

A LIGHTWEIGHT, FOLDABLE MOTORIZED TRANSPORT CHAIR TO EASE CAREGIVER BURDEN

Kimberly Gustafson
University of Minnesota
Minneapolis, MN

William Durfee
University of Minnesota
Minneapolis, MN

Gregory Voss
Minneapolis VA Health Care
System

Andrew Hansen
Minneapolis VA Health Care System
University of Minnesota
Minneapolis, MN

Gary Goldish
Minneapolis VA Health Care System
University of Minnesota
Minneapolis, MN

ABSTRACT

As the population ages, the number of caregivers in the United States is growing rapidly. The burden on these caregivers is exacerbated by steadily increasing obesity rates, which are highest in adults aged 50 to 70. The Caregiver-Assist Transport Chair (CATC) is designed to address the difficulty many caregivers experience assisting in the transportation of moderate to low mobility care recipients outside of the home for appointments, community engagements, or fresh air excursions. It is not uncommon for the caregiver to be elderly or of a smaller build than the care recipient, increasing the difficulty of pushing a transport chair for extended distances or across uneven or unlevel terrain. The CATC is equipped with intelligent motorized wheels that engage in the forward or reverse directions to maintain a consistently low effort required from the caregiver, independent of the weight of the care recipient. The chair assists on uphill terrain and slows on downhill descents to match the walking speed of the caregiver. In addition, the chair has a drop-down footplate mechanism that eliminates the need for the legs of the care recipient to be lifted onto foot pedals once seated. This footplate also serves as a brake to eliminate safety concerns associated with the chair rolling back as the user transitions between sitting and standing. While the CATC contains motorized elements, unlike a typical motorized wheelchair, it is lightweight, foldable, and easy to maneuver in and out of a vehicle.

Keywords: transport chair, caregiver burden, intelligent, propelled, low-cost, foldable, lightweight, age in place

1. INTRODUCTION

In 2020, an estimated 19% of Americans served as a caregiver for an adult care recipient, up more than 17% from estimates made in 2015 [1]. This number continues to grow rapidly as the population ages. A study conducted in 2021 determined that if given the choice, 77% of adults over 50 would prefer to age in place [2]. If achieved, this would effectively shift the burden of care from care facilities to community-based caregivers. The resulting increased burden on caregivers is a significant concern, affecting not only the health of the caregiver but also the quality of care they are able to provide [3].

This burden is compounded by the increasing prevalence of obesity in the United States [4]. In 2013, the U.S. claimed the largest obesity rates in North America, with nearly one third of men and one third of women classified as obese, the highest concentration found in adults between the ages of 50 and 70 [5]. Obesity rates are especially high for low mobility individuals who require a caregiver and transport chair to commute outside the home [6]. It follows that it is not uncommon for a caregiver to be of similar or smaller build than the care recipient.

Oftentimes, the caregiver for an aging individual is someone aging alongside them, leading to an increased likelihood of becoming a caregiver later in life [7]. As strength diminishes with age, it becomes increasingly difficult for the elderly caregiver to maneuver the care recipient to appointments and wellness checkups, compounding health-related issues and decreasing the likelihood they will be able to remain independent and age in place [8].

The increasing number of caregivers, negative correlation between mobility and obesity, and prevalence of elderly caregivers all point to an emerging need to assist caregivers with

care recipient navigation outside the home. While a few products have been developed to achieve this goal, each has drawbacks that limit its ability to assist the caregiver.

The Empulse R20 (Sunrise Medical) and Wheelchair Powerpack (TGA Mobility) are accessory wheels that can be added to most standard transport chairs. The caregiver can engage these wheels for assistance on uphill ascents and long-distance terrains. However, these solutions require technical assembly, add anywhere from 10-15 lbs. to the weight of the transport chair, and retail for \$500-\$2500 on top of the cost of the transport chair, reducing their accessibility to many caregivers. An added drawback is these accessory wheels often inhibit folding and must be removed to collapse the transport chair.

As an alternative to marketing an accessory for an off-the-shelf transport chair, a second strategy is to produce a chair devoted to a motorized caregiver assist feature. The Air Hawk Lightweight Powered Wheelchair, the Ypush, and the Caregiver Operated Ranger (Porto Mobility) are examples of this approach. However, these chairs tend to be expensive and heavy, ranging from \$2000-\$4000 and weighing 40-50 lbs. This significantly limits the number of caregivers able to afford and load them in and out of a vehicle. These chairs also rely on a joystick or thumb lever that requires the caregiver to actively assess how strongly to engage the motorized propulsion with little protection against runaway.

The Caregiver-Assist Transport Chair (CATC) is designed for maximum caregiver assistance without compromising cost, weight, or functionality. It is a foldable, standalone chair devoted to assisting the caregiver with propulsion, but with intelligent control to automatically match the walking speed of the caregiver and assist with braking on downhill descents. The CATC is projected to be more than 10 lbs. lighter and an order of magnitude less expensive than currently available motorized assist chairs. In addition, the CATC employs a novel drop-down footplate mechanism that eliminates the need for the legs of the care recipient to be lifted onto foot pedals once seated.

2. MATERIALS AND METHODS

From reviews of existing products and feedback from therapists, doctors, and other members of the caregiver community, the list of design metrics provided in Table 1 were developed to meet the needs of the caregiver.

TABLE 1: CATC DESIGN DRIVERS

Caregiver Consideration	Design Metric
Low exertion for propulsion	Intelligent drivetrain assist
Easy to load in and out of vehicle	Foldable
Lightweight for transportability	Aluminum tubing
Eliminate need to lift feet	Drop-down footplate
Uncertain insurance coverage	Low-cost

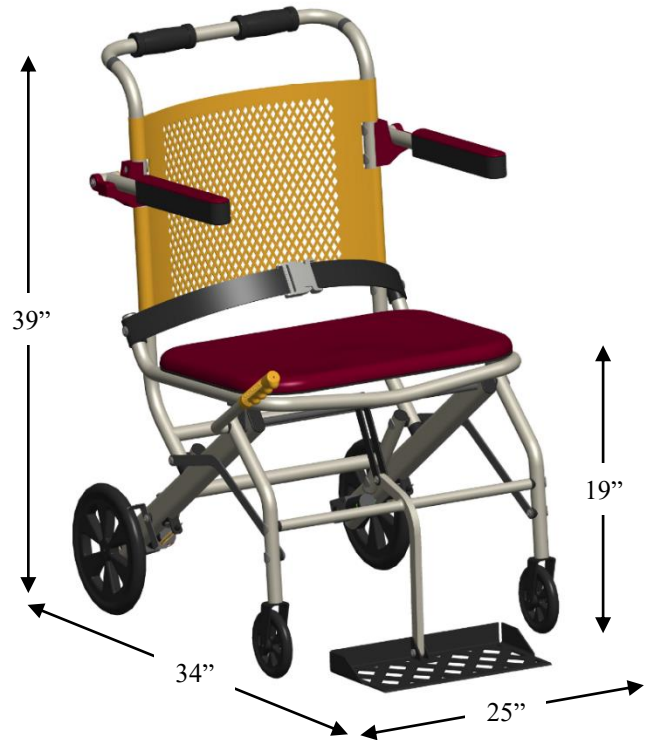


FIGURE 1: CAREGIVER-ASSIST TRANSPORT CHAIR (CATC) WITH DROP-DOWN FOOTPLATE AND INTELLIGENT DRIVETRAIN ASSIST

2.1 Foldability

The CATC folds in a manner similar to a stroller as shown in Figure 2. This results in a more ergonomic pushing handlebar over the two-handle design common for wheelchairs that fold in a scissoring manner.



FIGURE 2: CAREGIVER-ASSIST TRANSPORT CHAIR IN FOLDED CONFIGURATION

This design eliminates the need for the caregiver to lift the chair during folding, as is the case for scissor-folding chairs where the wheels move inwards toward the centerline. This

folding method also allows for a cushioned rigid seat with more support than a fabric sling and lends itself to being tipped into the back seat or trunk of a vehicle.

2.2 Drop-Down Footplate Mechanism

The CATC drop-down footplate eliminates the need for the user or the caregiver to lift the user’s legs onto foot pedals that flip down or swing in from the sides. It has a nonskid coating on the underside to keep the chair from sliding out from under the user as they transition between sitting and standing. The low-profile footplate begins flush with the ground (Fig. 3a), and the user steps onto it prior to sitting in the chair.

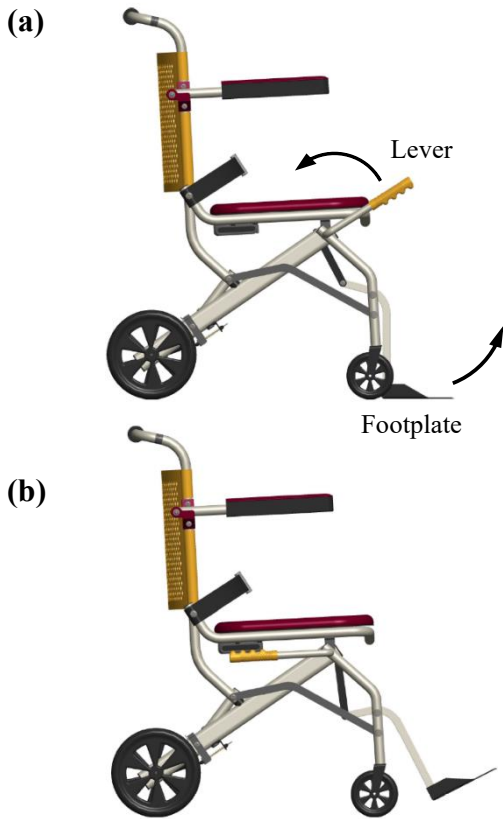


FIGURE 3: LEVER-ACTUATED DROP-DOWN FOOTPLATE MECHANISM SHOWN IN DOWN (a) AND UP (b) POSITIONS

Once seated, a lever located at seat height and accessible to both the user and the caregiver is rotated to lift the footplate off the ground for transport (Fig. 3b). The lever mechanism passes over center to keep the footplate from falling unexpectedly due to jostling from uneven terrain or movement from the user. Once the destination is reached, the lever is rotated to lower the footplate to the ground and the user can stand without fear of forgetting to apply the brakes.

2.3 Intelligent Drivetrain Assist

The primary purpose of the CATC is to assist the caregiver in propelling the chair over uneven ground and reduce the effort required to navigate ascending or descending terrain. The CATC

is outfitted with sensors on the handlebar to detect the force exerted by the caregiver and engage the motors to carry out the intentions of the caregiver (Fig. 4). As the force on the handlebar increases, the motors on the rear wheels engage to reduce the force required by the caregiver back to a baseline value. Similarly, if the chair begins a downhill descent and gains speed such that the caregiver applies a reversing force to the handlebar, the rear wheels assist in braking until the force exerted by the caregiver returns to the same baseline value.

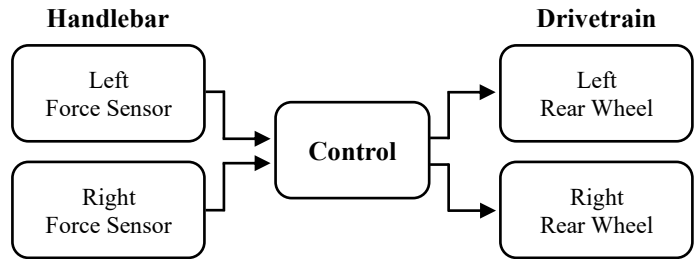


FIGURE 4: CATC CONTROL DIAGRAM

The sensors on each end of the handlebar detect if the caregiver intends to turn and how sharply. For wide turns, both rear wheels assist in the forward direction at different rates, but for sharp turns, the inner wheel assists in reverse, allowing the chair to turn in place. When there is no force on the handle, the motors remain in a locked position to prevent rollaway. However, to conserve battery, there is a mechanical brake that can be applied to disable the powertrain feature for extended stops. The rear wheels are driven by direct drive right angle motors attached at the wheel axle (Fig. 5).



FIGURE 5: DEPICTION OF MOTOR, BATTERY, AND HANDLEBAR FORCE SENSOR PLACEMENT

The control electronics and batteries are located on the underside of the plastic seat, and sensors to read the force input by the caregiver are located in line with the handlebar tubing on the right and left sides. The batteries can easily be removed for charging, and additional batteries can be interchanged for extended travel.

3. DISCUSSION

Constructing the CATC from aluminum tubing with the minimum required components for functionality allows for a weight reduction of more than 10 lbs. compared to other motorized caregiver-controlled transport chairs. This design also keeps the cost low to address the concern that insurance will not cover a chair designed for the caregiver rather than the care recipient. The cost of the CATC is projected to be an order of magnitude lower than currently available motorized transport chairs, costing a few hundred dollars rather than thousands. The intelligent drivetrain eliminates the need to size the motorized components for the weight of the care recipient or the walking speed of the caregiver. The drop-down footplate mechanism is a solution to circumvent the requirement of lifting the care recipient's legs onto foot pedals, which can be difficult for the care recipient and often requires the caregiver to bend down and assist.

The CATC is designed to provide intelligent control to the caregiver. The sensor feedback provided by the handlebar to the rear wheels prevents against sudden takeoffs or decelerations common for chairs with a joystick or thumb lever control, particularly for the case when the chair is unoccupied. The CATC matches the pace of the caregiver and seamlessly assists with turns, ascents, descents, and uneven terrain, reducing the effort required to maneuver the care recipient through the community.

While the CATC has a moderate seat width of 21 inches and weight capacity of 250 lbs, the stroller-like design easily lends itself to offering a wider and more robust model for bariatric users. The powertrain components and assembly procedure would remain the same, with the structural components being interchanged for ones of longer length and higher strength.

Upon completion of fabrication, next steps include implementing and validating the control strategy followed by obtaining performance feedback from therapists, doctors, caregivers, and care recipients.

4. CONCLUSION

The CATC eases the burden on caregivers by intelligently engaging motorized rear wheels to maintain a constant input effort independent of terrain and care recipient size. The minimal design allows the chair to be lightweight and foldable and priced similarly to standard issue transport chairs to maximize the accessibility of the chair to all populations. The novel drop-down footplate mechanism reduces strain on the caregiver and the care recipient and has the potential to prevent injuries caused by rollback falls.

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