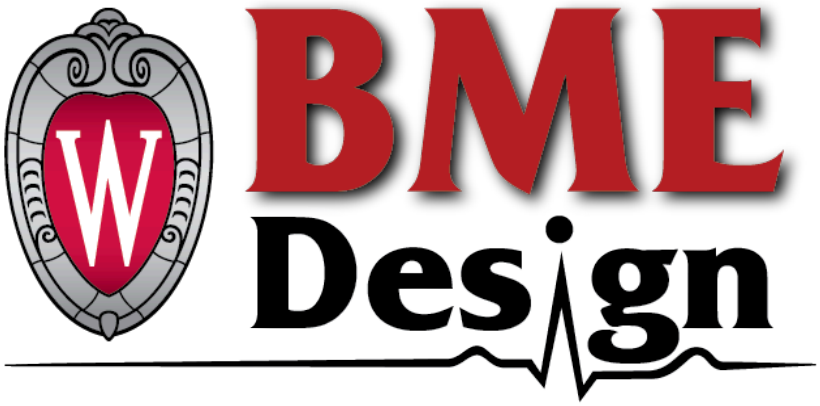

Low-Interference Wheelchair Footrest

Product Design Specification

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BME 200/300 Lab 301 Design Project

Team Name: Footrest Fanatics

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Project Function

Currently on the market, there are no known wheelchairs that allow for users who have remaining function in their legs to maintain use of their feet in everyday life. Use of the feet may include opening doors, putting their feet on the ground for better mobility overall, and picking up objects from the ground. Current footrest models are static in their position and do not allow for modification in position, as well as heavy and are not easily removed for storage. While wheelchair footrests are essential in supporting the user's legs and feet when reclined or tilted, it is vital to design the footrests to be able to allow for greater mobility of the feet should the user need it. The revised footrest should be adaptable to the user's abilities and lifestyle, be easily removable, and have reduced weight while still remaining functional as a traditional footrest when in the original position.

Client requirements

- Has the ability to be removed for translation to another wheelchair or be stored
- Provide the function of a traditional wheelchair footrest
- Total weight of less than 5 pounds
- Has the ability to move with the rest of the wheelchair during reclining

Design requirements

1. **Physical and Operational Characteristics**
    a. **Performance requirements**

        The wheelchair footrest will have a lifespan of 3 to 5 years, equal to the lifespan of the average wheelchair base [1]. The client must be able to retract and extend the footrest a minimum of 3 to 4 times per day, for everyday that the wheelchair is in use. The product must not have a total weight exceeding 5 pounds. The footrest should be able to retract to the extent where the client may reach an area of 0.762 m x 0.305 m around the wheelchair with no restricted movement.

    b. **Safety**

        The footrest extension should not take up much room in order to prevent the inability of the user to exit through doorways of an area safely and efficiently. The footrest should easily swing to the right of the wheelchair for the user's ease of movement from wheelchair to car, bed, chair, etc. All wiring of the extension should be safely stowed to prevent injury to the user as well as damage to the product from climate effects. If the footrest requires a battery proper labeling must be applied to make it known the mechanism is battery powered.[2] Material used in the footpads should be anti-slip to mitigate risk of a fall, in addition to this the material needs to be sturdy enough to withstand the load applied by the user's legs while avoiding materials that can be sharp or cause pinching.[3]

c. **Accuracy and Reliability**

The footrest needs to be able to attach to the user's wheelchair for as long as the wheelchair itself lasts. Speed of the footrest from "in use" to "stowed" must be accurate and efficiently timed. If battery powered - battery must be able to last the entirety of the day before needing a charge. The footrest must be able to withstand the weight of the user's legs without breaking or degradation to the mechanism.

d. **Life in Service**

The footrest will be used both indoors and outdoors, therefore the mechanism will need to be weatherproof with an emphasis on water resistance due to wiring in the motor. Throughout the product's life span it will need to be unharmed in the removal process from the wheelchair. The footrest is also required to be easily condensable for most efficient transportation and last the entirety of the wheelchair's lifespan (3-5 years)[1]

e. **Shelf Life**

Storage climate conditions are not harmful to the product. The footrest should be able to be stowed or folded for long periods of time without wear or degradation to the materials of the footrest or the mechanism and electrical system. Batteries will need to be stored in a safe, dry, and neutral temperature environment. All attachments, brackets, braces, or hinges must be able to withstand constant motion throughout the day without losing stability over time.

f. **Operating Environment**

The footrest will be exposed to both indoor and outdoor environments. The footrest must be able to withstand all weather conditions and range of temperatures in the Midwest including, water, ice, snow, rock, mud, uneven ground, cold and hot conditions and wide humidity ranges. The footrest must have proper clearance in order to account for these things and consideration of all safety and environmental concerns while deciding the materials that will be used in the project. While the footrest is being stored it must also be able to withstand less frequent use in areas where problems may arise, such as; hinges, braces, or brackets.

g. **Ergonomics**

The ergonomics of wheelchair footrests are incredibly important to consider, as most people bound to wheelchairs will spend a great deal of time utilizing them every day. There are four main components to the overall ergonomics of the footrest. Firstly, it must be safe for all users, meaning that it should not be able to pinch, cut, or hurt the user in any other way. Secondly, it needs to be the proper height both above the ground and below the seat level of the wheelchair. There is no universal height for footrests, so it is best to make them to customer specifications. The only requirement is that they maintain proper ground clearance, or about 0.05 meters [4]. The third is that it can withstand the

full weight of the human legs for extended periods of time, or about 33% of your body weight. This means that they should be able to withstand (on average) 250 N of force. The fourth is that the footrest is comfortable, meaning that it should be longer than the average human foot (0.269 meters) and should have a good deal of traction [5].

h. **Size**

The footrest should be large enough to fully support the average human foot length (0.269 meters) and should be at least as wide as the average human's hip width (98.70 cm) so that their feet may sit comfortably straight out in front of their body [6]. The footrest should also be able to easily fit through door frames, the standard width of which is about 91.44 cm in the U.S. [7]. In order to decrease the size of the wheelchair footrest during storage, it would be beneficial to make the individual parts hinged or be able to collapse in on themselves. Preferably, the overall dimensions of the collapsed attachment should be no more than 35.56 cm x 45.72 cm [8], which is the average size of a drawstring bag. If the device was needed to be larger, it could be made to be smaller than 48.26 cm x 33.02 cm x 17.78 cm [9], which is a standard size for a backpack. By these standards being met, the footrest would be quite easy to store and transport.

i. **Weight**

The client will need to be able to lift, store, and reattach the footrest with minimal exertion, thus the design must be lightweight while also maintaining structural integrity. Standard wheelchair footrests with various compositions range in weight from 3-10 pounds. The aim for this product is to reduce the amount of work required for removal and installation of the footrest, thus the team aims to have the design weigh in on the lower end of this range, with 3-5 pounds being the target.

j. **Materials**

The client has specified that they have no particular allergies to materials that may be used in the footrest. As the footrest will be subjected to all sorts of weather conditions and terrain, it would be best to use a material that is not capable of rusting and is easy to clean. All mechanization (motors, winch systems, hinges, locks, cables, rail systems, etc.) should be able to withstand these conditions. As there is a weight requirement given by the client of 5 pounds, the structure would preferably be made out of a lightweight material that is also sturdy enough to withstand the 250 N or force required. Aluminum is an appealing material choice due to its low price and low weight, paired with decent strength and durability. Steel is a more sturdy, albeit more expensive and heavy choice of material for the structure. A combination of the two in the overall design depending on parts should be researched. The other main material will be utilized on the footrests, which will likely be a rubber or resin material for its higher degree of friction and comfort for the operator's feet.

k. **Aesthetics, Appearance, and Finish**

Due to our product's design being specialized for our client, any cosmetic/aesthetic choices are made to his preferences. When asked about cosmetics during our meeting, the client stated that he has no preferences as long as the design is reasonable and that he encourages us to be creative with the aesthetics of the products. This leaves a high degree of freedom for our design in regard to aesthetics. Since there are no preferences from the client, the aesthetics of the footrest will probably be simple and emphasize durability over eye-catching designs. Due to the wheelchair being subjected to outdoor conditions and contact with different materials, the finish of any metal parts should offer rust resistance, and parts that may make contact with the client or surroundings should have textures and finishes that are relatively resistant to abrasion, yet not uncomfortable to make contact with.

2. **Production Characteristics**
    a. **Quantity**

The client has not expressed a desire to create multiple units of the footrest but has mentioned that he has several backup wheelchairs. If he is satisfied with the completed design it is reasonable to assume that a few more units could be made for his backup wheelchairs. The client is open to the possibility of mass production but stressed that the product is mainly meant for his own personal needs and use.

    b. **Target Product Cost**

While there are few other detachable footrests for wheelchairs that are sold separately, the ones that are usually range from $35 to $60 dollars. Most of those are not automatic and require work on the part of the operator to move them. In the event that an automatic footrest is designed, it is likely to cost a deal more than the manual ones, likely in the range of $80 - $120. As the prototype will likely cost more than any units of the final product that might be mass produced, it is expected to cost not more than $200 dollars to produce.

3. **Miscellaneous**
    a. **Standards and Specifications**

ISO 7176: This standard outlines the specifications in which wheelchairs are tested and the requirements they must meet. Parts 1 [10] and 2 [11] outline the requirements for static and dynamic movement of the wheelchair as a whole. The product must not obstruct the movement of the wheelchair in any way in order to meet this. Part 14 [12] outlines the testing standards to all electrical systems that are a part of the wheelchair. If battery powered or rechargeable, the product must be tested in accordance with this section.

CFR890.3920: The FDA classification of a wheelchair is a class I medical device. This regulation is in reference to wheelchair accessories that have the intention to meet the specific needs of the user. Because the product is not intended for use as a protective

restraint, it is exempt from the premarket notification procedures [13], as well as the good manufacturing practice requirements, subject to limitations.

If the product has the intention for mass manufacturing, it will be important to keep billing and insurance standards in mind, such as Medicare Insurance [14]. The footrest needs to be up to date on electric wheelchair regulations in the state of Wisconsin.

b. **Customer**

During our initial meeting, the client mentioned several preferences for the design of his footrest. Notably, he stated that he prefers designs that feature two separate footrests, one for each leg, as opposed to a single piece. However, he is still open to any design as long as it meets his needs. The client has expressed interest in designs that are less bulky, referring to previous designs. He also said that in the case we design a single-piece design, he would prefer it to swing to the right when stored. The client has mentioned that he disliked how loud the previous design was, so any motorized designs should be evaluated for noise. Additionally, the client informed the group that he likes unique designs that "think outside the box" and innovate, since many footrests on the market are similar.

c. **Patient-related concerns**

This device is designed specifically for the needs and abilities of our client, but it is possible that others can benefit from it as well. If we intend to mass produce this device, our design should take into account a patient's degree of mobility in their lower extremities and how well they can use their arms to operate the functions of the device. The device should offer some adjustability to fit the patient's feet under different circumstances. The device should also be removable and storable while being able to fit wheelchairs of different sizes and models than our client's for it to be available to patients.

d. **Competition**

Most commercial wheelchairs have footrests custom to the brand and model of wheelchair, however there are models of removable and modular footrests. The model from Fold-&-Go [15] highlights a foldable design, but only works with certain models of wheelchair, and is priced at $129.99. The standard footrests that are not retractable have an average price of around $50 [16]. Comprehensive research into foldable wheelchairs can be found [17], which highlights the folding of the entire wheelchair, making the device unusable while folded. The team's product intends to fold independently from the rest of the wheelchair to maintain usability.

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