Design and Evaluation of a Stand-Up Motorized Prone Cart

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Abstract

Background/Objective: Prone carts are used for mobility by individuals with spinal cord injury in whom seated mobility (wheelchair) is contraindicated due to ischial or sacral pressure ulcers. Currently available prone carts are uncomfortable, subjecting the user to neck and shoulder strain, and make social interaction and performing activities of daily living difficult. A better design of prone carts is needed. In addition, standing devices have shown some medical benefits. The objective was to design and evaluate an improved prone cart that facilitates standing.

Design: Engineering development project with user feedback through questionnaire. Users selected by convenience sampling.

Methods: A marketing survey was performed of nurse managers of spinal cord injury units. Then 2 prototype carts were designed and built. These carts are able to tilt up to 45° and have a joystick-controlled motor for propulsion and other design features, including a workspace storage shelf and rearview mirrors. The carts were evaluated by both patients and caregivers at 2 Veteran's Administration hospitals.

Outcome Measures: Questionnaire of subjects, both patients and caregivers, who used the cart.

Findings: Both patients and caregivers liked the carts and the ability to assume a nonhorizontal body angle. The major complaint about the cart was that it seemed too long when it came to making turns.

Conclusion: This prone cart design is an improvement over the standard, flat variety. However, further design changes will be necessary. This study provided valuable information that will be useful in the next-generation prone cart design project.

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Key Words: Spinal cord injuries; Locomotion; Mobility; Osteoporosis; Pressure ulcers; Nursing; Activities of daily living; Bone loss; Self care

INTRODUCTION

This paper reports on the continuing research collaboration among 2 Veteran's Administration (VA) Medical Centers (VAMCs) and an academic Industrial Design Department towards the design of an optimal prone cart to improve the quality of life of persons with spinal cord injury (SCI) who have pressure ulcers.

Purpose of Prone Carts

Prone carts are used for mobility by persons with SCIs in whom seated mobility (wheelchair) is contraindicated due to ischial or sacral pressure ulcers (1,2). This is not an uncommon problem in the SCI population, because people with SCI are at high risk for developing pressure ulcers (3,4), with admission incidence rate of 7.5% (3), annual incidence rate of 13% (5) (computed from a 3-year incidence rate of 39%), and a self-reported prevalence of 38% (6). Risk factors for developing pressure ulcers in SCI are numerous; more than 200 have been described (4). The profound impact of pressure ulcers upon the subjects' lives includes changes in physical, social, and financial status; change of body image; and/or loss of independence and control (7). Healing a pressure ulcer nonsurgically requires lengthy periods, with hospitalizations averaging 150 days (5). Although it has been noted that the literature does not

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provide evidence that bed rest facilitates healing of pressure ulcers (8), the belief that unlimited sitting time is detrimental to healing is common in clinical practice.

Prolonged bed rest has many disadvantages, including decreases in cardiac reserve and stroke volume (8), increases in spasticity (9), contractures, muscle atrophy, pathologic fractures, urinary tract infections, resting and postexercise tachycardia, orthostatic hypotension, pulmonary embolism, deep venous thrombosis, pneumonia, anorexia, constipation, bowel impaction (8), bone loss (10), and risk for a developing a sacral pressure ulcer (11). In addition to physical problems associated with prolonged bed rest, psychosocial concerns include depression, learned helplessness, perceptual changes, and fatigue (8).

Prone carts provide mobility during the healing process, potentially ameliorating pressure on affected areas and the adverse effects associated with prolonged bed immobilization. Motorized prone carts are used by persons who are unable to self-propel a manual cart due to limited arm/hand function, fatigue, or other medical conditions. Motorization extends the use of prone carts to tetraplegics with insufficient upper extremity strength and to all persons with SCI who have developed pain in the shoulders, a common problem in chronic SCI (12,13).

Review of Literature

Prone Carts. A search of the medical literature for “prone cart” only yielded 2 references. The older (1996) reference (2) evaluated 3 commercially available prone carts and identified a major problem that limits user comfort and widespread acceptance: the need to raise the trunk and head to carry out activities of daily living (ADL), including social interaction. Consequently, the authors of that study designed a prototype cart that provided an angled torso support. They evaluated this prototype with 20 users and 19 caregivers.

The results of that pilot work led to a VA Rehabilitation Research and Development (RR&D) grant to design a refined prototype and to evaluate it clinically. The second prone cart reference (1) reported on the 3 products developed under that grant and the feedback given by users and caretakers at 2 SCI centers. These products were not final entities in themselves but rather iterative design embodiments characteristic of the product design process. These designs were tested, and the clinical feedback led the designers to a new design to address newly discovered requirements. The report covered the following prone cart design iterations: (a) the previously described prototype cart (#1) with the angled torso support (2); (b) a manual cart (#2) with angled torso support (0°–23°) and cutout center section for urine/ostomy drainage; (c) a more refined version of cart #2, using tubular steel for the frame instead of square steel; and (d) a motorized version of cart #3, driven by joy-stick control.

The 2002 paper (1) discussed the possible benefits of standing the user up higher than 23°. This concept, termed a “stand-up motorized prone cart,” would offer the potential medical benefits of standing to those of the basic motorized prone cart. Standing in patients with SCI may be facilitated by standing frames, wheelchairs with standing capability, and bracing systems with or without functional electrical stimulation. Many studies have been published on the medical benefits of these technologies, but the use of these technologies is yet to become commonplace.

Classes of Standing Devices

Standing frames have been described as early as 1954 (14) and periodically since then (15–19). *Standing wheelchairs* combine the ability to stand with the wheelchair’s ability to move (20–22). *Functional electrical stimulation* enables an active form of standing by stimulating the muscles of the lower extremities (25–35). For balance purposes, functional electrical stimulation must be combined either with bracing and upper extremity aids, such as a walker, or with a standing device.

Medical Benefits of Standing Devices. The evidence base for benefits of standing devices for persons with SCI is small, but a few studies have demonstrated benefits in tissue oxygenation, bone density, and subjective/psychological outcomes.

Tissue Oxygenation. Bogie and Triolo studied the effects of standing using an implanted neuromuscular electrical stimulation system in conjunction with a standing frame (32). In their sample of 8, they showed that tissue oxygenation in the ischial region improved after 8 weeks of standing. This study, while encouraging, would have been stronger with a control group. Further, tissue oxygenation has not been validated as a proxy for reduced pressure ulcer risk.

Bone Mineral Density. Goemaere et al measured bone mineral density using dual-energy radiograph absorptiometry and self-reported use of standing frames in a study of 53 individuals with paraplegia, 38 of whom reported regularly using standing frames (36). They found that standers had increased bone mineral density in the femoral shaft but not in the hip compared with nonstanders. Dauty et al studied 31 SCI subjects 1 year post injury using self-reported activity (37). They found that biomechanical stress (eg, standing, walking, sitting) did not influence sublesional bone mineral density. The opposite findings of these 2 retrospective studies may be due to recall bias and to confounding (eg, those subjects who choose to stand more may have different health factors than those who do not, such as smoking, diet, and general health).

In a prospective study on standing, Kunkel et al looked at 6 subjects who stood for approximately 1 hour per day for 135 days and found no impact on osteoporosis, joint contractures, or spasticity (19). His

sample size may have had insufficient power to detect a possible difference.

Subjective Outcomes. Kunkel's study also examined general well-being as a secondary measure. In a follow-up interview, he found that 4 of the 6 subjects continued to stand and felt healthier because of standing. He concluded that standing has a positive psychological impact.

Two studies addressed subjective outcomes in their primary analysis. Dunn et al investigated the perceived benefits of standing mobility devices through a national survey of persons who returned their manufacturer's warranty card to 2 companies (38). He received 99 responses (response rate 32%). Of the respondents, 21% reported increased ability to empty their bladder more completely, while others reported improved bowel regularity, reduction of urinary tract infections, reduction of leg spasticity, and reduction of number of pressure ulcers. A secondary analysis of these data showed that respondents who stood 30 minutes or more per day had significantly improved quality of life, fewer pressure ulcers, fewer bladder infections, improved bowel regularity, and improved ability to straighten their legs compared with those who stood less time (39).

These questionnaire-based studies are subject to selective response bias, low levels of participation, and lack of objective measures to supplement self-assessment. Despite these limitations, these studies are encouraging and suggest that adding standing functionality would provide added benefit to an improved prone cart design.

Estimating the Market

Before applying for funding for this product development project, we attempted to establish that a market for such a product would exist. To estimate the demand for a stand-up version of a motorized prone cart, the investigators sent a survey to 51 SCI centers in the United States. These centers were randomly selected from the membership directory of the American Association of Spinal Cord Injury Nurses, VA and non-VA. The survey was addressed to the nurse manager of the SCI center.

The results of the marketing survey are shown in Table 1. A total of 27 surveys were returned for a response rate of 53%. Of the centers that responded, 63% (n = 17) were VA facilities and 37% (n = 10) were non-VA.

From the 17 VA SCI centers responding, 131 annual purchases were projected. Because there are 26 VA SCI centers, 200 purchases per year was projected for the entire VA SCI system. From the 10 non-VA SCI centers responding, 66 annual purchases were projected. We estimated that there are more than 200 SCI units in the United States (SCI model centers, university-based facilities, private rehabilitation centers, and others). Using this figure, we projected 1,320 purchases per year for non-VA SCI centers. Thus, the projected annual US demand would be 1,520/year.

This survey has 2 major limitations: (a) The nurse managers were being asked to provide an estimate for a notional device without knowing its cost, whether these devices can work in a home environment, and whether it would be purchased for each person with a pressure ulcer or loaned for the duration of the pressure ulcer. (2) The model is very simplistic: it assumes the device will work in all homes and does not adjust for size of the SCI center, differences in regional pressure ulcer incidence or prevalence rates, budgetary changes, cost of device, or lifetime of device.

Despite these limitations, this preliminary marketing survey was useful to justify the potential for a market to the funding agency.

Design Criteria

The design team consisted of a physicians, nurses, safety researchers, and industrial designers. The design process was a stepwise process: (a) developing a set of basic design criteria, (b) examining required functional interactions, (c) developing detailed design specifications, (d) constructing a prototype, (e) clinical evaluation of the prototype, and (f) analysis of needed design revisions.

Basic Design Criteria. The team developed the following basic design criteria:

1. The cart should be designed to accommodate persons of different heights, ranging from the 5th to the 95th percentile. To accomplish this, 2 versions would be built: a short version, for persons in the 5th to 55th percentile measuring from 1.60 m to 1.75 m (5 ft 3 in to 5 ft 9 in), and a long version, for persons in the 65th to 99th percentile measuring from 1.75 m to 1.90 m (5 ft 10 in to 6 ft 3 in).

2. The cart should safely support persons weighing up to 115 kg (255 lb).

3. The cart should have the ability to raise the body support's angle from 0° to 45° and consequently offer caregivers and users a graduated angle of positioning.

Required Functional Interactions. The design team then considered the unique needs of the person using the cart, the user/caregiver interaction while using the cart, and the caregiver's interaction with the cart. Each of these considerations is described below.

1. *User-Cart Interaction.* A person with a pressure ulcer is likely to spend most waking hours of the day on a cart. As such, the new stand-up motorized prone cart must incorporate design features that make life on the cart comfortable. Design features should include (a) easily accessible joystick controllers for controlling direction/speed and for elevating the body support, (b) elbow and arm supports, (c) a front deck for eating and working, (d) a storage drawer, and (e) a contoured body support for safe positioning and pressure relief. Additionally, the cart must be structurally sound, accommodate a wide range of heights and limb proportions, and be balanced to enable rolling up and down ramps safely.

Table 1. Market Survey Results

Market Survey Items	VA (17)	Non-VA (10)	Total (27)
Awareness of current use of stand-up motorized prone carts	0	0	0
Estimated number of inpatients who would have benefited from stand-up motorized prone carts in the past year, had they been available	238	91	329
Estimated number of outpatients who would have benefited from stand-up motorized prone carts in the last year, had they been available	103	284	387
Estimated number of stand-up motorized prone carts you would recommend purchasing annually for the unit, if they were commercially available	67	45	112
Estimated number of stand-up motorized prone carts you would recommend purchasing annually for the patient homes, if they were commercially available	64	21	85
Total projected purchases	131	66	197

2. User–Caregiver Interaction. The user/caregiver interaction can be extensive for a person with SCI and a pressure ulcer, including time spent on treatment and ADL (eg, daily hygiene, grooming). These tasks can be physically demanding because caregivers must often assume awkward positions or postures to perform them. The height of the cart should facilitate ergonomically sound access by the caregiver to the cart user.

3. Caregiver–Cart Interaction. The cart should be easily operated by a person standing beside it. The design should facilitate cleaning the cart and recharging the batteries. It is crucial to allow the caregiver to attend the user without incurring a job-related injury, particularly when transferring the user between the cart and bed.

Design Specifications. The above considerations then led to the following design specifications:

General. The cart should be usable indoors and outdoors. The body support system is adjustable from 0° to 45°. The front deck is designed to remain horizontal at whatever angle the body support is set. This front deck incorporates joystick controllers, elbow rests, a work surface, and a storage drawer. The cart is driven by a power base with 2 heavy-duty electric wheelchair motors, batteries, and angle adjustment actuator.

Frame. There are 2 frame sizes to accommodate persons of different heights. The long frame measures 203 cm (80 in) long and the short frame 178 cm (70 in). Both size frames are 80 cm (31.5 in) wide and 76 cm (30 in) high. The distance between front and rear wheels is 106 cm (42 in).

Body Support. The stand-up motorized prone cart has a body support available in 2 lengths, 147 cm and 134 cm, and comprises 4 sections: torso and lower body supports, a front deck with elbow support pads, and an adjustable foot support. The torso support has a trapezoidal shape with a chin cutout. The lower body

support has built-in bolsters on each side to keep the user centered and a slot for passage of a urine bag to prevent the tubing from compressing. An adjustable foot support, consisting of a sliding structure that enables the foot support to be adjusted to accommodate differing leg lengths, gives the feet a cushioned pad on which to rest.

Cushioning. Medium-firmness polyurethane foam with a density of 1.7 to 1.9 g/mL and indentation load deflection of 110 to 120 is used as cushioning material. This foam was used on previous cart designs (1,2) and found to provide an ideal balance between firmness and softness for pressure relief based on pressure mapping.

Support Straps/Belts. Three straps and a harness with fail-safe latch hardware are used to hold the user safely on the body support. The harness holds the shoulder area. The straps hold the lower back level, the legs, and the user's feet.

Construction. Two identical prototypes were built (1 for each test site) in the long version. The frame was made from tubular steel that was bent, welded, and painted. The driving wheels were located in the front, simulating the effect of user-propelled driving wheels. Bilateral rearview mirrors provided a 360° field of vision. The motors were brushless DC motors powered by sealed gel-type batteries. The cart could elevate from horizontal (Figure 1) to 45° (Figure 2). A workspace (Figure 3) and storage drawer (Figure 4) were integral to the design.

Testing. The protocol for testing the cart was approved by the VA RR&D and Institutional Review Board Committees with separate questionnaires and informed consent forms for users and caregivers. Caregivers included professionals (experienced SCI nursing and physician staff), family members, and attendants. Over 5 months, we recruited 11 users and 33 caregivers from the 2 SCI centers. The user subjects were asked to perform a predetermined test course on the prototype of the cart, and the caregiver subjects were

Figure 1. Rear three-quarter view, horizontal.

asked to help the user transfer to and from the cart and to accompany and observe the user over the test course. This course consisted of the following activities:

Indoor Activities. Transfer from bed to cart; access the in-room sink for grooming; leave the room; navigate through corridors; use an elevator, a public phone, and a water fountain; go to the cafeteria (obtain food and eat at wheelchair table); go to the VA retail store; go to the ADL apartment (use upper cabinets, stove, refrigerator, washer/dryer, dining table, sink, etc); transport liquids and objects; return to the bedroom; transfer back to bed.

Outdoor Activities. Go up and down a wheelchair ramp; travel along walkways; maneuver around the hospital grounds and over concrete, grass, and gravel.

All testing with the stand-up motorized prone cart was conducted after a period of acclimatization to the cart, allowing the user to become fully familiar with the cart's operation and maneuverability.

Users and caregivers were provided with questionnaires (Appendix 1) that addressed use of the stand-up motorized prone cart. The questions related to

Figure 3. Front three-quarter view, showing workspace and elbow rests.

the user's body positioning on the cart, the physical characteristics of the carts, and the carts' maneuverability and performance. Questionnaires included a combination of dichotomous (yes/no) items, polychotomous (eg, too long, too short, just right) items, and environmental-interaction questions that utilized a 5-point Likert-type ranking system.

RESULTS

Sample Characteristics

Table 2 shows the demographic characteristics of the user sample. All 11 user respondents were male with an age range of 26 to 61 years (mean = 48 y). User heights ranged from 175 cm to 188 cm (5 ft 9 in to 6 ft 2 in), and weights from 55 kg to 127 kg (122 lb to 280 lb). By self-report, 58% were paraplegic, 25% were tetraplegic, and 17% answered "other." Of the paraplegic users, 71% reported themselves as complete, as did 100% of the

Figure 2. Side view of cart at 45°.

Figure 4. Front three-quarter view at 45° showing storage drawer in open position.

Table 2. User Characteristics (n = 11)

Variable	Units	Value		
		Range	Mean	SD
Age	Years	26–61	48	11
Time since injury	Years	1–14	5.6	4.8
Weight	Kilograms	55–127	80	22
Height	Centimeters	175–188	181	4.8
		n	%	
Gender	Male	11	100	
Hand dominance	Right-handed	7	64	
	Ambidextrous	3	27	
	Left-handed	1	9	
Body frame self-assessment	Large	4	36	
	Medium	6	54	
	Small	0	0	
Class of impairment	Tetraplegic			
	Complete	2	18	
	Incomplete	0	0	
	Paraplegic			
	Complete	5	46	
	Incomplete	2	18	
Ambulatory status	Other	2	18	
	Prone cart only	2	18	
	Mixed prone cart/wheelchair	9	82	

tetraplegic users. Respondents had been injured on average 7 years (range 1–23 y).

The caregiver sample consisted of 33 subjects, drawn from the hospital nursing staff and home health workers (relatives or hired aides). There were 9 men (27%) and 24 women (73%).

Cart Evaluation

The responses of the users and the caregivers to the evaluation questionnaires are presented in Table 3. There were 4 questions that were eliminated from further analysis because the patient nonresponse rate was > 20%. These questions were the location of the battery shelf, the ease of crossing thresholds, the ease of going up ramps, and the ease of rolling on pile carpet.

For 13 of the 19 items, users and caregivers gave near-unanimous approval of the characteristic of the cart in question. Six characteristics of the cart had markedly less approval (< 80%) by either users or caregivers: the comfort of the body support padding, the location and size of the drink holder, the location and size of the storage container, and the length of the cart while turning around. There was discordance between the users and caregivers on 4 of these 6 items. Users had lower rates of approval than caretakers on the comfort of

the support padding and the location and size of the drink holder. Conversely, the caregivers had lower rates of approval for the size of the storage drawer. For 2 items, users and caregivers were concordant in their lackluster support: the location of the storage drawer and “the cart seemed too long when turning around.”

The users were separately questioned about the ease of access to 15 environmental objects. There was excellent-to-good approval on all items except for the fountain, washer-dryer, and sink.

DISCUSSION

Demonstration of Need

Clinical practice guidelines recommend avoiding positioning the wheelchair-seated person directly on the pressure ulcer and that sitting be limited (40). However, evidence shows that bed rest has many adverse effects. Thus, current clinical practice is a compromise between (a) getting a person out of bed to avoid the deconditioning and other problems associated with prolonged bed time and (b) reducing the amount of time that a person puts pressure on the healing ulcer.

Prone carts facilitate this compromise because they allow the user to get out of bed without subjecting the healing area to pressure for any additional time.

Table 3. Cart Evaluation

Yes/no questions	Users n = 11		Caregivers n = 33	
	Number Responding	% of Responders Agreeing	Number Responding	% of Responders Agreeing
Is body support wide enough	11	100	33	88
Is body support padding comfortable	11	*64	33	82
Is the body support long enough	11	100	33	94
Is the footrest area long enough	10	100	33	97
Is there enough room for patient's elbows	11	82	33	100
Is the joystick controller located conveniently	11	82	33	100
Is the drink holder located conveniently	11	*45	33	97
Is the drink holder large enough	11	*73	33	91
Is the storage drawer large enough	11	82	33	*73
Is the storage drawer in a convenient location	11	*64	33	*70
Is there enough area to write/work while lying	11	91	33	97
Do you feel stable on the cart	11	100	0	0
Do you like the ability to be in a near-standing position	9	89	0	0
Does cart turn easily	11	91	33	97
Does cart seem too long when turning around	11	*55	33	*76
Does cart roll in a straight line	10	100	33	97
Is cart able to roll easily on Hospital Corridors	11	100	33	95
Is cart able to roll easily on tile floor	11	100	33	88
Is cart able to roll easily on concrete walkway	9	89	0	0
Items with * had agreement < 80%				
Multiple answer questions				
Is the front deck				
Too small		0		5
Just right	11	100	21	95
Too long		0		0
Which angle of body support is most appropriate				
Low		9		6
Medium	11	64	33	36
High		27		58
Rate the overall length of the cart for your needs				
Too short		0		3
Just right	11	60	33	82
Too long		40		15

However, the conventional prone cart is uncomfortable, causing neck and shoulder pain, and offers little design features that address comfort and ADL. Adding the functionality of supported standing is justified by a body of supportive clinical evidence.

Our marketing survey indicates a perceived need for better design and access to prone carts. Despite notable limitations, this survey served a valuable purpose because these data were included in the grant proposal as justification of the importance of the study and will help build a business case for commercial production of the carts.

Design Issues

The evaluations by users and caretakers were positive in most regards. Users and caretakers had high levels of acceptance (>80%) on 13 cart characteristics, which may be grouped as follows: (a) size and shape: width and length of body support, length of footrest, size of front deck, elbow room, work room, and location of joystick, (b) dynamic characteristics: feeling stable; rolling on a straight line; ease of turning; and rolling on hospital corridors, tile floor, and concrete walkways.

Six characteristics of the cart that had <80% agreement: the comfort of the body support padding, the location and size of the drink holder, the location and

size of the storage container, and seeming too long when turning around. The first 5 of these could be redesigned with minor modifications to the cart. Only the length of the cart when turning around presented a design dilemma. This problem was most evident when maneuvering the cart around corners. Because the drive wheels were mounted under the front, when the user wanted to turn to the right, the back of the chair swung to the left, banging into walls, doorways, etc.

There were 2 solutions proposed to solve this design dilemma: (a) put the driving wheels in the center, which would reduce the turning radius by a factor of two, or (b) because the body support takes up less horizontal space as it angles higher and because the frame of the cart need not be a fixed length, design an articulated linkage so the frame shortens as the body support angles upwards. This concept, a “folding frame prone cart,” would offer several novel design features that may increase user acceptance and utility. Not only could the cart frame be made to shorten as the platform elevates, but by the same mechanism of using an articulated linkage, the platform could be made to bend at the waist and knees. This would put the user in a more natural position than previous designs, which only bent at the waist. It should also take pressure off the chest and anterior abdominal wall that might inhibit breathing and intestinal function. Conversely, such a design would increase pressure on the knees and anterior legs (shins), which could then become sites for pressure ulcer formation if the resulting pressure was not well distributed.

Consequently, a new grant application was written and funded by VA RR&D for the development of a folding frame prone cart. This cart is currently in development, as the design team continues to address the compelling need to improve the quality of life for persons with SCI. This design and evaluation will be the subject of a future paper.

CONCLUSIONS

A stand-up motorized prone cart was developed to improve on currently available prone carts. The cart was well received except for being perceived as too long and difficult to turn around. A redesign to reduce its turning radius and simultaneously offer further positional advantages is under way.

Design efforts to enhance the function and features of existing prone carts address the compelling need to improve the quality of life and independence for persons with a SCI who have a pressure ulcer. Providers of medical and nursing care for persons with SCI will need product education through marketing efforts because many are unaware that the product class even exists.

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Appendix 1

User Questionnaire

Part #1. Subject profile					
Physical profile?	Small	Medium	Large		
Length of time since spinal cord injury or other disability?	Years	Months			
Gender?	Male	Female			
Age?	Years				
Height?					
Weight?					
What hand do you normally use?					
Left handed	1				
Right handed		2			
Ambidextrous			3		
Ambulatory status?					
Non-ambulatory (prone cart user only)	1				
Non-ambulatory (wheelchair and prone cart user)		2			
Present living accommodations?					
Home or apartment alone	1				
Home or apartment with family/friend		2			
Home or apartment with attendant			3		
Home modifications for independent living?	Yes	No			
Type of impairment?					
Paraplegia (complete)	1				
Paraplegia (incomplete)	2				
Quadriplegia (complete)	3				
Quadriplegia (incomplete)	4				
Hemiplegia	5				
Lower limb amputation	6				
Other	7				
Part #2. Folding frame motorized prone cart evaluation					
Body positioning on the cart					
Is the body support wide enough?	Yes	No			
Is the body support padding comfortable?	Yes	No			
Is the body support long enough?	Yes	No			
Is the footrest area long enough and comfortable?	Yes	No			
Is the front deck	too small	just right	too long		
Is there enough room for your elbows?	Yes	No			
Is the joystick controller located conveniently for you?	Yes	No			
Is the drink holder located conveniently for you?	Yes	No			
Is the drink holder large enough?	Yes	No			
Is the storage drawer large enough?	Yes	No			
Is the storage drawer in a convenient location?	Yes	No			
Is there enough area to write/work while	Yes	No			

lying on the cart?					
Mechanical characteristics of the cart					
Which angle adjustment of the torso support is most appropriate for your use?	0°	15°	25°		
How easy or difficult is the use of the torso support adjustment mechanism?	1 Easy	2	3	4	5 Difficult
Is the battery shelf in a convenient location?	Yes	No			
Rate the overall length of the cart for your needs.	Too long	Just right	Too short		
Rate the horizontal height of the body support.	Too high	Just right	Too low		
Rate the vertical height of the tilting body support.	Too high	Just right	Too low		
Do you feel stable on the cart?	Yes	No			
Do you like the ability to be in a near standing position?	Yes	No			
Cart maneuverability and performance					
Do the rearview mirrors help you maneuver on the cart?	Yes	No			
Does the cart turn easily?	Yes	No			
Does the cart seem too long when turning around?	Yes	No			
Does the cart roll in a straight line?	Yes	No			
Is the cart able to cross thresholds easily (elevator-outdoor)?	Yes	No			
Is the cart able to go up a ramp easily?	Yes	No			
Is the cart able to roll easily on the following surfaces?					
Hospital corridor	Yes	No			
Low pile carpet	Yes	No			
Tile floor	Yes	No			
Concrete walkway	Yes	No			
Gravel-sand trail - dirt road	Yes	No			
Rate access from the cart to following:	Easy				Difficult
Hospital bed	1	2	3	4	5
Bathroom sink in your room	1	2	3	4	5
Kitchen counter	1	2	3	4	5
Upper kitchen cabinets	1	2	3	4	5
Lower kitchen cabinets/refrigerator	1	2	3	4	5
Refrigerator	1	2	3	4	5
Stove	1	2	3	4	5
Washer/dryer	1	2	3	4	5
Serving line at the cafeteria	1	2	3	4	5
Table at the cafeteria	1	2	3	4	5
Public telephone	1	2	3	4	5
Public elevator	1	2	3	4	5
Vending machine	1	2	3	4	5
Water fountain	1	2	3	4	5
Picking an object on the floor with a reacher?	1	2	3	4	5
Thank you for your time and answering this questionnaire					

Appendix 2

Caregiver's Questionnaire

Today's date _____, 2005

Part #1. Participant profile					
Caregiver Gender?	Male	Female			
Part #2. Folding frame motorized prone cart evaluation					
Patient Body positioning on the cart					
Did you consider that the patient transfer from bed to cart was safe?	Yes	No			
Is the body support wide enough?	Yes	No			
Is the body support padding comfortable?	Yes	No			
Is the body support long enough?	Yes	No			
Is the patient's position on the body support safe?	too small	just right	too long		
Is the footrest area long enough and comfortable?	Yes	No			
Is the front deck	Yes	No			
Are the elbow support pads on the front deck big enough?	Yes	No			
Is the main joystick controller (for speed & turning easily reachable by patients?	Yes	No			
Is the torso support joystick controller in a convenient location? yes: 1 no:	Yes	No			
Is the prone cart allowing for catheter drainage?	Yes	No			
Is the drink holder located conveniently for the patient's reach?	Yes	No			
Is the drink holder large enough?	Yes	No			
Is the storage drawer large enough and in a convenient location?	Yes	No			
Is there enough area on the front deck for a magazine, a book, a tray or a keyboard?	Yes	No			
Mechanical characteristics of the cart					
Is the body support adjustment joystick easy to use?	0°	15°	25°		
Is the footrest adjustment mechanism easily reachable?	1 Easy	2	3	5	5 Difficult
Is the leg support adjustment mechanism easily reachable?	Yes	No			
Are the battery shelves in a convenient location?	Too long	Just right	Too short		
If necessary could you reach and change a battery?	Too high	Just right	Too low		
Can you reach and connect the battery charger?	Too high	Just right	Too low		
Rate the overall length of the cart for your patient needs (circle appropriate answer)	Yes	No			
Rate the height of the body support for treatment purposes? (activities of daily living, catheter care, dressings, medications, transfer from hospital bed, etc.)	Yes	No			
Cart maneuverability and performance					
Does the cart turn easily?	Yes	No			
Does the cart seem too long when turning around?	Yes	No			
Does the cart roll in a straight line?	Yes	No			
Is the cart able to cross thresholds easily (elevator-outdoor)?	Yes	No			
Is the cart able to go up a ramp easily?	Yes	No			
Is the cart able to roll easily on the following surfaces?					
Hospital corridor	Yes	No			
Low pile carpet	Yes	No			
Tile floor	Yes	No			
Were there adverse patient events occurring on the cart?	Yes	No			
If yes please describe:					
Thank you for your time and answering this questionnaire					