, where they may encounter stairs before they are able to transition to other mobility aids. The design focuses on reducing the physical effort required to maneuver the device while maintaining stability and safety. Its lightweight aluminum construction, adjustable height, padded knee support, non-slip base, and repositioning handle are intended to accommodate users of different heights while reducing the risk of slipping or tipping during stair navigation. By targeting a weight of approximately 4 lb, supporting users up to at least 180 kg, and allowing adjustment for users approximately 5'0"–6'0", the Knee Crutch aims to provide a practical and accessible solution for patients who need temporary assistance navigating stairs during recovery. This design addresses a specific gap in existing mobility aids by prioritizing stair-specific stability, lightweight construction, adjustability, and ease of repositioning for non-weight-bearing patients.

### B. Codes and Standards

Several standards are relevant to the design and testing of the Knee Crutch. ISO 22523:2006, *External limb prostheses and external orthoses—Requirements and test methods*, provides guidelines for strength, materials, safety, and risk considerations for devices that support the lower limb [6]. Although the Knee Crutch is not an orthosis or prosthesis, these requirements can help guide its mechanical and safety testing. ASTM F3580-24, *Standard Test Method for Exoskeleton Use: Stairs*, provides testing considerations for devices used during stair ascent and descent, making it relevant to evaluating the Knee Crutch's stability and performance on stairs [7]. ISO 11334-1:2007, *Assistive products for walking manipulated by one arm—Requirements and test methods—Part 1: Elbow crutches*, includes testing for load capacity, fatigue, safety, and performance of crutches [8]. While this standard applies specifically

to elbow crutches, its testing principles can inform the mechanical testing of the Knee Crutch. Together, these standards provide guidance for evaluating the device's strength, safety, durability, and performance during stair navigation.

### *C. Existing devices*

Several mobility devices are currently available for individuals who require lower-limb support, including the iWALK Hands-Free Crutch, Freedom Leg, and JOMCYDM Walking Aid Knee Crutch. The iWALK Hands-Free Crutch is designed to support the lower leg while allowing the user to remain hands-free during mobility. Clinical research comparing hands-free crutches with traditional axillary crutches has reported reduced physical demands and favorable patient preference for hands-free designs [8]. However, the iWALK uses a strap-based system to secure the device to the user's leg, which may make putting the device on and removing it more cumbersome for some users. The Freedom Leg is another hands-free mobility device that provides lower-limb support without requiring traditional crutches, but its more generalized design leaves an opportunity for a device specifically optimized for stair navigation [9]. The JOMCYDM Walking Aid Knee Crutch provides a height-adjustable knee support and gripped feet, offering features similar to those required for the proposed Knee Crutch; however, it is a commercially available generalized mobility aid rather than a device specifically designed around the stair-navigation requirements identified by the client [10].

These existing devices demonstrate that hands-free lower-limb support can provide an alternative to traditional crutches, but they do not address all of the requirements identified for the proposed Knee Crutch. The design specifically prioritizes stair navigation, lightweight construction, simple height adjustment, a compact base to reduce tipping, and a handle that allows the user to reposition the device between stairs. The proposed design will also incorporate a padded knee support, non-slip base, and materials that can be cleaned and sanitized between users. By combining these features into a single device, the Knee Crutch is intended to address the specific needs of non-weight-bearing patients navigating a small set of stairs during the transition from rehabilitation to home.

### *D. Problem statement*

This project aims to design a lightweight, stable, and adjustable Knee Crutch to assist non-weight-bearing patients with safely navigating a small set of stairs during recovery. Current mobility aids, including crutches and canes, may require significant strength, balance, and stability, while many existing devices are designed primarily for level-ground mobility rather than stair navigation. This can create challenges for patients transitioning from a rehabilitation facility to their home, particularly for individuals who have difficulty using traditional mobility aids. The objective is to develop a compact device that can accommodate users approximately

5'0"–6'0", support at least 180 kg, weigh approximately 4 lb or less, and provide sufficient traction and stability during stair use. By incorporating an adjustable aluminum frame, padded knee support, non-slip base, and handle for repositioning, the design aims to provide non-weight-bearing patients with a safer and more manageable method of navigating stairs while minimizing the strength and balance required to use the device.

## ***II. Background***

### ***A. Background Research***

Nearly 1 in 3 adults over 65 report difficulty climbing a flight of stairs [11]. A large number of people with a lower limb amputation have to climb stairs in their home environment after amputation and ensuing rehabilitation treatment. They report a decreased ability to climb stairs, especially among women and people of older age [12]. The client frequently has patients with charcot foot, below the knee amputees, etc. This means that “hopping” is not a safe option and they need something to assist them [3].

### ***B. Design Research***

The device is designed for people to efficiently and easily get up stairs. It is an essential aid in which the materials chosen directly impacts both performance and comfort in everyday use. Aluminum alloy has become the standard choice for regular underarm crutches. This material has a lot of obvious advantages. Traditional crutches, usually made of steel or wood, can weigh between 2.5 to 3.5kg. Aluminum crutches weigh only 1.3 to 1.7kg which is about 40% to 50% lighter, a noticeable difference. The lightweight material reduces arm strain, which is a positive for older patients with less strength and balance [13].

### ***C. Client Information***

The client is Mr. Daniel Kutschera, a proud graduate of UW Madison. Dan has been a physical therapist for 33 years now, primarily working in neurorehabilitation. Throughout the course of his career, he has often had to come up with creative solutions to assist patients in overcoming physical and environmental barriers. The knee crutch is a great example of one of these solutions that is commercially unavailable which the group has been tasked with.

### ***D. Design Specifications***

The Product Design Specifications included in Appendix A covers a list of requirements the design must meet. Requirements per the client are that the device must be lightweight, around 4 lbs or less with handles for portability. It should accommodate users from 5 to 6 feet tall while being easily adjustable and support up to 180 kg. Lasting approximately two years, it will remain stable and stationary during use, helping avoid one-legged squats. It can also be easily sterilized while costing less than \$500.

### ***III. Preliminary Designs***

#### **Design 1: Screw It**

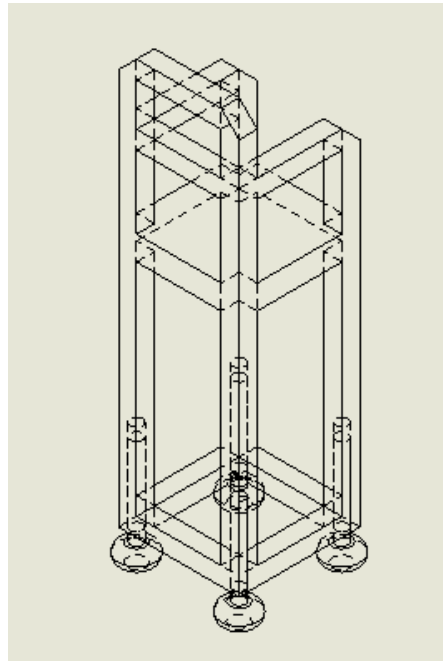


Figure 1: Isometric View of Screw It Knee Crutch Design

The design consists of 5 major parts, a main body composed of 1.2in x 1.2in aluminum bars with a 8in x 8in x 1.5in plate in the center for resting the knee, a cushion will be added on top of this plate for added patient comfort. The main structure is 4 columns of aluminum which connect together with a square set of bars at the top and bottom respectively the top portion of connectors has an open face to allow the knee and thigh to freely be placed within the design. There is a handle built into the design on the front of the main structure for the patient to grab and maneuver while in use. On the bottom of the structure there are 4 drilled holes of 0.8in diameter and 6in depth to make room for the 4 legs which comprise the rest of the parts. The legs are 8in tall with a rubberized foot structure for added grip. The feet and the holes are threaded to allow the whole design to be adjusted in height for up to about 5in of extra height from fully extending the legs.

## Design 2: Light Step

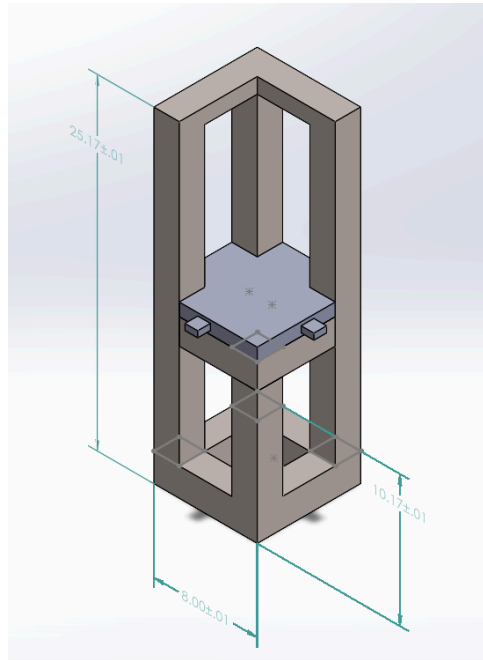


Figure 2: Isometric View of the Light Step Knee Crutch Design

This design consists of 2in x 2in aluminum bars that form a 9in x 9in horizontal square. From four vertices of the base square extends vertical 2in x 2in aluminum bars. The bars extend 23in from the floor and terminate with two connecting horizontal bars that provide structural support and function as handles for ease of movement. Foam casings will be added to these bars for comfort. A permanent 9in x 9in plate is placed 10.5in from the ground to act as a starting point for the adjustable height component of the product. A cushion is attached to the top of the plate, and during use, the knee is placed on top of the cushion. To adjust the height of the plate and its cushion, additional 9in x 9in x 1in plates may be added on top of the permanent plate. The plates include small tabs for ease of removal. A belt will also be added around the cushion and removable plates to ensure no lateral movement occurs during use.

### Design 3: Bolt Step

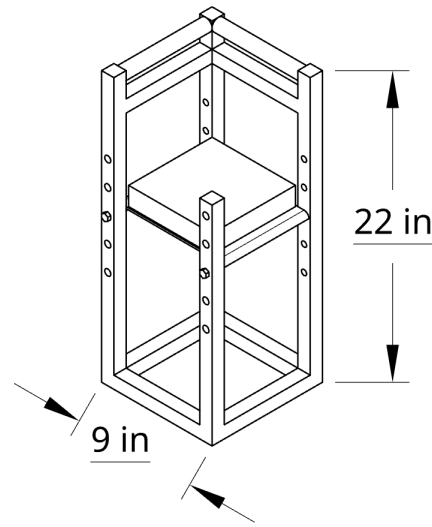


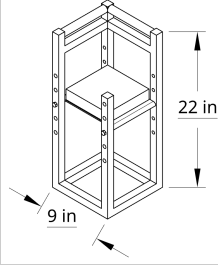
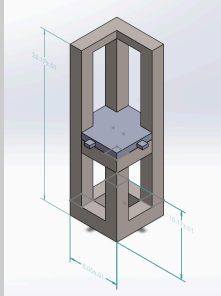
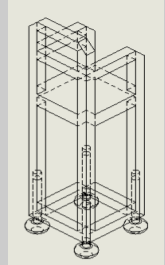
Figure 3: Isometric view of the Bolt Step Knee Pad Design

The base of the design consists of four 1 in x 1 in aluminum bars that form a 9 in x 9 in horizontal square. From each vertex of the base square extends a vertical 1 in x 1 in aluminum bars, one of which is shorter than the others. The longer bars extend 22 inches from the floor and terminate with four connecting horizontal bars that provide structural support and function as handles for ease of movement. In each of the four vertical bars, there are five  $\frac{1}{2}$  in diameter horizontal holes spaced two inches apart, starting eight inches from the floor. The direction of the holes is such that each hole can be matched with another hole on another vertical bar. In each pair of holes, one is tapped. Two 9 in long bolts are inserted through one hole and screwed into its pair. These bolts occupy holes of the same height, and an aluminum plate is placed across the bolts. The plate is bent at two ends to better grip the bolts and avoid sliding off. A cushion is attached to the top of the plate, and during use, the knee is placed on top of the cushion. To adjust the height of the plate and its cushion, the bolts are moved to a different set of holes at a different height.

#### IV. Preliminary Design Evaluation

##### A. Design Matrix

**Table I: Knee Crutch Design Matrix**

| Design Criteria     | Weight     | Bolt Step                                                                         |    | Light Step                                                                         |    | Screw it                                                                            |  |
|---------------------|------------|-----------------------------------------------------------------------------------|----|------------------------------------------------------------------------------------|----|-------------------------------------------------------------------------------------|--|
|                     |            |  |    |  |    |  |  |
| Weight              | 20         | 5/5                                                                               | 20 | 4/5                                                                                | 16 | 4/5                                                                                 |  |
| Adjustability       | 20         | 4/5                                                                               | 16 | 4/5                                                                                | 16 | 5/5                                                                                 |  |
| Sterility           | 20         | 4/5                                                                               | 16 | 5/5                                                                                | 20 | 5/5                                                                                 |  |
| Ease of Use         | 20         | 4/5                                                                               | 16 | 4/5                                                                                | 16 | 3/5                                                                                 |  |
| Comfort             | 10         | 3/5                                                                               | 6  | 5/5                                                                                | 10 | 5/5                                                                                 |  |
| Ease of Fabrication | 10         | 3/5                                                                               | 6  | 5/5                                                                                | 10 | 2/5                                                                                 |  |
| <b>Total Score</b>  | <b>100</b> | <b>80/100</b>                                                                     |    | <b>88/100</b>                                                                      |    | <b>82/100</b>                                                                       |  |

##### Evaluation Criteria:

*Weight (20%):* The final design must be light and easy to lift and transport weighing approximately 4 lb or less while maintaining enough stability and strength to safely support users up to 180 kg. Using aluminum metal in the design will be the most reliable for durability but also lightweight. The design has four legs to evenly distribute the weight to prevent tipping and allow users to easily move the device while navigating stairs.

*Adjustability (20%):* The final design will have a simple adjustment mechanism that accommodates users ranging from 5'0"–6'0". The design chosen has approximately three height

settings along with two tabs on the edge of the square plates to allow for easy access to remove and adjust the height.

*Sterility (20%):* The final design must be suitable for use in hospital and rehabilitation settings and allow for easy cleaning between users. The entire frame and handlebar will be constructed from aluminum, providing smooth surfaces that can be easily wiped and sanitized. The knee cushion will be covered with a leather-like material that is also resistant to moisture and can be wiped down between uses. The design will minimize areas where dirt, moisture, or contaminants can accumulate, allowing the device to be cleaned efficiently and reused between patients.

*Ease of Use (20%):* The final design must be user friendly and intuitive for individuals with limited lower-limb mobility and varying levels of strength and balance. This criterion considers the number and complexity of steps required to use the device, the number of moving or removable components, and how easily the device can be adapted to different users. The proposed Knee Crutch is designed to require minimal user interaction once properly adjusted. The user will place their knee onto the padded support, use the handlebar for stability, and advance the device while navigating stairs. The aluminum handlebar will be oriented to accommodate both left- and right-limb injuries, eliminating the need for separate left- and right-sided designs. The removable plates will include tabs to allow for quick removal and adjustment without requiring complex tools or procedures. Additionally, rubber on the bottom of the device will provide increased traction and reduce the likelihood of slipping during use. The lightweight aluminum construction is also intended to make the device easier to move between stairs compared to the client's current heavier design. Overall, the design minimizes the number of steps and adjustments required from the user while incorporating features that improve stability, adaptability, and ease of handling.

*Comfort (10%):* The final design must have the patient's knee comfortably fit into the cushion and provide support so the patient does not have to put additional strain on the lower back. The criteria for comfort is assessed by how secure the patient's knee is on the cushion. Additionally, comfort is determined based on how easily the plate with the knee cushion may be adjusted and removed based on users needs. The handles for the knee crutch are also a factor for comfort. The criteria for comfort on the handles is determined based on how much strain is put on the palm and wrists. Also the cushion material used on the handle is determined by how much force the handles will have acted on them, therefore analyzing the comfortability of the handles.

*Ease of Fabrication (10%):* The ease of fabrication is an essential factor when determining the most effective final design. The criteria is determined by resources available, as well as availability of materials. The client has provided a charitable budget for this project therefore finances are not a significant constraint for fabrication.

### *B. Proposed Final Design*

After evaluation through the design matrix and the criteria outlined in the Product Design Specification (PDS), the final design for the Knee Crutch is an aluminum stair-mobility device intended to help non-weight-bearing patients safely navigate stairs during recovery. The aluminum frame and handlebar were selected to reduce the overall weight of the device while maintaining the stability needed to support users. The design incorporates a padded, concave knee support with lateral support to help keep the injured limb secure without placing unnecessary pressure on the affected area. Adjustable components allow the device to accommodate different user heights and limb positions, while rubber gripping material on the bottom helps reduce slipping during use. The handlebar also allows the user or caregiver to lift and reposition the device when moving between stairs. The design accommodates both left- and right-limb injuries and incorporates wipeable surfaces to support cleaning in hospital and rehabilitation environments. The final design aims to provide a lighter, more adjustable, and purpose-built alternative to the plastic garden bench currently used by the client. The device will be evaluated against the established design requirements, including a minimum load capacity of 180 kg, a budget of \$500 or less, and a minimum service life of one year, to assess its safety, durability, and practicality for stair mobility.

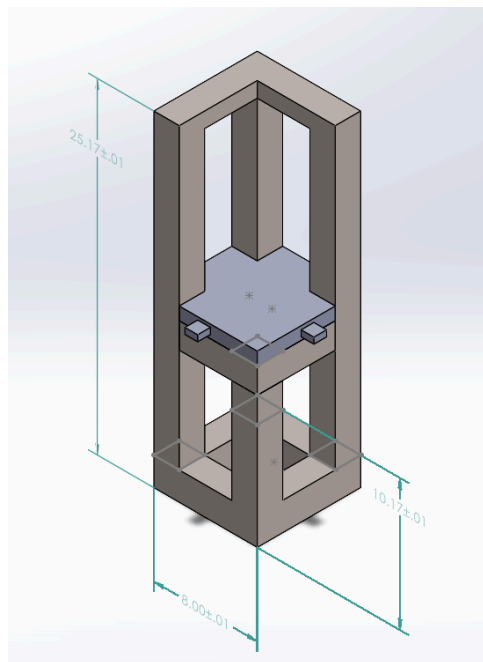


Figure [4]: Final Preliminary Design Drawing: Light Step

## ***V. Fabrication***

### ***A. Materials***

The entire device must weigh less than 4 pounds, and withstand patients upwards of 180 kg. For the frame, aluminum bars featuring aluminum will be used, for a light weight and an adjustable frame. The base will also be made of aluminum, however to ensure no traction a rubber plate will be used. Additionally, the handles for this device will be made of aluminum bars, with foam casting on each handle to increase the comfortability of the bars. The permanent knee plates will be made out of PLA, as well as the adjustable pieces will be made of PLA of different thicknesses. PLA is a lightweight and durable material which will fulfill the weight constraints of this device. A cushion will be placed on top of the final plate, to increase comfortability when the user's knee is placed. Finally, a belt will be added around the cushion, as well as, the PLA adjustable field for minimal lateral movement when device is used.

### ***B. Methods***

Fabrication will begin with assembling the aluminum frame. The structural support bars will be cut to specific lengths to meet the required height specifications and provide adequate support. Next, SolidWorks will be used to design the PLA knee plates and determine the thickness of the additional stackable components. These components will then be fabricated using 3D printing. Rubber gripping material will be purchased and attached to the bottom of the aluminum frame to improve traction and reduce the risk of slipping. The aluminum handles will then be fabricated and secured to the frame. Finally, foam padding will be added to the knee support and secured in place to improve user comfort and help protect the affected limb during use.

### ***C. Final Prototype***

There is no final prototype at this time.

## ***VI. Testing and Results***

The fabricated product must fulfill certain testable criteria in order to be considered a functional product. These criteria include strength, stability, accessibility, and ease of use, and are defined within their respective tests below. Some tests will be used to help dictate areas of

future work based on participant and client feedback. As of now, none of the following tests have been completed, so there are no results.

### **Strength Testing**

The strength of the design is defined as the amount of downward force that can be applied to the knee pad before material failure. The strength of the design is important because the user will be placing the entirety of their body weight upon the knee pad while climbing stairs, and a material failure due to this stress could result in injury or death. To evaluate the strength of the design, weight will be added to the knee pad until material failure or until the target weight of 180 kg is reached. This process will be repeated three times for each height accessible to the knee pad.

### **Stability Testing**

The stability of the design is defined as the ability of the product to resist wobbling, or sliding during use. The stability of the design is important because the user will be relying upon the device to assist in maintaining balance, and thus the device cannot experience any unexpected movement during use. The ability to resist wobbling will be evaluated by placing the device on a clean, flat surface devoid of debris, and pressure will be applied to the top of each vertical pole. Angular displacement will be measured using a digital level, with a target displacement of  $<1^\circ$ . The ability to resist sliding will be evaluated by measuring the coefficient of static friction between the floor and the base of the device. Several floor types, including carpet, hardwood, and tile will be tested.

### **Accessibility and Ease of Use Testing**

The accessibility of the device is defined as the ability of the device to maintain functionality when used by individuals of varying heights and leg lengths. The ease of use of the device is defined as how easy and understandable the process of adjusting the knee pad's height is. To evaluate these criteria, participants of varying heights will be given a brief explanation of the device, how it works, and how to adjust it. They will then attempt to adjust the device to their liking and use it on their own to ascend and descend several stairs. Afterwards, they will fill out a short questionnaire to provide their judgements and feedback regarding the device's ability to accommodate their height, and the difficulty of the adjustments.

## ***VII. Discussion***

### ***A. Analysis***

While other current assistive walking devices are available on the market they place too much of an emphasis on long term/full time usage for the purposes of the design. Many of these walking devices like the iWalk and Freedom Leg, when operated by users with sufficiently capable balance can be used to navigate stairs, they are not usable by others who need additional assistance with balancing or the strength needed to pull the devices up stairs. The team's design works to place the focus of the device solely on the ascending and descending of stairs and providing ample balance support to allow patients the assistance needed to utilize stairs with greater confidence. To achieve this the team has placed a large emphasis on keeping the design light, stable, and adjustable. The light step design fulfills this goal best by having cheap, reusable plates to change the height of the device without complicated mechanisms that can fail. By having plates to alter the knee height it can be made sure that every patient who uses the device will be able to use it as both a stabilizer on the stairs, and leverage to bring their functional leg upwards the next step.

### ***B. Ethics***

Some considerations to keep in mind with the further development of the project is to protect the dignity and independence of the user of the device. Before the project was created a makeshift device constructed with garden equipment was recommended for the patients, while this may have worked for some, a large part of assistive technology is making the patient feel empowered by being able to complete previously difficult tasks without any additional help. By having a makeshift device this may leave patients feeling less secure in their own situation due to there being no specific product to help them, which can amplify feelings of otherness. Another ethical consideration is the usage of this as a medical aid in injury prevention. This device is used in a situation where improper balance and other potential mishaps can lead to patient injury from falling. To ethically create a device for this purpose, it must take extra care to keep it as stable as possible to promote patient safety, instead of allowing other avenues of patient injury.

## ***VIII. Conclusions***

Non-weight-bearing patients can experience significant difficulty navigating stairs during recovery, particularly when traditional mobility aids require substantial strength, balance, and coordination. Existing hands-free mobility devices can reduce some of these demands, but they are not specifically designed to provide the stability, adjustability, and ease of repositioning

needed for short-term stair navigation. The Knee Crutch design aims to address this gap by providing a lightweight and stable device specifically intended to assist non-weight-bearing patients when transitioning from rehabilitation facilities to their homes.

The proposed design uses an aluminum frame to reduce weight while maintaining the strength needed to support users up to 180 kg. The device incorporates an adjustable knee support, padded cushion, rubberized base, and handlebar to provide stability, comfort, traction, and easier repositioning between stairs. The adjustable components are intended to accommodate users approximately 5'0"–6'0", while the removable plates allow the knee height to be changed without requiring a complex adjustment mechanism. The design also considers use in healthcare environments by incorporating materials and surfaces that can be wiped and sanitized between users.

Future testing will determine whether the Knee Crutch meets the required strength, stability, accessibility, and ease-of-use criteria. Strength testing will evaluate whether the knee support can withstand the target 180 kg load at different height settings, while stability testing will measure angular displacement and resistance to sliding on different floor surfaces. Accessibility and ease-of-use testing will evaluate how effectively users of different heights can adjust and operate the device while navigating stairs. Results from these tests, along with client and participant feedback, will guide further modifications to improve the device's safety, comfort, and functionality. These efforts will help determine whether the final Knee Crutch can provide a practical and reliable stair-navigation solution for non-weight-bearing patients.

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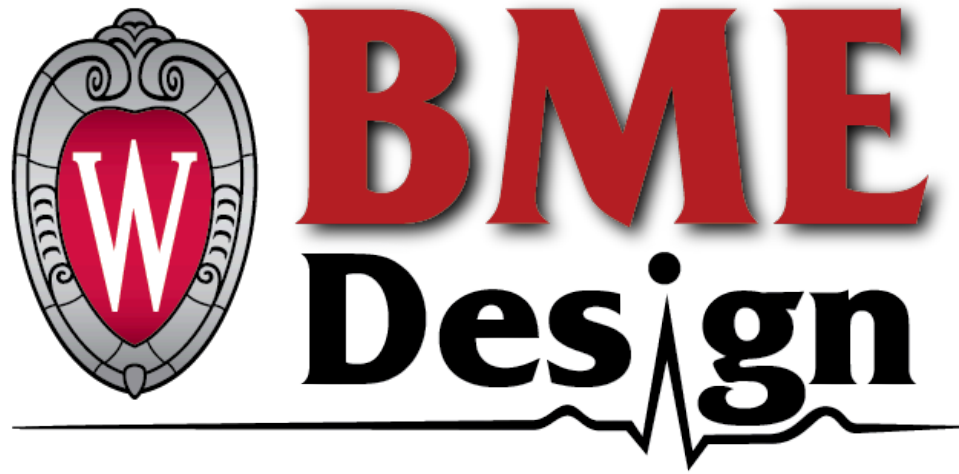
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***Appendices:***

***Appendix I: Product Design Specification***



**Knee Crutch**

***Product Design Specifications***

**BME 200/300**

September 11, 2026

Client: Daniel Kutschera

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**Function:** Individuals recovering from below-the-knee injuries may rely on crutches or canes to navigate stairs, but these aids are not always practical or safe. While stair lifts and stair chairs offer alternatives for wheelchair users, they are often unreasonable for individuals recovering from short-term injuries. Many existing mobility devices are designed for level surfaces and may lack the height, stability, or ease of repositioning needed when one leg must remain elevated [1].

The proposed Knee Crutch addresses these limitations by providing a lightweight, stable support specifically designed for stair navigation. Its mechanically tested, adjustable frame will accommodate different user heights, while a handle will allow easy repositioning between stairs. A padded knee support will also provide comfort without placing unnecessary pressure on the injured area.

### Client requirements

- **Frame:** Height-adjustable and made from a lightweight, durable material; should be stable during use.
- **Height:** Accommodate users approximately 5'0"–6'0", with 3 adjustable positions and a target range of 9–14 in.
- **Foot:** Include a non-slip material for stability on stairs; device length should be  $\leq 9.5$  in. to prevent tipping on stairs.
- **Knee Rest:** Should be padded, and provide lateral knee support without interfering with the injured area. Padding should be securely fastened and replaceable.
- **Weight:** Target approximately 4 lb and lighter than the current prototype without compromising stability.
- **Portability:** Include a handle or alternative mechanism that allows the user to easily move the device up stairs.
- **Weight Capacity:** Safely supports users up to 400 lb.
- **Adjustability:** Height adjustments should be quick and simple without requiring stacked components or cumbersome screw adjustments.
- **Stair Use:** Allow the user to lead with the injured leg and device when navigating stairs in their homes.
- **Mechanical Safety:** Mechanically stress test the device to verify it can withstand expected loads.
- **Sterilization:** Materials should be compatible with hospital cleaning/sterilization, including wipeable or replaceable knee padding.
- **Service Life:** Designed to last approximately 2 years, with replaceable knee padding as needed.
- **Budget:** Target cost of \$500 or less.

Design requirements:

## 1. Physical and Operational Characteristics

- a. *Performance requirements:* The knee crutch should allow non-weight-bearing users to quickly and easily ascend and descend stairs while requiring minimal strength and balance. The device should be easily adjustable for users ranging from 5'0"–6'0" and should have approximately three simple adjustment positions. It should be stable during stair use, lighter than the current prototype, and durable enough for repeated use. The device should also be easy to clean and sanitize between uses.
- b. *Safety:* The device should maintain stability and withstand expected forces without mechanical failure or tipping. It should safely support users weighing at least 450 lb, with the weight capacity clearly indicated. The base should provide sufficient traction on stairs and uneven surfaces, and the overall design should minimize the risk of tipping during stair navigation and transfers to a wheelchair.
- c. *Accuracy and Reliability:* The device should provide consistent support and stability during repeated ascents and descents of stairs. Height adjustments should produce consistent device dimensions and positioning for different users. The device should reliably support users up to 400 lb without excessive movement, slipping, or mechanical failure.
- d. *Life in Service:* The device should continue to work and provide assistance for a minimum of one year.
- e. *Shelf Life:* The device should withstand storage in typical indoor environments without compromising its functionality, structural integrity, or materials. Typical storage conditions include temperatures of 15–30°C and relative humidity of 30–80% [2].
- f. *Operating Environment:* The device should be suitable for indoor use by non-weight-bearing individuals with lower-limb injuries. The base should maintain traction on surfaces such as tile, concrete, carpet, wood, and uneven terrain. The device should also be capable of being cleaned or sanitized between users in a healthcare setting.
- g. *Ergonomics:* The device should accommodate users from 5'0"–6'0" through a simple height-adjustment mechanism. The knee rest should be concave and padded to provide lateral support and comfort without interfering with the user's

injured area. The padding should remain securely attached during use. The base should provide adequate cushioning and traction to improve stability and comfort.

- h. *Size:* The device should accommodate users ranging from 5'0"–6'0" while remaining compact enough for stair use. The overall device length should not exceed approximately 9.5 in., based on the average stair tread depth, to reduce the risk of tipping. The design should also be compact enough to allow easy transfer between the stairs and a wheelchair.
- i. *Weight:* The device should weigh no more than approximately 4 lb and should be lighter than the current prototype without compromising stability. Weight should be distributed to minimize tipping during stair use and allow users to easily lift and reposition the device when moving between stairs and a wheelchair.
- j. *Materials:* This product must be light weight and strong to support users over 250 lbs. Aluminum will be used throughout the crutch, especially for the legs to adjust height and be light weight for older users to easily lift the crutch when using stairs. For stability and a on-stick feel, rubber crutch bottoms will be used to rubber crutch bottoms will be used to ensure safety and stability for users when using the crutch on wood and uneven surfaces.
- k. *Aesthetics, Appearance, and Finish:* The device should be simple and utilitarian, the finish should lack any sharp edges which could be cause for harm. The total appearance should mimic that of a lower leg, with a region for the patient to brace against, and a separate region for the patient to maneuver the device.

## **2. Production Characteristics**

- a. *Quantity:* One single device will be created for this semester. This product is meant to be scalable, however only one working prototype is required for the purpose of this class.
- b. *Target Product Cost:* This product is meant to be affordable for users. Competing designs like the iWalk [1] are priced at \$179.00. This product aims for a higher price point, with a \$500 budget. Once the product is fabricated and ready for the market it will be lower in price around \$100 to ensure patients are able to afford getting up and down stairs safely, whereas the iWalk is used for multiple activities a day which reflects its design.

## **3. Miscellaneous**

- a. *Standards and Specifications:*
  - i. Must meet ISO 22523:2006 [3].
  - ii. Must meet the testing standards outlined in ASTM F3580-24 [4].
  - iii. Must meet ISO 22523:2006, 2006. [7]
  - iii. Must meet ASTM F3580-24 [8]
  - iiii. Must meet ISO 11334-1 [9]
- b. *Customer:* The Knee Crutch is intended for non-weight-bearing individuals with lower-limb injuries who need to safely navigate a small set of stairs, particularly when transitioning from a rehabilitation facility to home. It is designed for users who may have difficulty using traditional crutches due to limited strength, balance, or stability. The device should accommodate users approximately 5'0"–6'0" and allow them to safely ascend and descend stairs before transitioning to other mobility aids.
- c. *Patient-related concerns:* The device must be able to be steady while in use, the weight must be lower to facilitate maneuvering by patients. The device must be structurally sound enough to hold the weight of the patient while kneeling on the device.
- d. *Competition:* There are other currently functioning products on the market but all don't quite meet all of our requirements, the JOMCYDM Walking Aid Knee Crutch, the iWalk Hands-Free Crutches, and Freedom Leg are similar to our design needs but fail to meet our expectations due to high costs, a strap in system that is too cumbersome to take on and off, and more generalized designs which leave space for a better, more specialized device.
  - i. JOMCYDM Walking Aid Knee Crutch [5]
  - ii. iWalk Hands-Free Crutches [1]
  - iii. Freedom Leg [6]

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