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CLINICAL REPORT

Design of the advanced commode-shower chair for spinal cord-injured individuals

Pascal Malassigné, MID, IDSA; Audrey L. Nelson, RN, PhD; Mark W. Cors, BFA; Thomas L. Amerson, PhD
Research Service, Clement J. Zablocki VAMC, Milwaukee, WI 53295-1000; Milwaukee Institute of Art and Design; Nursing Service, James A. Haley VAMC, Tampa, FL 33612; Dept. of Physical Medicine and Rehabilitation, Medical College of Wisconsin, Milwaukee, WI; Gales Ferry, CT.

Abstract—The purpose of this development project was to design a new commode-shower chair that can be safely used by individuals with spinal cord injuries (SCI) and their caregivers. The need for this new design was consumer-driven. Patients and caregivers identified the following fatal flaws in the commode-shower chairs used in Spinal Cord Injury (SCI) centers: 1) risk for patient falls during transfers, propelling, and while leaning over for showering; 2) risk for pressure ulcers due to inadequate padding and seat positioning for lengthy bowel care regimes; 3) inadequate caregiver access to the perianal area of the patient to perform bowel care procedures; and, 4) wheel-related inability to properly position the chair directly over the toilet. The new, self-propelled chair addresses each of these concerns. Lockable, swing-away, pivoting armrests and improved, lever-activated brakes were designed to facilitate safe transfers. An innovative foot-lift was invented to facilitate washing of feet. Larger handrims were designed to aid in propulsion in wet environments. To prevent pressure ulcers, a chair frame and padding combination was designed to facilitate a seating position that optimally distributes body weight to prevent the development of pressure ulcers in the sacral and ischial areas. To address the common risk of heel ulcers, footrests, featuring edgeless, rounded heel cups, were designed. A new tubular chair frame, a new seat and smaller wheels were designed to enhance caregiver access and ensure proper chair positioning over the toilet. Following its successful clinical evaluation at the Milwaukee and Tampa VA Medical SCI Centers, the Advanced commode-shower chair is being patented by the Department of Veterans Affairs (VA). The VA has partnered with Everest & Jennings®, to make this chair available commercially.

Key words: *activities of daily living, spinal cord injuries, wheelchairs*

INTRODUCTION

There are over 220,000 individuals with spinal cord injury (SCI) in the United States today (1). The majority of them have bowel incontinence, requiring bowel care an average of three times a week. While some are able to transfer to a toilet for bowel care, many need to use a commode-shower chair. Most of the existing commode-shower chairs were designed for the elderly, and do not

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Address all correspondence and requests for reprints to: Pascal Malassigné, IDSA, Research Service, 151, Clement J. Zablocki Veterans Affairs Medical Center, 5000 West National Avenue, Milwaukee, WI 53295-1000; email: pmalassi@miad.edu.

meet the needs of a younger SCI patient population managing a neurogenic bowel. A survey of 147 veterans with SCI was conducted to evaluate existing commode-shower chairs (2,3). Findings revealed numerous safety-related problems with existing chairs. Specifically, 66 percent felt unsafe self-propelling, and 47 percent felt unsafe transferring to an existing commode-shower chair. Forty-two percent indicated that the brakes were unreliable. Twenty-four percent reported development of pressure sores and cuts from the seats and 35 percent indicated falling from commode-shower chairs. Of those who reported injuries due to fall, over 23 percent were hospitalized ranging from 1 mo to 4 yr. Patients reported flaws in commode-shower chairs that negatively impacted their quality of life, self-esteem, and physical well-being.

METHODS

Before beginning the new chair design, the authors evaluated existing chairs as part of VA Rehabilitation R&D Service pilot study. This evaluation involved the design and clinical use of the chair by patients and caregivers. From this evaluation, functional and performance criteria were established in order to develop chair prototypes for clinical evaluation at the Milwaukee and Tampa VA Medical Centers. Typical of many such projects, an iterative process of prototype development, laboratory evaluation, and clinical evaluation was used to develop this new chair. The responses received from patients and caregivers were incorporated into the next prototype until the new chair design was completed. During the process, several new features were invented: a new seat design, a foot-lift, oversized pushrims, swing-away pivoting armrests and new footrests featuring edgeless heel cups (**Figure 1**).

Two chairs, one self-propelled and the other an assisted-care chair, were actually designed; however, only the self-propelled chair (the Advanced commode-shower chair) was clinically evaluated.

Safety and Performance Criteria

Safety and performance criteria were delineated based on consumer input, data from pilot studies (2–8), as well as International Standards Organization (ISO) American National Standards Institute/Rehabilitation Engineering Society of North America (ANSI/RESNA) wheelchair standards (9), as recommended by the funding agency. The chair was designed based upon the following safety and performance criteria:

Figure 1.
The Advanced commode-shower chair.

• *Overall chair safety:* The new chair must not contribute to the development of pressure ulcers, nor cause injuries to patients due to falls while transferring, bending forward to shower, or propelling the chair in wet environments.

• *Chair positioning over a toilet:* The chair must fit properly over a toilet bowl to prevent fecal matter from falling on the floor. While this seems like an obvious need, the wheel size of existing models prohibits proper chair positioning over the toilet bowl, making this a hygiene problem and a threat to the dignity of the patient and caregiver.

• *Seat design:* The chair must have a waterproof seat that provides full thigh support, thereby minimizing pressure on the sacral and ischial areas. The seat must be cushioned for appropriate pressure relief and designed for

hand access to the perianal area, necessary for bowel care procedures, such as digital stimulation (10).

• *Seating position:* The seat must be sloped toward the back to hold the user safely in place. Multi-function armrests must provide a resting-place for the forearms of the users, support their body weight, and create areas for body positioning.

• *Hand access to the perianal area:* The chair must provide unrestricted under-seat hand access to the perianal area from at least three positions (right, left, and front).

• *Caregiver friendly:* The chair must provide for unrestricted hand access to the perianal area of the patient. The footrests must adjust easily for users of varying size and weight. The chair armrests must be able to swing away for ease in transfer, but should not be removable, since they are likely to be lost in institutional settings.

• *Durability/rust-proofing:* The chair must survive long-term use in wet environments.

• *Propulsion pushrims:* The chair must have appropriately sized pushrims for optimum hand positioning and grip. The handrims must be coated with non-slippery material to assist propelling in wet environments.

• *Static stability:* The chair must be designed for a minimum tip angle of 20º in forward, rearward, and sideways tipping.

• *Design of two versions:* Two rigid chairs were developed—a self-propelled and an assisted-care version.

Development Process

Both the self-propelled chair and the assisted-care chair were designed and engineered; however, it is the self-propelled chair for which prototypes have been tested, and clinically evaluated.

The project began with the design of an adjustable chair frame, in order to establish the proper relationship between the seat, the toilet bowl, and the bathroom wall. With the frame geometry established, all other aspects of the development of the chair followed.

This design and development process is presented using ANSI Wheelchair Standards #00 (WC/00) nomenclature (9).

Body Support

WC/00 defines the body support system as "Those parts of the wheelchair which directly support or contain the body of the user."(9).

Pressure, positioning, and postural support are critical aspects in the design of a new commode/shower chair for persons with SCI (4). A properly fitted chair disperses weight over the entire length of the thighs. To accomplish this, footrests must be adjusted until the thighs are parallel to the ground. If the feet are too high, the weight is thrown back on the bony protuberances of the buttocks. If they are too low, the weight comes forward onto the thighs, causing pressure ulcers (4,5).

Seat Design

Two types of seats were developed for clinical evaluation: square and rectangular.

Square seats: a repositionable, square seat with an opening to one side is common on commercially available commode-shower chairs (6). The main advantage of a square seat is that the opening can be rotated on any side depending on the preferences and abilities of the users or caregivers; however, its disadvantage is the limited thigh support area, typically much shorter than the thigh length of the user. Forty square seats were designed with various foam densities and openings. These seats were evaluated with a pressure-mapping system (4,5), with results showing dangerously high pressure at the seat opening, even when an optimal foam density was used. An optimal foam density provides maximum support, comfort, and pressure relief. These results confirmed the idea that the disadvantages of square seats outweigh their positive aspects (rotation on all sides) and led to concentration on the design of a fixed, rectangular seat for the new chair.

Rectangular seats: several seats of various dimensions and sizes of hole opening were developed and evaluated with the pressure-mapping system. From these various designs, a new "C" shape seat was created, allowing hand access by the caregiver in three positions (front, left and right side). This seat measures 49×54 cm and incorporates front "wings" projecting on the sides to facilitate wheelchair to wheelchair transfers (**Figure 2**).

Seat Cushioning

In developing seats, the authors experimented with two types of open cell conforming and cushioning foams. Brands used for conforming foams were Pudgee® and Sun-Mate® while Laminar® and Clark® were used for the

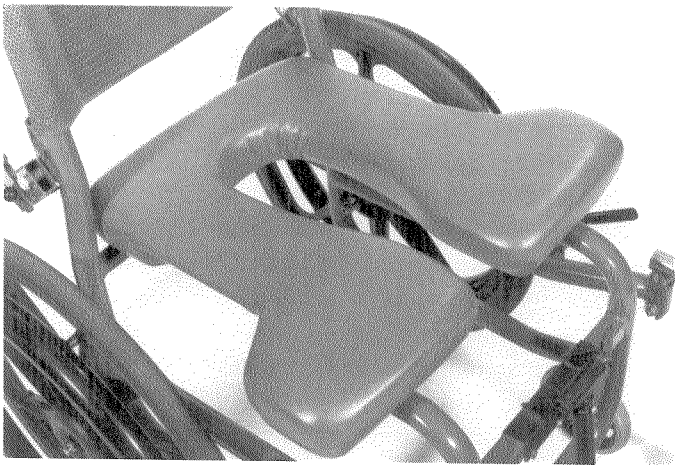

Figure 2.
Seat with side wings.

cushioning foams. Four different foam densities were evaluated for each brand. The seats were tested with the Force Sensing Array (FSA) pressure-mapping system. This system uses a seat-sized sensing pad with a graphic display to measure the full buttock-seat interface (11). Recommended maximum acceptable pressures for persons with SCI have been established (12). Testing involved recording the amount of pressure being exerted on the surface of the seat by a variety of patients, chosen based on their level of risk, defined as high (no sensation, with history of sores at the site of measurement), moderate (no sensation, no history of skin breakdown), and low (partial or full sensation, no history of skin breakdown). The results indicated that low-pressure readings were dependent not only on the amount of padding, but also on the position of the body in the chair.

The design of the chair significantly impacted body positioning, affecting the angle of the seat, angle of the backrest, and position of the seat opening. The authors concluded that the seat cushioning of the chair must work in concert with the frame to achieve safe pressure levels. From the various tests, Clark firm foam was selected for the final design, based on effective pressure relief and cost.

Swing-away Armrests

Armrests are used in multiple ways: to help positioning in the chair or transfer into/out of it, to rest the arms, to lift and hold up on the armrests, to hook up or put the arms under the armrests, to brace in the chair for stability, and to push down on the armrests to shift the body on the chair. Based on these multiple uses, lockable pivoting armrests, capable of holding patients weighing upward of 100 kg and more, were designed. In the locked position, users can latch under them and pull up without fear that they will detach. To meet needs identified by caregivers in institutional settings, the two armrests swing away without being removable: a lever release mechanism was developed to lock and unlock them. For added comfort, longer armrest pads have been selected to provide more surface area for the arms and elbows (**Figure 3**).

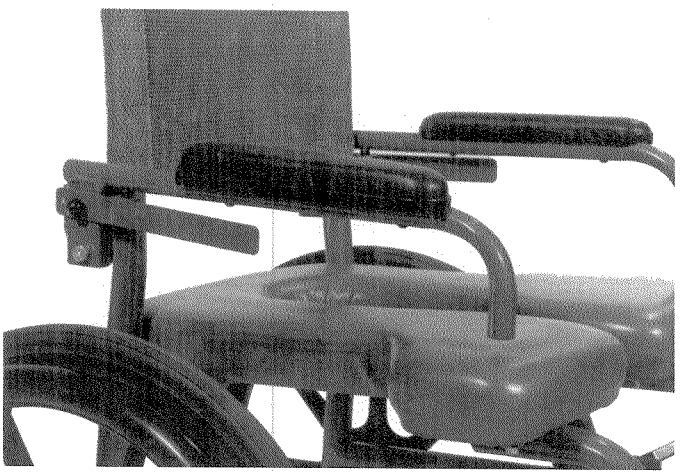

Figure 3.
Swing-away armrest and armrest release lever.

Footrests

Footrest Adjustment

The ability to adjust footrests in accordance with the height of the patient is critical in establishing a good seating position for bowel care, yet footrests typically require the use of tools for adjustment. This is particularly problematic in institutional settings where multiple users are of varying heights. Since tools are seldom available on hospital units, footrests are rarely adjusted for the height of each patient, and this lack of adjustment can force the patient to sit in an awkward position, predisposing him or her to increased risk for pressure ulcers. In developing new footrests, the authors used telescoping footrest posts and two different locking mechanisms: 1) a quick release system used for racing bicycle wheel removal, and 2) a handle. In clinical evaluations, the quick release system confused caregivers unfamiliar with this technology. Although the handle required more tightening strength, it was intuitively easier to use. The footrest and the lever-

type handle become a single moveable unit, adjusted along the entire length of the post and easily tightened without the need for tools. This adjustment mechanism was designed for caregivers in institutional settings, since chairs used in a home setting rarely need to be modified once they are initially adjusted for the thighs of the individual user (**Figure 4**).

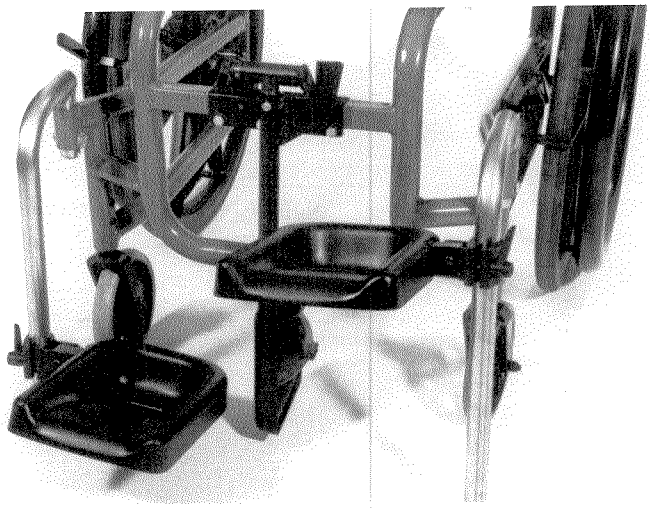

Figure 4.
Footrest adjustment.

Footrest Design

Typically, existing footrests are flat metal plates incorporating a heel-strap supported by two vertical bolts. The bolt heads are often sharp and can cut patients' ankles, unprotected during bowel care and showering procedures. Footrest development started with designs that held the entire foot instead of only the heel. The new design is a footrest with a deep heel-cup, contoured to fit the bottom of the foot. To avoid potential ankle injuries, all edges of the footrests are rounded and smooth, and they are easy to clean and drain when showering. This improved design helps with weight distribution on the thighs (**Figure 5**).

Footlift

It is not uncommon for users to fall out of the chair while trying to reach their feet during showering. Discussions with users about showering in a chair revealed two techniques for safely washing their feet: using a long brush and lifting the leg over a bathtub ledge, the latter being the inspiration for the new foot-lift design, a unique and innovative accessory that allows the

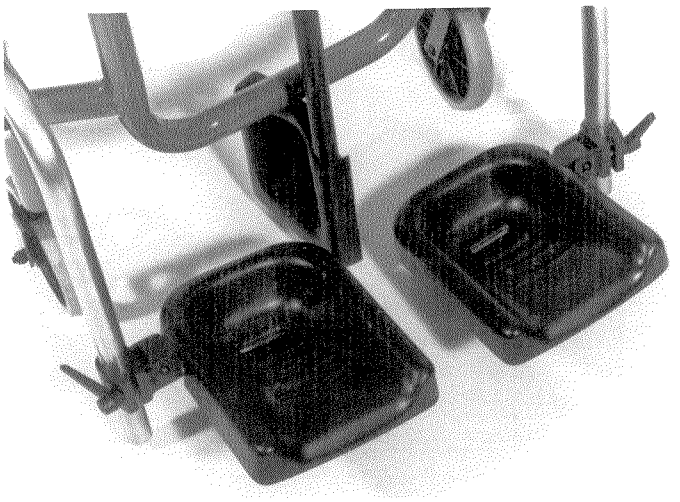

Figure 5.
Rounded footrest.

independent and safe cleaning of the feet and legs. The footlift is a hinged mechanism that hangs in front of the frame when not in use. To use the footlift, the user swings it up into position and manually brings each foot up into the heel-cup to wash it (**Figure 6**).

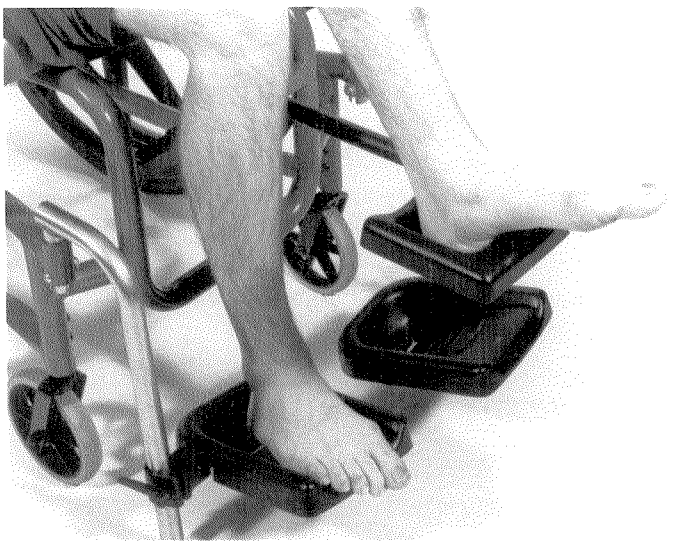

Figure 6.
Footlift.

Commode Pan

The commode pan is used as an accessory when a toilet is not available. Typical commode pans can be difficult to use, since they are small and have limited grasp-

ing areas. They are also difficult to remove from the chair, and spills are common. As a solution, the authors developed a tray, supported by the chair frame and equipped with a recessed pocket, to hold the pan in place. Removal of the pan is performed easily by sliding it across the tray for emptying and replacement (**Figure 7**).

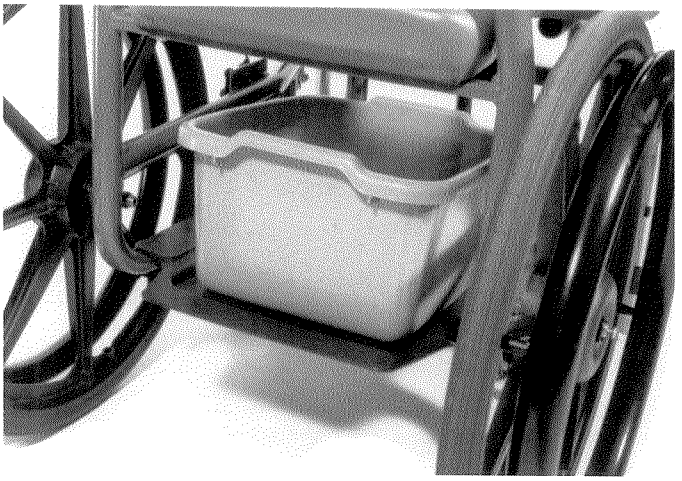

Figure 7.
Commode pan.

Backrest

Typically, the backrest of shower chairs is rigid and made of non-breathable, solid vinyl material. In some instances, its height interferes with access to the patient's back for showering. In the new design, a soft, open-weave, nylon mesh was selected to facilitate showering and drying. Clinical evaluations in hospital and home settings revealed that the mesh material was easily cleaned and self-drying between uses.

Driving Wheels

WC/00 (9), defines the driving wheel of a wheelchair as "a wheel that is connected to the driving system and when in contact with the underlay develops the propelling force." Typical commode-shower chairs are equipped with 61-cm diameter wheels and 2-cm diameter metal handrims. In designing a chair that must roll over a toilet and must be used for showering, it was critical to consider self-propelling and gripping in wet environments. Additionally, it was necessary to select a wheel size that would enable level access to the seat from another chair and would not touch the back wall before centering over the toilet.

Driving Wheels Selection Process: Self-propelled Chair

The team selected wheels of 50 and 55 cm in diameter, instead of the customary 61-cm wheels, for clinical evaluation. While the standard wheel size provides easier hand access to the pushrims, it also creates problems by butting against the wall before centering over the toilet. The decision to use smaller wheels solved access over the toilet but made self-propelling slightly more difficult. In clinical evaluation, participants preferred the 55-cm wheel size to the 50-cm wheels. Consequently, this size wheel was selected for the self-propelled chair. While the new wheel dimension is slightly more restrictive, it must be noted that self-propelling with a commode-shower chair is limited to short distances, generally from bedroom to bathroom.

Assisted Care Chair

Wheels of 32.5 cm in diameter will be used for this version of the chair, intended for patients that need caregiver assistance.

Pushrim Development

The team used ergonomic data on the dimensions of the hand, combined with knowledge from previous studies related to grab bar design, to develop new pushrims. The goal was to increase the surface area for the hands when grasping the pushrim. A test mock-up was built, made of curved PVC tubing and mounted to the wheel of a wheelchair, with 3 different diameters: 27, 35, and 42 mm. It was then possible to compare one size handrim to another. Ten veterans with SCI participated in a patient preference study of the three diameters. The 35-mm was the preferred size, and was produced in aluminum and coated with rubber. The larger pushrims were mounted on the new chair prototypes. The new pushrims are 15 mm larger in diameter—35 mm instead of 20 mm—and enable users to achieve a stronger grip. The enhanced grasping ability in a wet environment, with the rubber coating handrims, was greatly appreciated in the clinical evaluations (**Figure 8**).

Caster Wheels

WC/00 (9), defines the caster wheel of wheelchair as "A wheel that can pivot but is not intended to govern the driving direction." Standard 15-cm caster wheels were used on all the chair prototypes, with the stems mounted inside the frame to protect the bearings from rusting. After 12 months of clinical evaluation in two active hospital settings, no rust was detected on any of the prototypes.

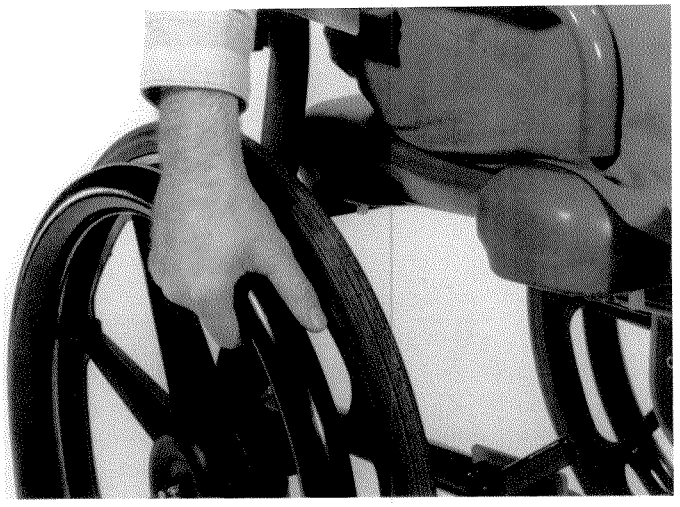

Figure 8.
Oversize pushrims.

Parking Brakes

WC/00 (9), defines the parking brake as: "The braking system that is intended for keeping the wheelchair stationary on sloping ground whether or not the wheelchair is occupied." Lever-type parking brakes were selected for all the chair prototypes. Clinical evaluation indicated complete user satisfaction with these brakes.

Frame Development and Static Stability Testing

WC/00 (9) defines a wheelchair frame as follows: "The frame unites and supports the other parts of the wheelchair. Seat-frame-backrest, etcetera, could form, or be combined into, one unit or consist of separate parts." An adjustable chair frame was developed in order to establish the proper relationship between the seat, toilet bowl, and wall. This adjustable frame allowed changes in the distance between the seat and the rear wheels. The development of later frames used this optimal seat-to-wheel relationship.

The frames were tested for static stability with the ANSI Wheelchair Standards: WC 01: Determination of Static Stability, for forward, rearward and sideways tipping (7,9). Static stability was measured when the chair was positioned on a platform with a 75-kg subject. The platform was tilted up-slope and tipping was achieved when the front or rear wheels of the chair lifted off the platform. The same procedure was repeated with a 100-kg subject. Frame configurations were modified until a 20º tipping angle was established. This configuration was used throughout the development process and is on the final frame design. The new chair, the self-propelled model, was tested for static stability and for forward, rearward, and sideways tipping (7).

Clinical Evaluation

The development of the new, self-propelled chair involved an iterative process of prototype fabrication, and long term clinical evaluation at the Milwaukee and Tampa VA Medical Centers. The primary evaluation method used one questionnaire for patients and one for caregivers. The secondary form of prototype evaluation involved discussions and focus groups with patients and caregivers about the prototypes provided for clinical evaluation.

Chair assessment: patients and caregivers used questionnaires addressing issues of their interaction with the new commode-shower chair. The questions were related to the features of the chair relative to bowel care and showering, issues of seating, and transfer safety to and from the chair.

RESULTS AND DISCUSSION

Reflecting the need for a proper seating position as key to a safe and functional chair, the Advanced commode-shower chair (the self-propelled chair) offers the following features:

- Seat designed with wings extending to the front corners to allow more area for transfers and grasping, and a large cutout area for under-seat hand access;
- Oversized and non-slip pushrims, fitting properly in the hand;
- Easily adjusted and contoured footrests;
- Locking, swing-away armrests;
- Footlifts that allow the user to wash feet and legs independently and safely;
- Smaller wheels to allow for a closer position to the wall and to center over the toilet;
- Handles at the top of the backrest, bent past 90º, to help hold the patient's arm in place when wrapped around it, and
- Absence of sharp edges on the chair, for safe and easy grasping.

Dimensions for the two chairs (self-propelled and assisted care) are depicted in **Figure 9**. The self-propelled chair is 102 cm high, 70 cm wide and 108 cm long. The assisted care chair is smaller: 102 cm high, 60 cm wide, and 70 cm long.

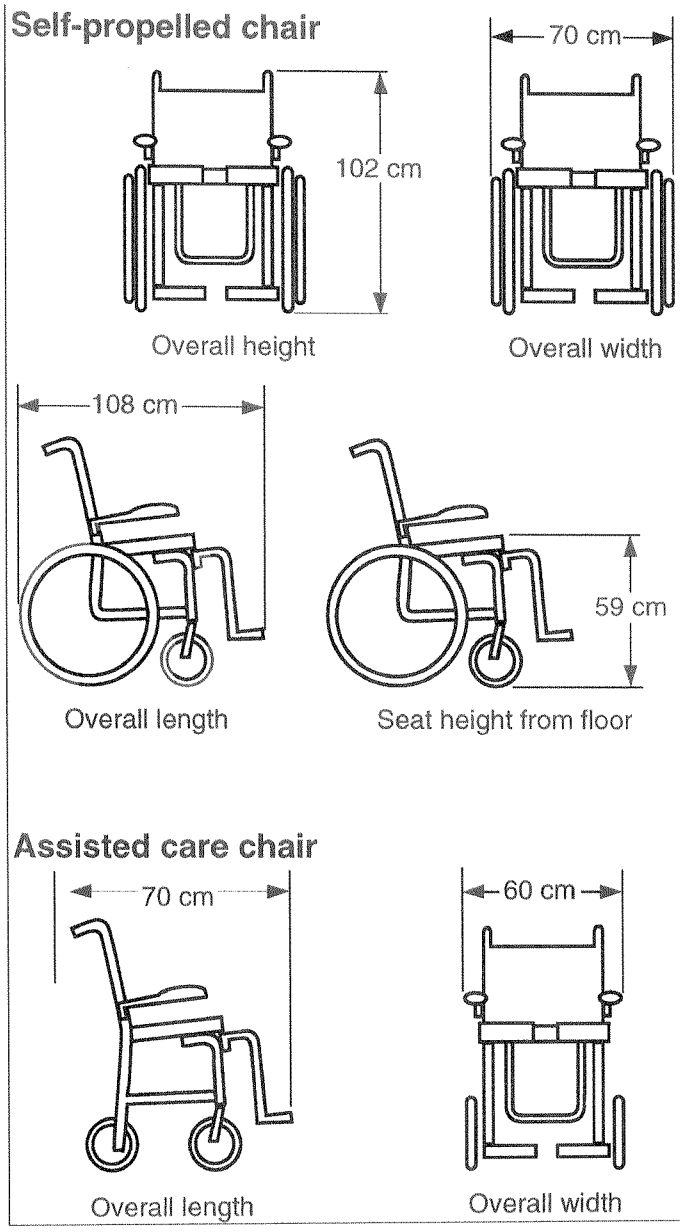

Figure 9.
Dimensions for the self-propelled and assisted care chairs.

Static Stability Testing

The results presented in **Table 1** below, indicate that the chair is very stable. There is no difference in the average static stabilities between the 75-kg and 100 kg subjects in the rearward and sideways tipping tests. The static stability difference of 2º between the averages for the 75-kg and 100 kg subjects in the forward tip testing is minimal.

Table 1.
Static stability testing results.

Static tipping angles	75 kg	100 kg
Toward the rear	23	23
Toward the front	20	18
Toward the side	21	21

All measures are in degrees.

Clinical Evaluation

Overall Comments

The new chair was found to roll as easily as other chairs. The chair did fit conveniently in shower stalls and over toilets, and improved showering and toileting, via the many places available for patients to grasp and hold. The chair held the patients in an appropriate position and provided a wide, comfortable seat.

Chair Stability

Both the patients and the caregivers considered the brakes easily activated and effective in holding the chair in place. Patients and caregivers found the chair stable during showering and bowel care.

Transferring

The patients found the footrests and armrests easy to move out of the way for transferring. Neither the curved front seat supports of the frame nor the footlift interfered with transfers. The caregivers found the brakes effective in holding the chair in place during transfers, with no evidence of sliding or giving way over the duration of the 12-mos evaluation. Overall, the patient and caregiver responses to the final chair prototypes were unequivocal and strongly favorable.

Backrest

Caregivers reported that the backrest provided sufficient space to wash the back, and the open weave fabric of the backrest was easy to clean and dry. The patients reported that the backrest was comfortable, with an appropriate height and a bottom edge that was not too low.

Seating Comfort

Patients responded that the seat was comfortable and not too firm. Both patients and caregivers were able to reach under the seat easily. They found the opening of the seat to be an adequate size and the seat cover material not overly slippery when wet. The patients felt secure and did not feel that they were falling into the seat opening. Access to the perianal area was adequate for digital stimulation necessary for bowel care procedures.

Armrests

The armrests were found to be strong, with comfortable armrest pads. In addition, patients liked the curved ends of the armrests for grasping. The armrest length and height were rated as ideal.

Footrests

The footrests were found to hold the patients' feet properly and safely in place, and to be easily adjustable by caregivers.

Footlift

The footlift did not interfere with patient transfer. However, because of its location (slightly hidden under the seat of the chair), patients expressed concern, at first, regarding its use and operation, while caregivers favored it. The initial hesitancy of some patients to use the footlift is likely explained by the novelty of this new wheelchair feature. Over time, patients became familiar with its use. Both patients and caregivers found the footlift made washing of feet easy, and caused no discomfort or loss of balance for patients.

Pushrims

The large pushrims reveived postitive responses for their gripping effectiveness when wet and for the fact that they were much larger than the standard pushrims.

CONCLUSIONS

This 2-yr development project enabled the successful design of two versions of a rigid-frame commode-shower wheelchair: a self-propelled and an assisted care chair. During the clinical evaluation of the self-propelled chair, caregivers and patients suggested that a folding commode-shower chair be designed for home use. With sponsorship of the VA Rehabilitation R&D Service, and in collaboration with Everest & Jennings, the design of a folding commode-shower wheelchair is nearly completed.

Patenting

An invention report was submitted to the Office of the VA General Counsel by the authors. Following positive review, the VA decided to patent the many new and innovative features of the Advanced commode-shower chair.

Technology Transfer

The authors first collaborated with Milwaukee-based Ortho-Kinetics® (OKI) during the development stages of the Advanced commode-shower chair. However, OKI decided not to commercialize this chair when it was completed. The chair was then presented to Invacare®, Active Aid® and Everest & Jennings. Although both Active Aid and Everest & Jennings were interested in the new chair for their product line, Everest & Jennings decided to manufacture and market the chair under a licensing agreement with the Department of Veterans Affairs.

REFERENCES

1. Stover S, DeLisa J, Whiteneck G. Spinal cord injury: clinical outcomes from the model systems. Gaithersburg, MD: Aspen; 1995.
2. Nelson AL, Malassigné PM, Amerson TL, Binard J, Saltzstein R. Descriptive study of bowel care practices and equipment in spinal cord injury. Spinal Cord Injury Nurs 1993;10(2):65–7.
3. Malassigné PM, Nelson AL, Amerson TL, Binard J, Saltzstein R. Design of a new bowel care chair for spinal cord injury: a pilot study. Spinal Cord Injury Nurs 1993;10(3):84–90.
4. Nelson AL, Malassigné PM, Murray J. Comparison of seating pressures on three bowel care/shower chairs in SCI: results of a pilot study. Spinal Cord Injury Nurs 1994;11(4):104–6.
5. Malassigné PM, Nelson AL, Murray J. Determination of static stability of bowel care/shower chairs. Proceedings of the 17th Annual RESNA Conference; 1994 Jun 17-22; Memphis, TN. Washington, DC: RESNA Press; 1994. p.318–20.
6. Malassigné PM, Nelson AL, Amerson TL, Saltzstein R, Binard J. Evaluation of three bowel care-shower chairs. Proceedings of RESNA International '92; 1992 Jun 7-10; Toronto, ON, Canada. Washington, DC: RESNA Press; 1992. p. 271–3.
7. Malassigné PM, Amerson TL, Nelson AL. Determination of static stability of bowel care/shower chairs in spinal cord injury. Proceedings of the 17th Annual RESNA Conference; 1994 Jun 17-22; Memphis, TN. Washington, DC: RESNA Press; 1994. p. 318–20.
8. Malassigné PM., Nelson AL, Cors M, Amerson TL. Design and development of a new commode-shower chair. Proceedings of the 20th Annual RESNA Conference; 1997 Jun 20-24, Pittsburgh, PA. Washington, DC: RESNA Press; 1997. p. 202–4.
9. American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA). Wheelchair standards. Washington, DC.: RESNA Press; 1990.
10. Zejdlik CP, editor. Management of spinal cord injuries. 2nd ed. Boston: Jones & Bartlett Publication Company; 1992.

11. Ferguson-Pell M, Cardi M. Prototype development and evaluation of wheelchair pressure mapping system. Assist Technol 1993;5(2):78–91.
12. Ferguson-Pell M. Seat cushion selection. J Rehabil Res Dev 1990; 27(Suppl 2):49–73.

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