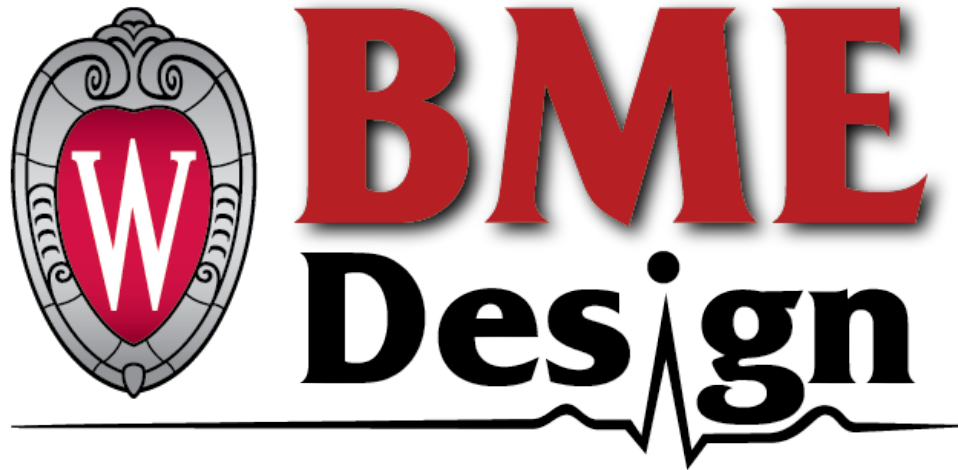




Knee Crutch

Product Design Specifications

BME 200/300

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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 and rough terrain; device length should be ≤ 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.
- **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 and outdoor 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 [1] are priced at \$179.00. This product aims for a higher price point, with a \$500 budget.

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].

- 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]

References:

- [1] iWALKFree, "Clinical Research," iWALKFree. Accessed Sep. 11, 2026. [Online]. <https://iwalk-free.com/clinical-research/>
- [2] Y. Zhao *et al.*, "Prediction of daily home indoor temperature and relative humidity using a deep ensemble machine learning approach," *Build. Environ.*, vol. 295, p. 114392, May 2026, doi: 10.1016/j.buildenv.2026.114392.
- [3] P. Technical Committee ISO/TC 168 and orthotics, "ISO 22523:2006." [Online]. Available: <https://www.iso.org/obp/ui/#iso:std:iso:22523:ed-1:v1:en>.
- [4] ASTM Standards "Standard Test Method for Exoskeleton Use: Stairs." Book of Standards Volume: 15.13. Developed by Subcommittee: F48.03. Accessed Sep. 16, 2026 [Online]. <https://compass.astm.org/content-access?contentCode=ASTM%7CF3580-24%7Cen-U>

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[5] “JOMCYDM Walking Aid Knee Crutch, Walking Assistive Device Knee Crutch with Grippy Feet, Height Adjustable Knee Crutch Walking Aid, Applicable Person Height 4.92-6.23ft Health Beauty Health Care Mobility Accessibility Aids Crutches,” accessed Sept. 15, 2026.

Alumigogo.com, 2026.

[6] “Hands Free Crutch - Crutch Alternative - Freedom Leg.” Freedom Leg Brace, 16 Sep. 2026, <https://www.freedomleg.com/>.